PACIFIC SALMON COMMISSION
SELECTIVE FISHERIES
EVALUATION COMMITTEE

SPECIAL ASSIGNMENT
REVIEW OF MARKING FOR CODED-WIRE-TAGS
AND MARK SELECTIVE FISHING

REPORT SFEC (06)-1

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Report to the Pacific Salmon Commission
February 2006

Special Assignment: Review of Marking for CWT and MSF

Background

At the PSC Post-Season Meeting held in January, 2006 the Commissioners tasked the Selective Fishery Evaluation Committee (SFEC) with a special assignment, which arose from the Commissioner's discussion of the CWT Expert Panel Report. This special assignment requested the SFEC provide answers to three specific questions related to marking of salmon for the purpose of identifying coded-wire tags (CWT) and for selective harvest of hatchery origin salmon in mark selective fisheries (MSF). The full text of this assignment and these three specific questions are provided in Appendix 1.

The PSC Commissioners instructed the SFEC to provide a response no later than the PSC Annual Meeting (February 14-17, 2006). Due to the limited amount of time available, the SFEC focused on Question 1. The scope of the work was restricted mainly to answering the specific questions as worded in the original tasking from the Commissioners. However, some additional information is provided where possible in the time available. For example, mortality rate information is summarized for some alternative marks, in addition to the mortality rate for ventral fin clips specifically requested in Question 1. The SFEC did not address other important questions regarding marking of salmon that were identified in the CWT Expert Panel Report

SFEC Conclusions

Question 1: the SFEC concludes that, of the marks examined that met the necessary criteria for retention to adult and minimum size for application, all alternative marks had mortality rates that were higher and more variable than those associated with adipose fin clips, for both coho and Chinook.

Question 2: the SFEC concludes that re-sequestering the adipose fin would partially restore the type and quality of information. However, recent decreases in fishery size and structure, and in sampling coverage and intensities, have also decreased precision and accuracy of exploitation rates. These issues will not be addressed simply by re-sequestering the adipose fin.

Question 3: the SFEC concludes that resequestering the adipose fin clip and using an alternative mass mark will impair our ability to estimate total mortality and exploitation rates of the unmarked fish using the double index tag system (DIT), if there is an additional delayed mortality due to the alternative mark, and if the delayed mortality continues through to adult escapement. The ability to estimate exploitation rates for marked fish will also be impaired.

DETAILED REVIEW AND ANALYSES

Question 1: Based on a search of available literature and agency information, how would the mortality rates of these alternative marks compare to those that may be associated with adipose clips and would it be the same for chinook and coho?

SFEC RESPONSE: Of the marks examined that met the necessary criteria for retention to adult and minimum size for application, all alternative marks had mortality rates that were higher and more variable than those associated with adipose fin clips, for both coho and Chinook.

Introduction

Because of the anadromous life history and physiology of Pacific Salmon (*Onchorynchus sp*.), finding suitable marking techniques has been a challenge. Because of the importance of the salmon resource, this subject has received substantial interest from fisheries management agencies, other fishery research institutions, and private entrepreneurs. The current interest is in identifying a suitable mass mark for use in identifying hatchery fish for mark-selective fisheries or another mass mark for use as a flag for identifying a fish carrying an internal coded-wire tag.

Prior to the implementation of MSF, the adipose clip was sequestered as the identifier of a Chinook or coho carrying a CWT. With the implementation of mass marking based on the adipose clip, electronic detection became necessary for CWT recovery. ETD has not been fully implemented in Canada or the US due to increased sampling costs and logistical problems. This has renewed interest in identifying an alternate mark for either the MSF or the CWT identifier.

Literature Review

The current status of fish marking technologies was reviewed through the following:

1) An electronic literature search for published literature,
2) A survey of Agency Mark Coordinators and SFEC members for unpublished or “grey” literature, and
3) Contacts with companies that sell marking technologies.

The literature search was conducted using with the following criteria:

- Search was made of ASFA, USFWS and UW Library holdings and using Google Scholar,
- Key word search: tag salmon, finclip, freeze branding, dye visual, brand salmon brand trout, dye mark, carlin tag, floy tag, data storage tag, dart tag, flourescent pigment, flourescent mark, flourescent, anal fin clip, ventral fin clip, pectoral fin clip, hot brand, cold brand, pan jet, mass mark fin clip, tattoo, calcein.

A bibliography is attached (Appendix 2) and is also available in electronic form at http://filedownloads.fws.gov/ftp%5Fwestwafwo/SFEC/mark bibliography.mdb

The literature search and review was limited to studies that had been conducted on salmonids. The recommendations are based on studies where the results were reported through to adult return. Our review emphasizes effects on survival and mark retention through the adult stage.

The scope of the review was therefore narrowed to exclude studies reporting on short term survival and retention.

Criteria

A wide variety of marking techniques have developed over the last few decades, but most of them have limits to their applicability. Marks suitable for mass marking (MM) and CWT indicators require that the marking technique meets the following criteria:

Criteria common to MM or CWT Identifier Marks:

- Can be applied to large groups of fish within a short period of time
- Minimal additional mortality due to the mark
- Permanent (i.e., retained at high rate throughout life of fish)
- Low cost of application

Additional Criteria for MM:

- External mark that is readily visible (i.e., quick visual recognition for catch and release fisheries)
- Easily recognizable by untrained observers (e.g., anglers)
- Applicable to juvenile coho and Chinook as small as 60 mm fork length.

Additional Criteria for CWT identifier marks:

- Conducive to rapid detection, either visually or with specialized equipment
- Applicable to juvenile fish as small as 60 mm fork length (pre-release marking size for many groups of sub-yearling fall Chinook)

Table 1-A summaries the characteristics of marks that met our criteria.

Categories of Marks

The PSMFC Mark Committee previously produced a report on this topic titled "*Mass Marking Anadromous Salmonids: Techniques, Options, and Compatibility with the Coded Wire Tag System*" (PSMFC 1992). In this review, marking technologies were classified into three categories of detection:

1) Immediate Visual: Marks that can be easily and immediately seen by the un-aided eye.
2) Immediate Specialized Detection: Marks that can be immediately detected with the proper sampling equipment. Because these marks do not have a visual identifer every fish must be analyzed.
3) Delayed Detection: Marks that require sacrificing the fish or sampling harvested fish to obtain the tag or tissue for specialized laboratory analysis.

This categorization is still relevant for identifying which technologies are useful for MM and/or CWT Identification. Using the above criteria and categories, the following guidelines were used for evaluating current marking technologies.

Mass Marks used for MSF must be in the “Immediate Visual” category. This is due to the requirement that a fisherman needs to be able to quickly identify the mark, preferably while the fish is still in the water, so unmarked fish can be released with minimal handling.

Marks used for CWT identification can be in either the “Immediate Visual” or the “Immediate Specialized Detection” categories. An “Immediate Specialized” mark, however, cannot be used for voluntary visual recovery programs. The use of specialized detection can be useful if an agency mark sampler can quickly detect the mark and thereby only process CWT fish. This approach can avoid long delays at commercial buyers, processing plants, or at recreational landing sites.

Immediate Visual Marks

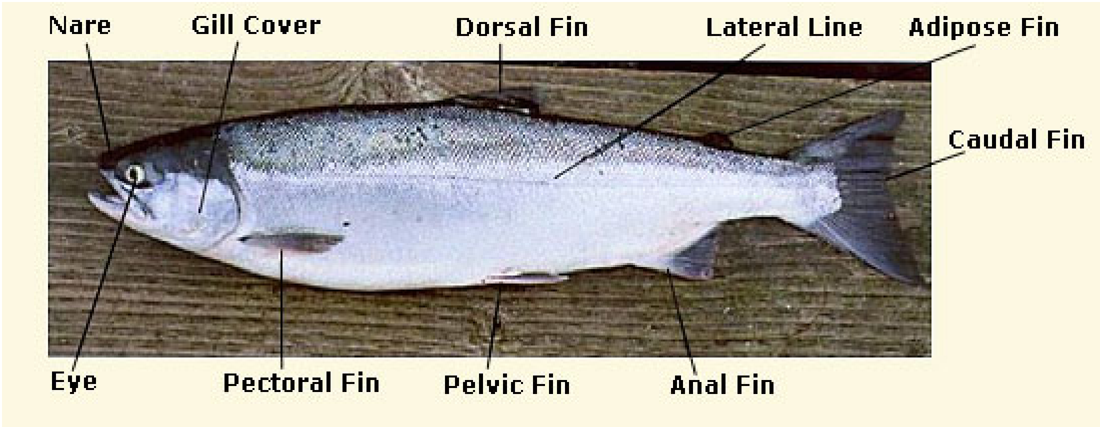
Numerous types of marking techniques of this type have been used on salmonids. These include the following:

- Attached body tags (e.g. anchor, dart, spaghetti, jaw tags, etc.)
- Fin clips and fin mutilations
- Freeze branding and searing
- Laser marks
- Fluorescent pigment sprays
- Immersion dyes
- Tattoos

The SFEC was not able to identify any mark, other than fin marks, that could be considered Immediate Detection technology and suitable for mass marking of anadromous salmon. All of the marks listed above allow immediate visual detection of marked fish. However, with the exception of fin clipping, none of these marks have been found to be permanent for salmon (i.e. although they can be successfully applied to juvenile salmon they are not detectable on a high percentage of returning adults). There are many examples in the literature of the use of these techniques on trout or juvenile salmon studies. The difficulty in finding a permanent external mark is a reflection of the unique life history and physiology of anadromous salmon. If juvenile salmon are to be handled with minimal mortality, marking needs to be done prior to smoltification. The fish then go through 2-5 years of substantial growth with significant pigment changes and the ability to regenerate damaged tissue.

Fin Clipping

Prior to the advent of the CWT, fin-clipping was commonly employed to identify fish for experimental purposes. Various combinations of clips involving the adipose, pectoral, pelvic (also referred to as ventral), dorsal, and anal fins have been attempted (see figure below) with varying degrees of success.



The adipose fin mark has been considered to have minimal impacts on survival and low fin regeneration rates. A recently published study evaluated the impacts of the Ad+CWT mark in a three year study on fall Chinook salmon (Vander Haegen et al., 2005). Although there were some difficulties with correct identification of the otolith control mark, the authors found no significant difference in return rate between marked and unmarked fish. Another study evaluated the impact of the AD+CWT mark on chum salmon fry (Bailey, 1995) found significant impacts on survival. However, CWT studies on salmon fry are generally considered as pushing the limits of this technique and are confounded by impacts of handling small fish.

In another study, no regeneration of the adipose fin occurred when the fin was completely clipped (Thompson and Blankenship 1997). However, when only 2/3 of the fin was removed, the fin completely regenerated in 23% of the fish.

The ventral fin (pelvic fin) is generally considered the next preferable fin to clip after the adipose clip. There is an extensive volume of literature on the impacts of ventral fin marking on salmonids. The majority of these studies report increased mortality associated with ventral fin over the adipose fin, although the study designs varied. Mortality estimates are confounded by fin-regeneration, so only studies which included a control group (i.e., CWT or otolith) in the study design were reviewed (Table 1-B). Significant differences in mortality between ventral fin clipped and control groups were noted for both Chinook and coho studies.

None of the studies reviewed assessed whether the delayed mortality occurred prior to recruitment to the fisheries (Age 2) or throughout the life of the fish. The distribution of delayed mortality is important to answering the issue raised in Question 3 and further work is required in this area.

Previous reviews (ASFEC 1995, Coombs et al. 1990) also identified concerns regarding mark recognition errors and increased handling required for ventral clips.

Fin regeneration is a common problem when clipping bony fin rays. Regeneration rates were highly variable between studies and were often reported with different categories of regeneration. Rates of complete fin regeneration ranged from 0 to 44%.

No studies were found that compared fin regeneration of fin clips other than ventral and adipose clips on Pacific salmon. However, Mears (1976 b) compared fin regeneration for anal, dorsal, pelvic, pectoral, and adipose fins for brook trout. This study found the highest fin regeneration rate for the anal fin and the lowest for the adipose. Mears and Hatch (1976) reported for brook trout that the adipose fin clip resulted in the highest survival rate over all other types of fin clips and that single fin clips resulted in higher survival than multiple fin clips.

Immediate Specialized Detection Marks

"Immediate Specialized Detection" marks require specialized equipment to provide rapid detection in the field. Therefore these marks would not be suitable for a mass mark, due to the fact that they could not be readily identified by a fisherman in a MSF. They would, however, be candidates as identifiers for CWTs. The current Electronic CWT Detection (ETD) falls into this category. Other examples include fluorescent pigment sprays, body area coded-wire tagging and electronic tags.

One type of technology reviewed, the Visual Implant (VI) elastomer tag, could be considered as an "Immediate Visual Detection" mark. However, its recognition is enhanced with the use of a blue spectrum or UV light, so it is probably most appropriately considered a "Specialized Detection" mark. The application involves injecting a colored liquid material (e.g. a silicone compound) under a transparent tissue on the fish. This type of marking has been tried with various materials, with different types of applicators, and at different body locations.

The most successful application location is just posterior to the eye with the elastomer tag injected under the adipose tissue that covers the eye. This location provides better retention, but retention can still be relatively low and highly variable on returning adults (0-100%). The technique also has a fairly large minimum size requirement. This technique is used extensively at WDFW's Lyon's Ferry Hatchery for adult broodstock identification. However, because of its poor and variable retention, it is always used in conjunction with a AD+CWT marked fish.

Agencies have investigated several variations of injection of fluorescent material throughout the 1990s. These included Photonic VI and VI Jet marks. These also involve injection of fluorescent material sprayed on fin rays or injected at the base of fin rays. Unfortunately, several studies showed marks applied using this technique were not permanent. This may be a result of the pigmentation that develops on the surface of the bony fins.

New electronic tags, including Radio Frequency Transponder Tags and Micro Acoustic Tags, are being used experimentally for marking juvenile salmonids. The technology has not yet developed where it could be applied for marking large numbers of juvenile salmonids quickly and inexpensively.

The one relatively new technology that has potential as an Immediate Specialized Detection mark is Calcein. This organic compound has been used as a marker for studies of resident and anadromous trout and salmon. The dye is administered most commonly through an immersion technique that involves placing fish in a highly saline solution prior to immersion in the calcein solution; it has also been injected at the base of fins (Frenkel et al. 2002). The dye is incorporated into tissue and can be identified as a mark, but requires a specialized lens and light source of the right frequency for detection. Handheld detectors are available for field mark detection. The mark does degrade with exposure to UV light and several studies on hatchery reared salmon have reported complete loss of capability of external mark detection (the mark could still be identified from a sectioned otolith, (Mortensen et al., 2005)). No studies were found with mark retention data for adult returns. Mohler (2004) reports no impact of calcein on growth or survival. The biggest deterrents to the use of calcein as a mark for salmon is the lack of FDA approval for general use, the potential for the mark to degrade to the point that it could not be detected externally, the cost of specialized recovery gear, and the challenges of applying the mark.

Delayed Detection Marks

"Delayed Detection" marks involve techniques where thermal or chemical means are used for marking bony structures. Current technologies include:

- Thermal marking: for otolith banding induced by changes in water temperature
- Elemental marking: either induced (e.g. strontium) or natural geographical occurrence levels differences in natural occurrences and detected in bony structures with spectrometry
- Chemical marking - tetracycline antibiotics or alizarin compounds for marking bony structures.

Detection of these marks requires that a bony part of the fish is sent to a laboratory for preparation and analysis, and therefore isn't practical for MSFs or for CWT field sampling where rapid detection is necessary. These techniques (especially thermal otolith marking) are currently widely used for permanent marking of large groups of hatchery fish. Marking is efficient and inexpensive, but recovery and analysis can be costly.

Conclusions of SFEC Review of Marking Studies

Adipose and ventral fin clips were the only Immediate Visual marks the SFEC identified as potential alternative mass marks for either MSF or CWT identifier.

Recent adipose fin mark studies on chinook support the common assumption that adipose fin clipping does not cause significant mortality and does not have substantial fin regeneration.

SFEC review of ventral fin mark studies indicated significant impacts to survival and substantial fin regeneration. For chinook, ventral fin marking was found to have a variable impact on survival, decreasing survival by 38-75%. For coho, ventral fin marking significantly decreased survival by 0-58%.

No new technologies were identified for an acceptable alternative identifier for the CWT. Calcein marking and Radio Frequency Transponder Tags were identified as interesting potential technologies, but both are in the experimental stage.

Table 1-A. Characteristics of Marks

Mark	Application			Mark Characteristics			
	Cost per 1,000	Rate	Min. Size	Differential Survival *	Stability	Detectability	Reference
Adipose Fin Clip	$25	625-875 per person hour	60 mm with MM trailer 50 mm by hand	No significant difference	0 - 4% Regeneration	Immediately detectible by untrained observers	SFEC, 1997 Appendix 2
Ventral Fin Clip	$30	500-600 per person hour	55 mm	Significant mark mortality (-4 to 75%)	0 - 44% Regeneration	Immediately detectible, but slower than adipose clip.	SFEC, 1997 Appendix 2
V.I. Elastomer (in Eyelid Adipose)	Tags = $105 Applicator = $5,000 Light detector = $115	300-400 fish per person hour	100 mm	Unknown	Variable (0-100%)	Enhanced with blue or UV light	WDFW pers. comm. & Lower Snake Comp. Plan Annual Report, 2005
Calcein	Inexpensive but requires FDA approval	unlimited	Emergent fry	No difference	Degraded by UV. Mark endurance associated with fish size at marking	Immediately detectible with black light	Mohler, 2004 Frenkel et al. 2002
PIT (Passive Integrated Transponder)	Tags = $2000-$4,300 Applicator = $250 Reader = $2,850	100 fish per person hour	65 mm	Unknown	No studies found but believed to be permanent	Immediately detectible with specialized equipment (8-12” range)	Biomark pers. comm.

* differential survival is the additional mortality compared to no mark

Table 1-B. Fin Clip Studies

Adipose Fin Clip Studies

Species	Treatment	Control	Project	Brood	Release		Recoveries		Recovery Rate			Sig[2]	Reference
					Treatment	Control	Treatment	Control	Treatment	Control	Ratio[1]		
Chinook	AdCWT	CWTOnly	Spring Cr	1994	190,205	197,347	76	76	0.040%	0.039%	1.04		PSMFC Mark Meeting 1998
Chinook	AdCWT	CWTOnly	Spring Cr	1993	185,575	194,489	195	220	0.105%	0.113%	0.93		PSMFC Mark Meeting 1998
Chinook	AdCWT	Otolith	Carson	1989	617,921	1,863,691	499	1701	0.081%	0.091%	0.88	*	Vander Haegen et al 2005
Chinook	AdCWT	Otolith	Carson	1990	731,198	1,504,881	206	423	0.028%	0.028%	1.00		Vander Haegen et al 2005
Chinook	AdCWT	Otolith	Carson	1991	767,864	1,551,967	151	280	0.020%	0.018%	1.09		Vander Haegen et al 2005
Chinook	AdCWT	Otolith	Cowlitz	1989	628,605	1,317,541	3204	6721	0.510%	0.510%	1.00		Vander Haegen et al 2005
Chinook	AdCWT	Otolith	Cowlitz	1990	692,988	1,445,863	1950	4012	0.281%	0.277%	1.01		Vander Haegen et al 2005
Chinook	AdCWT	Otolith	Cowlitz	1991	664,410	1,342,871	541	1029	0.081%	0.077%	1.06		Vander Haegen et al 2005
Chinook	AdCWT	Otolith	S Santiam	1989	390,934	819,389	627	1359	0.160%	0.166%	0.97		Vander Haegen et al 2005
Chinook	AdCWT	Otolith	S Santiam	1990	416,241	837,497	631	1547	0.152%	0.185%	0.82	*	Vander Haegen et al 2005
Chinook	AdCWT	Otolith	S Santiam	1991	441,308	900,054	565	1256	0.128%	0.140%	0.92	*	Vander Haegen et al 2005
Coho	AdCWT	CWTOnly	Skagit	1991	50,223	50,658	2479	2563	4.936%	5.059%	0.98		WDFW unpubl; 1999
Chum	AdCWT	Otolith	Cook Cr	1989	93,133	198,301	224	1037	0.241%	0.523%	0.46	*	Bailey, 1995

[1] The ratio is the treatment recovery rate divided by the control recovery rate. A value of 1.0 indicates the treatment mark does not impact survival. The treatment mark negatively impacts survival if the ratio is significantly less than 1.0. For studies that were not significant, no treatment impact could be detected.

[2]A ratio that is significantly different from 1.0 is indicated by an asterisk. Statistical significance indicated in this table is based on a two-sided p-value using an alpha of 0.10, that is, there is no greater than a 10% chance that the reported difference in recovery rates would be observed if the null hypothesis that there is no difference in recovery rates is true. The calculation formulas are provided in Appendix 3.

Ventral Fin Clip Studies

Species	Treatment	Control	Project	Brood	Release Treatment	Release Control	Recoveries Treatment	Recoveries Control	Recovery Rate Treatment	Recovery Rate Control	Ratio[1]	Sig[2]	Reference
Chinook	AdVentCWT	AdCWT	Cowichan	1987	53,578	53,119	282	641	0.527%	1.207%	0.44	*	CDFO unpubl; 2006
Chinook	AdVentCWT	AdCWT	Tenderfoot	1987	52,049	78,438	17	102	0.033%	0.131%	0.25	*	CDFO unpubl; 2006
Chinook	AdVentCWT	AdCWT	Tenderfoot	1991	30,259	100,506	50	347	0.166%	0.345%	0.48	*	CDFO unpubl; 2006
Chinook	AdVentCWT	AdCWT	Irrigon	1990	103,980	104,258	87	202	0.084%	0.194%	0.43	*	ODFW unpubl; 1996
Chinook	VentCWT	CWTOnly	Spring Cr	1992	194,496	198,823	26	74	0.013%	0.037%	0.36	*	PSMFC Mark Meeting 1998
Chinook	VentCWT	CWTOnly	Spring Cr	1993	193,745	194,489	112	220	0.058%	0.113%	0.51	*	PSMFC Mark Meeting 1998
Chinook	VentCWT	CWTOnly	Spring Cr	1994	194,127	197,347	46	76	0.024%	0.039%	0.62	*	PSMFC Mark Meeting 1998
Coho	AdVentCWT	AdCWT	B Qualicum	1983	41,846	21,868	592	297	1.415%	1.358%	1.04		CDFO unpubl; 2006
Coho	AdVentCWT	AdCWT	Capilano	1983	24,740	27,314	869	1088	3.513%	3.983%	0.88	*	CDFO unpubl; 2006
Coho	AdVentCWT	AdCWT	Chilliwack	1983	29,495	27,851	2791	4670	9.463%	16.768%	0.56	*	CDFO unpubl; 2006
Coho	AdVentCWT	AdCWT	Puntledge	1983	24,100	23,756	2685	3053	11.141%	12.851%	0.87	*	CDFO unpubl; 2006
Coho	AdVentCWT	AdCWT	Quinsam	1983	19,989	29,147	1793	3242	8.970%	11.123%	0.81	*	CDFO unpubl; 2006
Coho	AdVentCWT	AdCWT	Chilliwack	1991	39,940	39,673	1126	2682	2.819%	6.760%	0.42	*	CDFO unpubl; 2006
Coho	AdVentCWT	AdCWT	Puyallup	1990	45,122	44,404	2251	2413	4.989%	5.434%	0.92	*	WDFW unpubl; 1999
Coho	AdVentCWT	AdCWT	Green R	1991	45,153	45,421	1753	1976	3.882%	4.350%	0.89	*	WDFW unpubl; 1999
Coho	AdVentCWT	AdCWT	Skagit	1991	50,029	50,023	1865	2479	3.728%	4.956%	0.75	*	WDFW unpubl; 1999
Chum	VentCWT	Otolith	Cook Cr	1989	99,417	198,301	360	1037	0.362%	0.523%	0.69	*	Bailey, 1995

[1] The ratio is the treatment recovery rate divided by the control recovery rate. A value of 1.0 indicates the treatment mark does not impact survival. The treatment mark negatively impacts survival if the ratio is significantly less than 1.0, as indicated in the significance column. For studies that were not significant, no treatment impact could be detected.

[2] A ratio that is significantly different from 1.0 is indicated by an asterisk. Statistical significance indicated in this table is based on a two-sided p-value using an alpha of 0.10, that is, there is no greater than a 10% chance that the reported difference in recovery rates would be observed if the null hypothesis that there is no difference in recovery rates is true. The calculation formulas are provided in Appendix 3.

Combination Fin Clip Studies

Species	Treatment	Control	Project	Brood	Release Treatment	Release Control	Recoveries Treatment	Recoveries Control	Recovery Rate Treatment	Recovery Rate Control	Ratio[1]	Sig[2]	Reference
Chinook	VentCWT	AdCWT	Warm Spr	1987	97,397	89,047	34	36	0.035%	0.040%	0.86		Olson, 1997
Chinook	VentCWT	AdCWT	Warm Spr	1988	102,962	93,290	59	60	0.057%	0.064%	0.89		Olson, 1997
Chinook	VentCWT	AdCWT	Warm Spr	1989	101,291	95,260	21	12	0.021%	0.013%	1.65		Olson, 1997
Chinook	AdVentCWT	CWTOnly	Spring Cr	1992	195,497	198,823	18	74	0.009%	0.037%	0.25	*	Mark Meeting Apr 1998
Chinook	AdVentCWT	CWTOnly	Spring Cr	1993	191,405	194,489	88	220	0.046%	0.113%	0.41	*	Mark Meeting Apr 1998
Chinook	AdVentCWT	CWTOnly	Spring Cr	1994	196,529	197,347	44	76	0.022%	0.039%	0.58	*	Mark Meeting Apr 1998
Coho	VentCWT	AdCWT	Rogue R	1991	26,224	26,269	249	837	0.950%	3.186%	0.30	*	ODFW unpubl; 1994
Coho	VentCWT	AdCWT	Puyallup	1991	44,092	44,404	1852	2413	4.200%	5.434%	0.77	*	WDFW unpubl; 1999
Coho	VentCWT	AdCWT	Green R	1991	48,805	45,421	1769	1976	3.625%	4.350%	0.83	*	WDFW unpubl; 1999
Coho	VentCWT	AdCWT	Skagit	1991	50,150	50,223	1686	2479	3.362%	4.936%	0.68	*	WDFW unpubl; 1999

[1] The ratio is the treatment recovery rate divided by the control recovery rate. A value of 1.0 indicates the treatment mark does not impact survival. The treatment mark negatively impacts survival if the ratio is significantly less than 1.0, as indicated in the significance column. For studies that were not significant, no treatment impact could be detected.

[2]A ratio that is significantly different from 1.0 is indicated by an asterisk. Statistical significance indicated in this table is based on a two-sided p-value using an alpha of 0.10, that is, there is no greater than a 10% chance that the reported difference in recovery rates would be observed if the null hypothesis that there is no difference in recovery rates is true. The calculation formulas are provided in Appendix 3.

Question 2: Would the resequestering of the adipose fin clip to indicate the presence of a CWT restore the ability to collect the types and quality of information that existed prior to the desequestering of the adipose fin, given other related aspects of the CWT system are maintained (tagging rates, sampling, survival, etc)?

***SFEC Response*:** Re-sequestering the adipose fin would partially restore the type and quality of information. However, recent decreases in fishery size and structure, and in sampling coverage and intensities, have also decreased precision and accuracy of exploitation rates. These issues will not be addressed simply by re-sequestering the adipose fin.

In the absence of mass marking and mark-selective fisheries, resequestering the adipose fin clip to indicate a CWT means:

- sampling programs in fisheries, on spawning grounds and in hatcheries could rely on visual identification of tagged fish, eliminating the need for electronic tag detection (ETD),
- exploitation rates on CWT'd hatchery indicator stocks would be directly applied to associated wild stocks, eliminating the need for double index tagging (DIT).

However, since the adipose clip was desequestered as the identifier of a CWT, there have been changes to fisheries, tagging and sampling programs. Therefore, eliminating the need for ETD and DIT would not restore the types and quality of information for exploitation rate analysis that existed prior to the desequestering of the adipose fin. Relevant changes to the CWT system include:

- decrease in coverage due to
  - loss of indicator stock programs, e.g., Canadian coho,
  - loss of sampling programs for some fisheries where there is a low expectation of CWT recoveries
- decrease in precision of exploitation rates due to
  - reduced survival rates that has resulted in fewer recoverable tags,
  - reduced tagging programs (including indicator and non-indicator stocks),
  - decreased overall exploitation rates resulting in fewer tags recoverable,
  - decreased overall sampling rates due to an increased proportion of the harvest occurring in fisheries that are difficult to sample (e.g., sport fisheries) and a decreased proportion occurring in easily sampled commercial fisheries,
  - increased contribution of hatchery CWT fish to spawning grounds where sampling rates are lower (e.g., lower overall exploitation results in greater escapement which may exceed hatchery capacity. More fish may return to the spawning grounds rather than the hatchery)
- decrease in accuracy (increase in bias) in exploitation rates due to
  - unsampled fisheries (e.g., some freshwater sport fisheries, commercially caught fish sold "over the bank")
  - unreported harvest (e.g. some terminal fisheries)

Question 3: If the adipose fin was resequestered for identification of coded wire tagged fish, would the integrity of the CWT program be maintained in the presence of the alternative mark and mark selective fisheries?

***SFEC Response*:** Resequestering the adipose fin clip and using an alternative mass mark will impair our ability to estimate total mortality and exploitation rates of the unmarked fish using the double index tag system (DIT), if there is an additional delayed mortality due to the alternative mark, and if the delayed mortality continues through to adult escapement. The ability to estimate exploitation rates for marked fish will also be impaired.

Introduction

As defined by the ASFEC, SFEC, and CWT Expert Panel, the viability of the CWT system depends upon the capacity to estimate stock-age-fishery exploitation rates for natural stocks of interest to the PSC. No methods have yet been developed which are capable of generating unbiased estimates of stock-age-fishery specific exploitation rates of unmarked fish when multiple MSFs occur. Currently there are methods available that can provide estimates of total mortalities in all MSFs by age using the DIT model, both for coho and Chinook salmon.

Resequestering the adipose fin clip and using an alternative mass mark for MSFs would permit agencies to continue to utilize visual sampling methods to identify fish containing CWTs; consequently biases resulting from incomplete recoveries of unmarked fish in non-selective fisheries due to the lack of coast wide electronic tag detection would be eliminated. Presuming that adequate sampling programs are maintained for fishery catches and escapements, this marking strategy would result in complete recoveries of unmarked DIT fish in non-selective fisheries and escapements and of marked fish in all fisheries and escapements.

However, whether this would enable DIT to provide a means of estimating ***total unmarked mortalities and total exploitation rates*** of marked and unmarked paired CWT releases in MSFs depends on the mortality rate of the alternative mass mark and most importantly whether the mortality of this mark is delayed.

Assumption of DITs.

The DIT system consists of two tag groups, one having the mass mark and the other without the mass mark. Currently the DITs consist of an AD +CWT group and a CWT only group and electronic sampling is required to identify tagged fish. The two groups should be identical except for the mass mark, i.e., that the tagged fish are all from the same production group, of the same size, have been reared similarly, are tagged at the same time, are treated the same after tagging and released in the same manner. The basic assumption necessary to allow estimation of mortalities of unmarked fish in MSFs is that the only difference between the two tagged groups in a DIT pair is due to the difference in handling and release in the MSFs (i.e., there is no differential mortality between the AD+CWT and CWT only groups due to the fin clip). Thus, any difference detected between them at escapement is due only to the MSFs. Under the current system, the adipose fin is the mass mark and given no known rates of mortality associated with adipose fin clip, it is reasonable to make the assumption that there is no extra mortality on the AD+CWT tagged group compared to the CWT only tagged group.

Analysis of impacts on CWT system

There are two types of impacts that occur due to the use of an alternative mark if the mark used has an additional associated mortality. The first is the bias that can be introduced if the additional mortality is delayed, and this impact is evaluated and discussed in greater detail below. The second effect of an additional mortality on a mark used for the mass mark or the CWT indicator is the impact on precision. Precision depends on the number of tagged fish recovered, and if tagged groups have a mark that increases mortality, tag recoveries will decrease for those groups in fisheries and escapement and thus precision will be reduced.

In order to evaluate the impact of changes in the marking and tagging scheme used for mass marking and CWT identification, we simulated data for Chinook and coho salmon under three different mortality regimes. The simulated data were used to carry out cohort reconstructions, make estimates of MSF mortalities for the unmarked DIT group and of exploitation rates for the marked and unmarked fish, and calculate the resulting bias due to mark mortalities. Examples are shown for scenarios for Chinook and coho when the adipose fin clip is resequestered and an alternative mark is used for the mass mark. There is also a third scenario where the adipose fin clip remains the mass mark, but an alternative mark is used for an external CWT identifier. These analyses include no process or sampling error, in order to illustrate the bias that results only from violation of the assumptions of the DIT model.

Resequestering the adipose fin clip for CWT identification.

The proposal is to resequester the adipose fin clip as a CWT identifier, with an alternative mark as the mass mark. Then the question is whether with the new mass mark, a DIT system can still be used to estimate total MSF impacts. This depends totally on whether or not there is any differential mortality between the new mass mark and the adipose fin clip. If there is an additional mortality due to the new mass mark which can not be directly measured[1], then the basic assumption of no difference between the two groups is violated. Thus, the DIT system cannot produce unbiased estimates of total mortalities for all ages of unmarked fish in MSFs, and estimates of exploitation rates will be biased. This is true for both coho and Chinook salmon.

The extent of this bias depends on whether the additional mortality due to the mass mark occurs before age 2 recruitment or persists through-out all ages. Two examples below, for Chinook and coho salmon, illustrate how this occurs when a ventral fin clip is used for the mass mark (AD+CWT and AD+VENTRAL+ CWT) and when there is an additional mortality due to the mass mark.

Three cases are illustrated: (A) No differential mortality due to mass marking; (B) Mass Marking mortality occurs prior to age 2 recruitment; (C) Mass marking mortality occurs prior to recruitment and continues to reduce survival by 10% per year after age 2. In Tables 3-A and 3-B

[1] Note. If the differential mortality can be directly measured (e.g., if all differential mortality from mass marking occurs prior to release), then the DIT system will still work.

the shaded areas indicate data that can be directly observed. The outlined cells in these Tables indicate values that must be estimated from cohort reconstruction.

Example 1. Chinook salmon.

The cohort analysis method illustrated in Table 3-A for the unmarked DIT group depends on the estimation of maturation rates for the marked DIT group. Given an unbiased estimate of maturation rate, unmarked mortalities in MSFs can be estimated for ages 3-5.

In case A, when there is no difference in mortality between the DIT groups, there is no error in estimates of mortalities by age for unmarked fish in MSFs, in cohort size or exploitation rates for either DIT group.

In case B, when delayed mortality occurs prior to age 2, total MSF mortalities of the unmarked group can be estimated for ages 3-5, but cannot be estimated for age 2. The unmarked to marked ratio for the DIT has changed since release and the cohort size for age 2 is biased. Thus estimates of exploitation rates will be biased for unmarked fish in all fisheries. The size of this bias depends on the size of the MSFs on age 2 fish.

In case C, when delayed mortality continues through all ages, the mark mortality and the natural mortality are confounded. The estimates of mortalities for unmarked fish in MSFs are biased, as are the estimates of cohort size and exploitation rates in all fisheries. In this scenario the maturation rates estimated for the marked fish are biased and this bias results in the biased estimates of total mortalities for the unmarked DIT group. In addition, in this scenario the estimate of cohort size for the marked fish is biased, and the exploitation rates for the marked fish will also be biased.

Example 2. Coho salmon.

Table 3-B illustrates an example with age 2 and age 3 coho salmon. For coho salmon the cohort reconstruction method relies on using the unmarked to marked ratio of the DIT group at release for the estimation of the unmarked cohort size. In this case bias is the result of changes in this ratio that cannot be measured.

In case A, when there is no difference in mortality between DIT groups, there is no bias in estimates of the total mortalities for unmarked fish in MSFs, in cohort size or exploitation rates for either DIT group.

In case B, when delayed mortality occurs prior to age 2, the unmarked to marked ratio at age two has changed from the time of release. So, the estimate of cohort size for unmarked fish is biased and hence the estimate of total mortality in MSF for unmarked fish is biased and all exploitation rates, in MSFs and non-selective fisheries are biased.

In case C, when delayed mortality continues through all ages, the unmarked to marked ratio continues to change after age 2 due to the fin clip, and there will be bias in cohort size and estimates of exploitation rates for unmarked fish. And, as with Chinook salmon, the additional mortality after age 2 results in a biased estimate of the marked cohort size and biased marked exploitation rate estimates.

Sequester an alternative visible mark for the CWT indicator.

An alternative mark could be used for an external CWT indicator. This mark would have to be visible to the fishery and escapement samplers. The mark would be placed on both tag groups in the DIT pair, and any additional mortality would apply to both tag groups. It is possible to estimate the mortalities of the unmarked DIT group without bias for Chinook salmon ages 3-5. For coho salmon, mortalities at age 3 cannot be estimated without bias. And for both Chinook and coho, estimates of exploitation rate on the unmarked group would not be representative of natural fish as the natural fish do not have the extra mark mortality.

Table 3-A. Estimation of mortalities and exploitation rates for Chinook salmon from DIT tag groups given three clip mortality scenarios with the adipose fin clip as the CWT indicator and an alternative mass mark, e.g., a ventral clip.

	(A) No Differential Mortality		(B) Mortality occurs prior to Age 2		(C) Differential mortality occurs at all ages	
	AD+ CWT	AD+ CWT +VENT	AD+ CWT	AD+ CWT +VENT	AD+ CWT	AD+ CWT +VENT
SIMULATION OF DATA FOR THREE SCENARIOS						
Number CWT'd Marked	200,000	200,000	200,000	200,000	200,000	200,000
Survival To Age 2	0.01	0.01	0.01	0.01	0.01	0.01
Age 2 Recruits	**2,000**	**2,000**	**2,000**	**1,500**	**2,000**	**1,000**
Age 2 MSF Exploitation Rate on Vent-Marked Fish	0.10	0.10	0.10	0.10	0.10	0.10
Encounters of Age 2 Fish in MSFs	200	200	200	150	200	100
Release Mortality of Age 2 Fish in MSF	0.10	-	0.10	-	0.10	-
Age 2 Mortality in MSFs	20	200	20	150	20	100
Cohort Size Age 2 after fishing	1,980	1,800	1,980	1,350	1,980	900
Maturation Rate Age 2 Fish	0.01	0.01	0.01	0.01	0.01	0.01
Escapement Age 2	20	18	20	14	20	9
Survival Rate to Age 3	0.70	0.70	0.70	0.70	0.70	0.63
Cohort Size Age 3 Before Fishing	1,372	1,247	1,372	936	1,372	561
Age 3 MSF Exploitation Rate on Vent-Marked Fish	0.20	0.20	0.20	0.20	0.20	0.20
Encounters of Age 3 Fish in MSFs	274	249	274	187	274	112
Release Mortality of Age 3 Fish in MSF	0.10	-	0.10	-	0.10	0.10
Age 3 Mortality in MSFs	27	249	27	187	27	112
Cohort Size Age 3 after fishing	1,345	998	1,345	748	1,345	449
Maturation Rate Age 3 Fish	0.20	0.20	0.20	0.20	0.20	0.20
Escapement of Age 3 Fish	269	200	269	150	269	90
Survival Rate to Age 4	0.80	0.80	0.80	0.80	0.80	0.72
Cohort Size Age 4 Before Fishing	861	639	861	479	861	259
Age 4 MSF Exploitation Rate on Vent-Marked Fish	0.20	0.20	0.20	0.20	0.20	0.20
Encounters of Age 4 Fish in MSFs	172	128	172	96	172	52
Release Mortality of Age 4 Fish in MSF	0.10	-	0.10	-	0.10	-
Age 4 Mortality in MSFs	17	128	17	96	17	52
Cohort Size Age 4 after fishing	843	511	843	383	843	207
Maturation Rate Age 4 Fish	0.60	0.60	0.60	0.60	0.60	0.60
Escapement Age 4 Fish	506	307	506	230	506	124
Survival Rate to Age 5	0.90	0.90	0.90	0.90	0.90	0.81
Cohort Size Age 5 Before Fishing	304	184	304	138	304	67
Age 4 MSF Exploitation Rate on Vent-Marked Fish	0.20	0.20	0.20	0.20	0.20	0.20
Encounters of Age 5 Fish in MSFs	61	37	61	28	61	13
Release Mortality of Age 5 Fish in MSF	0.10	-	0.10	-	0.10	-
Age 5 Mortality in MSFs	6	37	6	28	6	13
Escapement of Age 5 Fish	298	147	298	110	298	54

	(A) No Differential Mortality		(B) Mortality occurs prior to Age 2		(C) Differential mortality occurs at all ages	
	AD+ CWT	AD+ CWT +VENT	AD+ CWT	AD+ CWT +VENT	AD+ CWT	AD+ CWT +VENT
COHORT RECONSTRUCTION USING DATA ABOVE						
CWT Recoveries Escapement Age 5	298	147	298	110	298	54
CWT Mortalities in Fisheries Age 5	6	37	6	28	(24)	13
Age 5 Cohort Size Pre-Fishing	304	184	304	138	273	67
Post Maturation Cohort Age 4	337	204	337	153	304	74
Maturation Rate Age 4		0.60		0.60		0.63
CWT Recoveries in Escapement Age 4	506	307	506	230	506	124
CWT Mortalities in Fisheries Age 4	17	128	17	96	(94)	52
Age 4 Cohort Size Pre-Fishing	861	639	861	479	750	250
Post Maturation Cohort Age 3	1,076	798	1,076	599	937	313
Maturation Rate Age 3		0.20		0.20		0.22
CWT Recoveries in Escapement Age 3	269	200	269	150	269	90
CWT Mortalities in Fisheries Age 3	27	249	27	187	(212)	112
Age 3 Cohort Size Pre-Fishing	1,372	1,247	1,372	936	1,133	515
Post Maturation Cohort Age 2	1,960	1,782	1,960	1,337	1,619	736
Maturation Rate Age 2		0.01		0.01		0.01
CWT Recoveries in Escapement Age 2	20	18	20	14	20	9
CWT Mortalities in Fisheries Age 2	20	200	20	150	365	100
Cohort Size Age 2	2,000	2,000	2,000	1,500	2,004	845
ESTIMATED MSF MORTALITY AND EXPLOITATION RATE						
True MSF Mortality	71		71		71	
Estimated Mortality						
Age 2	20		20		365	
Age 3	27		27		(212)	
Age 4	17		17		(94)	
Age 5	6		6		(24)	
Total	71		71		36	
Bias (Est-True)/True						
Age 2 Cohort Size	0%	0%	0%	0%	0%	-16%
Age 2 MSF Exploitation Rate	0%	0%	0%	0%	1722%	18%
Age 3 MSF Exploitation Rate	0%	0%	0%	0%	-1034%	9%
Age 4 MSF Exploitation Rate	0%	0%	0%	0%	-724%	3%
Age 5 MSF Exploitation Rate	0%	0%	0%	0%	-544%	0%

Table 3-B. Estimation of mortalities and exploitation rates for coho salmon from DIT tag groups given three clip mortality scenarios with the adipose fin clip as the CWT indicator and an alternative mass mark, e.g., a ventral clip.

	(A) No Differential Mortality		(B) Mortality occurs prior to Age 2		(C) Differential mortality occurs at all ages	
	AD+ CWT	AD+ CWT +VENT	AD+ CWT	AD+ CWT +VENT	AD+ CWT	AD+ CWT +VENT
Number CWT'd Marked	45,000	45,000	45,000	45,000	45,000	45,000
Survival to Age 2	0.05	0.05	0.05	0.03	0.05	0.03
Survival to Age 3	0.90	0.90	0.90	0.90	0.90	0.75
Age 3 Recruits	2,025	2,025	2,025	1,013	2,025	844
Age 3 MSF Exploitation Rate on Vent-Marked Fish	0.50	0.50	0.50	0.50	0.50	0.50
Encounters of Period 1 Fish in MSFs	1,013	1,013	1,013	506	1,013	422
Release Mortality of Period 2 Fish in MSF	0.10	-	0.10	-	0.10	-
Age 3 Mortality in MSFs	101	1,013	101	506	101	422
COHORT RECONSTRUCTION						
CWT Recoveries in Escapement Age 3	1,924	1,013	1,924	506	1,924	422
CWT Mortalities in Fisheries Age 3	101	1,013	(911)	506	(1,080)	422
Cohort Size Period 1	2,025	2,025	1,013	1,013	844	844
ESTIMATED MSF MORTALITY AND EXPLOITATION RATE						
True MSF Mortality	101		101		101	
Estimated Age 3 Exploitation Rate	5%	50%	-90%	50%	-128%	50%
Bias (Est-True)/True						
Cohort Size	0%	0%	-50%	0%	-58%	0%
Exploitation rate	0%	0%	-1900%	0%	-2660%	0%

Appendix 1. Terms of Reference for Special Assignment from PSC Commissioners

The following is the original wording of the special assignment from the PSC Commissioners to the SFEC:

> **"Description of tasks for the bi-lateral Selective Fisheries Evaluation Committee (SFEC) identified in the January 2006 Post-Season Meeting of the Pacific Salmon Commission (PSC)**
>
> **The concept of using another external mark for mass marking fish has been suggested as an alternative to the adipose fin clip. There is specific interest in utilizing a ventral (pelvic or anal) fin clip. Given this interest, the Co-Chairs of the SFEC, drawing upon members of the SFEC and/or others as they deem necessary, are tasked to answer the following questions and provide its assessment prior to or during the February 2006 Annual Meeting of the PSC:**
>
> 1. **Based on a search of available literature and agency information, how would the mortality rates of these alternative marks compare to those that may be associated with adipose clips and would it be the same for chinook and coho?**
>
> **If time permits, also respond to the following questions:**
>
> 2. **Would the resequestering of the adipose fin clip to indicate the presence of a CWT restore the ability to collect the types and quality of information that existed prior to the desequestering of the adipose fin, given other related aspects of the CWT system are maintained (tagging rates, sampling, survival, etc)?**
> 3. **If the adipose fin was resequestered for identification of coded wire tagged fish, would the integrity of the CWT program be maintained in the presence of the alternative mark and mark selective fisheries?"**

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Appendix 3. Equations estimating the significance of the treatment on the survival of fish in treatment group.

Given:

X is the indicator of groups (X = treatment, control)
R_X is the release size for group X
X is the number of tags recovered from group X
r_X is the proportion of tags recovered from group X

Then, the ratio is calculated as:

$$\frac{r_T}{r_C}$$

with approximate variance of:

$$Var\left(\frac{r_T}{r_C}\right) \cong \left(\frac{r_T}{r_C}\right)^2 \left[PSE^2(r_T) + PSE^2(r_C)\right]$$

where the PSE(r_X) using the binomial assumption is:

$$PSE(r_X) = \frac{\sqrt{Var(r_X)}}{r_X}$$

so that

$$P\hat{S}E(r_X) = \frac{\sqrt{V\hat{a}r(r_X)}}{r_X} = \frac{\sqrt{r_X(1-r_X)/R_X}}{r_X}.$$

Then

$$V\hat{a}r\left(\frac{r_T}{r_C}\right) = \left(\frac{r_T}{r_C}\right)^2 \left[\frac{(1-r_T)}{r_T R_T} + \frac{(1-r_C)}{r_C R_C}\right] = \left(\frac{r_T}{r_C}\right)^2 \left[\frac{(1-r_T)}{T} + \frac{(1-r_C)}{C}\right].$$

Under the assumption of normality, the significance level is calculated as the two-tailed p-value of the Z-statistic, where the Z-statistic is calculated as:

$$Z = \frac{{r_T}/{r_C} - 1}{\sqrt{V\hat{a}r\left(\frac{r_T}{r_C}\right)}} = \frac{\frac{r_T}{r_C} - 1}{\left(\frac{r_T}{r_C}\right)\sqrt{\frac{(1-r_T)}{T} + \frac{(1-r_C)}{C}}}$$

and the two-tailed p-value was calculated as:

$$2 * (1 - \Phi(|Z|)).$$