PACIFIC SALMON COMMISSION
SELECTIVE FISHERY EVALUATION

Ad-hoc Selective Fishery Evaluation Committee

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Table of Contents

Page

List of Tables

List of Figures

List of Appendices

List of Acronyms with Definitions

ADFG	Alaska Department of Fish and Game
BPA	Bonneville Power Administration
CDFG	California Department of Fish and Game
CDFO	Canadian Department of Fisheries & Oceans
CRITFC	Columbia River Intertribal Fish Commission
ChTC	Chinook Technical Committee
CoTC	Coho Technical Committee
CWT	Binary Coded Wire Tag
ESA	U.S. Endangered Species Act
FR	Fraser River
GS	Strait of Georgia
LFR	Lower Fraser River
LGS	Lower Strait of Georgia
MRP	Mark-Recovery Program
NA	Not Available
NMFS	National Marine Fisheries Service
NPS	North Puget Sound
NRC	Natural Resources Consultants
NWIFC	Northwest Indian Fisheries Commission
ODFW	Oregon Department of Fish & Wildlife
PFMC	Pacific Fisheries Management Council
PS	Puget Sound
PSC	Pacific Salmon Commission
PSMFC	Pacific States Marine Fisheries Commission
PST	Pacific Salmon Treaty
QIN	Quinault Nation
SPS	South Puget Sound
USFWS	U.S. Fish & Wildlife Service
WCVI	West Coast Vancouver Island - excluding Area 20
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
WDW	Washington Department of Wildlife

EXECUTIVE SUMMARY

Conservation concerns for wild salmon have increased interest in exploring alternative management approaches that permit harvest while reducing impacts on stocks needing protection. One such approach is the implementation of selective fisheries which would allow retention of marked hatchery fish while requiring release of unmarked fish. Although conceptually attractive, little is known about the potential impacts of selective fisheries on wild stocks or current management tools. Because of the importance of conservation, and potential implications of selective fisheries for the coastwide coded-wire-tag (CWT) system, the Pacific Salmon Commission (PSC) established an ad-hoc committee in October, 1993, to complete an assessment of selective fisheries. The assessment focused on two general questions:

> ***Can selective fishery regulations reduce harvest rates on unmarked salmon and can total exploitation rates be reduced and spawning escapements increase as a result?,***
>
> ***Can the viability of the existing coastwide CWT program for stock assessment and management planning be maintained if selective fisheries are implemented?***

Although broadly applicable, the results of our assessment should not be considered to represent a comprehensive evaluation of any specific selective fishery proposal. Furthermore, our assessment only evaluated the performance of selective fisheries and did not attempt to evaluate the effectiveness of selective fisheries relative to other management options. To address the general questions above, we investigated the more specific questions and selective fishery implementation issues presented below.

1. Can selective fisheries be applied to both chinook and coho salmon?

At this time, selective fisheries are only considered feasible for coho salmon. The logistics of marking chinook salmon are more difficult than for coho because of the large numbers of juvenile chinook salmon that would have to be marked, the smaller size of fish at release, the limited time for marking, and the necessity of handling the fish shortly before release. The complex life history of chinook, involving migration over multiple seasons and extensive geographic areas, greatly increases the difficulty of selective fishery assessment. Further, impacts of selective fisheries on chinook salmon would likely extend coastwide, increasing both costs and the difficulty of coordinating implementation. Because of these factors, our assessment focuses on evaluation of selective fisheries for coho salmon.

<u>Recommendation:</u>

1) ***Selective fisheries should not be considered for chinook salmon at this time.***

2. What external mark should be used to identify a hatchery fish?

Under selective fisheries, fish that can be retained must be easily distinguished from fish that are to be released. The adipose fin clip and ventral fin clip were evaluated as the two most feasible mass marks for selective removal on the basis of four criteria: (1) ease and cost of application; (2) ease of recognition by an untrained observer; (3) mark induced mortality; and (4) stability over the life of the fish. The adipose fin is superior across all criteria.

A Selective Fishery Model (SFM), was developed and used to evaluate the effectiveness of various selective fishing scenarios involving stocks with different patterns of exploitation. Based on assumed lower mark induced mortality and marked recognition error rates, escapements of unmarked fish and catch levels were higher with adipose clips than with ventral clips. Also, biases in CWT-based cohort analysis were lower for adipose clips than for ventral clips for the same reasons.

Recommendations:

2) ***The adipose fin should be used as the mass mark for hatchery coho if selective fisheries are implemented.***

3) ***Research should be undertaken to provide improved estimates of mark induced mortality and marked recognition error rates for adipose-clipped fish.*** Definitive data are not yet available to enable reliable estimation of these critical factors.

3. Can a selective fishery reduce harvest rates on unmarked stocks?

A fishery harvest rate is defined as the proportion of a total population available to a fishery that is killed by that fishery, whether as landed catch or incidental mortality. Harvest rates are assumed to be identical for all groups of fish available to the fishery.

Results from the SFM indicate that harvest rates on unmarked fish in selective fisheries can be substantially reduced. However, the magnitude of the reduction was variable, ranging from 10% to 80% and increased as release mortality of the gear decreased. Recreational gear, traps, and beach seines are believed to have the lowest release mortality rates. Gillnets and purse seine fisheries in which a large number of fish are caught per set are believed to have the highest release mortality rates. Troll and purse seine fisheries in which a small number of fish are caught per set are believed to have intermediate release mortality rates. The size of harvest rate reductions also depends to a lesser degree on the encounter rate of unmarked fish, marked recognition error (the probability that a marked fish will be inadvertently released), and the probability of multiple recapture of released fish.

4. Can the reduced mortality of unmarked stocks in a selective fishery be translated into reductions in total stock exploitation rates and increases in escapement?

A total stock exploitation rate is defined as the proportion of the initial cohort size that is killed by fishing, whether through landed catch or incidental harvest. The effectiveness of selective fisheries in reducing total stock exploitation rates and increasing escapements of unmarked fish varies depending upon the exploitation pattern of individual stocks as well as the regulations, placement, and size of the selective fishery.

Compared to the current situation where no fisheries are selective, we estimate that total stock exploitation rates of most unmarked stocks can be expected to be reduced by less than 5% under scenarios involving only a single selective fishery. Under the most positive circumstances, a stock's exploitation rate was reduced by greater than 30%. If all fisheries were to operate under selective regulations, total stock exploitation rates of unmarked fish can be expected to be reduced from 20% to 60%.

Changes in wild salmon spawning escapements were found to depend upon the proportion of a stock available to the selective fishery, the harvest rate reduction in the selective fishery, and the harvest of unmarked fish in nonselective fisheries.

5. How would the catches and incidental mortality in the fisheries be affected?

In our assessment, landed catch declined significantly in all cases for selective fisheries, compared to nonselective regulation. Across the range of selective fisheries simulated, landed catches in the selective fisheries were reduced by between 30% and 70%. Declines in catch levels varied with the proportion marked, the degree of marked recognition error, reduced abundance of marked fish due to mark induced mortality, and the proportion of the harvested population that is marked. The total catch in nonselective fisheries generally increased. This results from the reduced harvest rate on the unmarked fish and the marked recognition error in the selective fishery which creates greater abundance in subsequent fisheries. Incidental mortalities due to release mortality increased significantly (100% to 400%) in all selective fishery scenarios examined.

6. Can the viability of the CWT program be maintained?

Because the CWT is central to management of chinook and coho salmon, the viability of the CWT program is of vital concern. For this assessment, the viability of the CWT system is defined as:

- The ability to use CWT data for assessment and management of wild stocks of coho and chinook salmon;
- Maintaining the program such that the uncertainty in stock and fishery assessments and their applications does not unacceptably increase management risk; and

- The ability to estimate stock-specific exploitation rates by fishery and age.

Based upon our analysis, it is apparent that the viability of the CWT program will be impaired if selective fisheries are implemented on a broad scale. Substantial changes to tagging and recovery programs will be needed to minimize the potential loss of management information. Interagency coordination in research and management methods must be increased to reduce the risk to the CWT system. Further, during transition periods when selective fisheries are either implemented or terminated, there is a higher risk that management capabilities would be degraded.

To minimize the loss of information if selective fisheries are implemented, the CWT program should be modified as follows:

Recommendations:

4) ***Do not use an external identifier for CWT fish. Electronic detection should be employed to randomly sample for CWTs in all fisheries and spawning escapements where CWTs are expected to be recovered. CWTs of 1-1/2 length should be used to increase the reliability of electronic detection.*** Given the adoption of Recommendation 2, the adipose fin clip could no longer be used as the external identifier of CWT fish. In addition, voluntary recovery of tags in recreational fisheries would no longer provide useful information so random sampling of recreational fisheries would be required.

5) ***Implement double index tagging of marked (ad-clip + CWT) and unmarked (CWT only) hatchery groups.*** Double index tagging, involving the use of paired replicates, will be required regardless of which mass mark type is finally chosen. This will approximately double the numbers of tags released for indicator stocks.

6) ***Maintain "adequate" levels of tagging and recovery sampling.*** Our ability to generate useful estimates from the CWT system depends upon the recovery of a sufficient number of CWTs. Specific levels of tagging and sampling will depend upon the objectives of the CWT program and selective fisheries.

7) ***Sample all fisheries for the proportion marked.*** Our ability to estimate catch compositions and interceptions will be compromised if all fisheries are not sampled for mark ratios.

8) ***Ensure extensive inter-agency cooperation and coordination of mass marking, CWT recovery programs, and selective fishing. Mass marking of hatchery fish by removing adipose fins should not be permitted until assurances are received from substantially affected jurisdictions that CWTs will be electronically sampled.*** Piecemeal implementation of selective fisheries is not possible. Once an agency decides to mass mark fish in anticipation of implementing a selective fishery, the viability of the CWT program cannot be maintained unless required changes to

sampling programs in all affected agencies are made. If poorly implemented, selective fisheries could incur high costs while producing few benefits to fisheries.

9) ***Associate wild fish tagging programs with a representative hatchery marking program within the same production area for stocks that are significantly impacted by selective fisheries.*** Wild fish survivals and production cannot be evaluated without paired CWT experiments.

10) ***Management planning and stock assessment methods affected by selective fisheries must be modified prior to the implementation of these fisheries.***

Even with these efforts, however, some information and aspects of the present CWT program will be compromised or lost. The degree to which information is lost is directly related to the size of the selective fishery program.

- The independence of tag groups will be lost. Unmarked hatchery and wild tag groups must now be associated with marked and tagged hatchery groups. This association will be much more tenuous for unmarked wild tag groups.

- Uncertainty in our estimates obtained from cohort analysis will increase due to additional assumptions required to estimate incidental mortalities.

- We will not be able to estimate fishery-specific mortalities on unmarked stocks when multiple selective fisheries occur. Currently, fisheries are often regulated on the basis of limitations on stock-specific mortalities. The loss of information would impair management planning, allocation and stock assessment capabilities. This loss of information becomes increasingly critical as incidental mortalities increase.

- Under selective fisheries, incidental mortalities, which are not included in current estimates of interceptions, may become too large a component of interceptions to ignore.

On the other hand, many of the measures recommended for selective fisheries could improve the basis for fisheries management. For example, electronic detection of CWTs and direct random sampling of recreational catches could improve the precision of estimates of tag recoveries. In addition, the marking of all hatchery fish would increase the accuracy of accounting for this production in fisheries or escapement. However, we emphasize that these measures could be implemented independently of selective fisheries.

7. What are the costs associated with implementing a selective fishery program?

The monetary costs of selective fisheries are substantial. The table below summarizes some of the costs associated with implementing selective fisheries in the Strait of Georgia and Puget Sound. Cost estimates do not include expenses associated with evaluation, or implementation in other areas of the U.S. whose stocks or recovery programs may be affected, or revisions to analytical tools and management models.

Country	Capital Investment ($US)	Annual Operation (marking, tagging & sampling) ($US)
United States	1.446 million	0.844 million
Canada	1.219 million	0.893 million

The implementation cost for establishing the first selective fishery would be high since major changes to the sampling programs and management would be required. The costs of implementing additional selective fisheries would be lower since the major modifications would already be in place.

There are also costs associated with reduced catches, the loss of fish due to mark induced mortalities and increased incidental mortalities during selective fisheries. These costs could be large, depending on the selection of mass mark, the gear, the scale of the selective fisheries, and the ratio of marked to unmarked fish in the fishery.

8. How should selective fisheries be evaluated?

Considerable uncertainty exists around the outcomes predicted by our assessment, due to our limited experience with selective fisheries and the inherent variability in the many factors and processes defining selective fisheries. Given the uncertainty of expected outcomes, assessment of the effectiveness of any selective fishery implemented will rely heavily on observation and measurement of actual outcomes. Spawning escapement, total fishing mortality, exploitation rate, fishery opportunity and economic benefits and costs, are outcomes that can be monitored and used to assess the effectiveness of management programs involving selective fisheries.

Recommendation:

11) ***Selective fishery programs should not be implemented without specific, measurable criteria to provide an objective basis for performance evaluation.***

12) ***Differences in exploitation or escapement rates between paired replicate, double index tag groups should be the primary means of evaluating the impact of selective fishery regimes on individual stocks.***

9. Should selective fisheries be implemented?

Ultimately, decisions about selective fisheries will rest upon value judgements contrasting wild stock conservation and fishing opportunities against the loss of information essential for management and the financial costs of implementation. To maintain the positive aspects of both selective fisheries and CWTs, a full and coordinated effort by all marking and affected sampling agencies will be required. Our assessment indicates that greater interdependencies among management jurisdictions will exist under selective fisheries. Decisions made by one agency to implement a selective fishery will unavoidably affect other agencies.

Recommendations:

13) ***Establish and adopt a format for selective fishery proposals to provide for effective review by all affected jurisdictions.*** A recommended general outline for such a format is presented in Appendix C); the detail required for the items indicated in the outline should be determined on a case-by-case basis.

14) ***Establish and adopt a process to review, approve and implement mass marking and selective fishery proposals. This process should involve all affected jurisdictions.***

A broad array of potential benefits and costs to fisheries, management capabilities, and the resource have been examined in our assessment. Where serious problems with implementation have been identified, we have tried to develop alternative procedures to overcome those problems, but we have not been completely successful. During a period of reduced budgets and increasing public concern for conservation of biological diversity, these potential benefits and risks must be carefully weighed. While selective fisheries may prove useful in achieving certain management objectives, less risky and costly alternatives exist that could accomplish many of these objectives.

Recommendations:

15) ***Management alternatives to selective fisheries should be fully considered and evaluated before selective fisheries are implemented.***

CHAPTER 1. INTRODUCTION

Public concern for conservation of naturally-produced salmon stocks is increasing. In response, management agencies are seeking innovative approaches for fisheries regulation which expand the repertoire of tools that can be employed to achieve fishery and conservation objectives.

One such approach is selective harvest. Many fisheries are selective in that time, area, or gear restrictions are used to direct the harvest at specific species or stocks. In this report, however, a selective fishery will be defined as one in which only fish with an identifying mark may be retained for harvest. A selective fishery actually consists of two essential components: 1) mass marking to identify fish that can be retained; and 2) the implementation of regulations that require the release of unmarked fish. *In combination with appropriate regulations in other fisheries*, selective fisheries may theoretically bring total harvest impacts within desired levels for wild stocks of concern.

Conceptually, selective fisheries are straight forward and appealing. The basic concept is to enact regulations that provide protection for wild stocks by targeting harvest on hatchery-produced fish. However, selective fisheries are not a panacea that can resolve resource management problems in every situation. In practice, there are many complexities associated with their implementation.

Analyses are essential prior to implementation to determine the effectiveness of selective fisheries in achieving conservation objectives, impacts on fisheries, and implications for changes in management systems. The primary questions are:

Can selective fishery regulations reduce harvest rates on unmarked salmon and can total exploitation rates be reduced and spawning escapements increase as a result?

Can the viability of the existing coastwide CWT program for stock assessment and management planning be maintained if selective fisheries are implemented?

These two questions are critically important to the Pacific Salmon Commission (PSC). As a result, the PSC instructed the Coho (CoTC) and Chinook (ChTC) technical committees to undertake a technical assessment of selective fisheries. In addition to the two primary questions, the committees were to consider fishery impacts, costs, evaluation criteria, and related issues. It is important to note that the committee was not asked to evaluate selective fisheries relative to other management alternatives.

In response to this assignment, an Ad-Hoc Selective Fisheries Evaluation Committee was formed. The approach comprised three major elements, each with unique tasks:

1) **Steering Committee.** The purpose of the Steering Committee was to guide and coordinate the efforts of the work groups, oversee the completion of the final report and organize a workshop to present results of the selective fishery assessmen

2) **Work Groups.** Three work groups were created. Each work group was comprised of representatives of the CoTC and ChTC and agency staff. Work groups were charged with responsibilities for completing specific tasks:

a) Modeling and Analysis. Assess the probable effects of selective fisheries on harvest rates, exploitation rates, and spawning escapements for both unmarked and marked stocks. Also, changes in the distribution of mortalities, catch rate, total catch, and incidental mortalities were to be evaluated. The work group was also tasked with identifying critical data for post-fishery evaluation of selective fisheries.

A Modeling Subcommittee was formed to develop a simulation model to conduct the selective fishery assessments. This model would also facilitate an evaluation of a variety of selective fishery scenarios involving different gear types, fisheries, mark types, varying levels of post-selective fishery harvest, and hatchery contribution rates.

b) Management Capabilities. Assess the impacts of selective fisheries on current management tools such as the CWT program, cohort analysis, harvest management planning models, and stock composition estimation methodologies. Also, evaluate alternative methods for overcoming these impacts (e.g., alternative marking methods and sampling procedures).

c) Implementation and Evaluation. Evaluate potential mass marks and associated CWT detection regimes. Describe the program and quantify the costs of implementation and post-fishery evaluation (marking, regulation, monitoring). Determine perception and predicted responses of user groups to selective harvest (e.g., compliance, redirection or re-location of fishing effort).

3) **Workshop.** Results of the selective fishery assessment were presented to the PSC in fall 1994, followed by a technical workshop to facilitate the exchange of information between representatives from the PSC, management agencies, and the general public. The presentation and workshop took place December 1 and 2, 1994, respectively.

This report documents the results from the studies of the work groups for coho salmon (*Oncorhynchus kisutch*). Conclusions are presented on the potential impacts of selective fisheries on wild salmon exploitation and conservation, and on the continued effectiveness of existing stock assessment and management planning tools, including the CWT program. Recommendations are provided to assist agencies interested in evaluating selective fishery proposals with a strong proviso that implementation must be conditional on concurrence of other agencies whose fisheries and stock assessment capabilities will be impacted.

Initially, selective fisheries were to be assessed for both chinook salmon (*O. tschawytscha*) and coho salmon. The results and conclusions presented in this report apply to coho salmon only. Selective fishery options for chinook salmon are considerably more difficult to assess than for coho salmon because of the greater complexity of the chinook salmon life history, variable release mortality rates for different age chinook salmon, and the more extensive ocean migration of individual chinook salmon stocks resulting in impacts on more fisheries and stock assessment programs. Further, the technology is not currently available to mass mark large numbers of chinook salmon in a short period of time, or to electronically detect CWTs, the preferred method for coho salmon, in large-bodied individuals. Reference is made to chinook salmon in some sections of the report, but no detailed assessment of selective fisheries for chinook salmon is provided.

CHAPTER 2. GEAR AND REGULATION CONSIDERATIONS

2.1 Gear Types

The effectiveness of a selective fishery in reducing the mortality of unmarked fish will depend on the release mortality rates. Release mortality rates vary with the gear used, the manner fished, and the condition of the fish brought to the boat. While numerous studies in the literature that have investigated the release mortality rates associated with hook and line gear (particularly recreational), published estimates for commercially fished gillnet and purse seine gear are limited. Additional research is needed to determine release mortality rates for these gear types.

Fishing methods typically employed in commercial gillnet fisheries are likely to result in high release mortality rates. Although the mechanism of capture itself (gilling and tangling) is often lethal, surviving capture and subsequent release is possible and likely depends on several factors. These include the time between capture and release of gilled fish, catch rate, size and tension of meshes, and physiological condition of the fish. Gillnetters in the Skeena River, B.C. recently began to release steelhead salmon (*O. mykiss*) while fishing for sockeye salmon (*O. nerka*). However, mortality rates resulting from single captures were estimated at 60% to 75% (S. Cox-Rogers, CDFO, Pers. Comm.).

Carefully monitored gillnetting is commonly used to collect adult salmon broodstock. WDF used gillnets to capture chinook salmon broodstock on the Skagit River with mixed success (Baranski 1980). Fish captured in the lower river during acclimation to freshwater experienced almost total mortality. However, fish captured one month later nearer the spawning grounds suffered less than 5% mortality. In 1993, Washington tribal and nontribal fishers in Quilcene Bay used gillnets as selective gear to identify release mortality rates of summer chum (*O. keta*) in a coho salmon directed fishery. A total of 39 chum salmon were caught and retained in pens during periods monitored by agency biologists. The immediate mortality observed was 26%. The surviving retained fish were successfully held to spawn. A similar program conducted in 1992, yielded 59 chum salmon and an immediate mortality of 10% (D. Zajac, USFWS, Pers. Comm.).

Chinook salmon mortalities resulting from purse seine capture and release are generally high. Scale loss, gilling, and stress associated with handling contribute to significant reductions in survival. Large sets exacerbate these problems (Cole 1975; Van Alen and Seibel 1986; Van Alen and Seibel 1987). ChTC (1987a) concluded that induced mortality rates may range from a minimum of 50% to as high as 100%. Preliminary results from recent CDFO studies using sonic tagging have estimated release mortality of chinook salmon tracked for 12-36 hours at approximately 24% (B. Riddell, CDFO, Unpub. Data). These studies also noted a relationship between mortality and total catch size, and handling practices. Mortality rates were lower when the catch was brailed. However, handling practices employed in these specialized circumstances are not often used in commercial applications.

Several recent independent studies have reported release mortality rates for commercial and recreational hook-and-line fisheries. The release mortality rate assumed for managing commercial troll fisheries by PFMC, Washington, Oregon, and California is 26% (30% rate reported by Stohr and Fraidenburg 1986, adjusted by PMFC for barbless hooks). Recent study results from Wertheimer et al. (1989) support this estimated value.

Recreational hook-and-line gears have a lower release mortality rate than commercial troll gear. Several authors have reported the release mortality rates associated with recreational fisheries for adult coho salmon in marine and riverine areas to be in the range of 6-10% (Gjernes 1990; Natural Resources Consultants 1991, 1993; Vincent-Lang et al. 1993). Release mortality rates for coho salmon in their first year of ocean residence (total age two) and in estuarine areas may be higher. Gjernes et al. (1993) estimated an average mortality rate of 13% for age two (<30cm) coho salmon in marine areas and the estimated mortality reported for adult coho salmon caught in estuarine areas was 69% (Vincent-Lang et al. 1993). Release mortality rates for larger (>30cm) chinook salmon caught in marine areas may be slightly higher (9-14%) than for coho salmon (Gjernes 1990; Natural Resources Consultants 1991). The mortality rate for sub-legal (<30cm) chinook salmon appears to be significantly higher. As with coho salmon, the mortality rate is greatest (approximately 30%) in the first year of ocean residence (Gjernes et al. 1993). Bendock and Alexandersdottir (1993) reported 4-11% overall mortality for adult chinook salmon caught and released in freshwater.

Other gears, such as traps, reef nets, beach seines, and fish wheels, may have even lower release mortalities than recreational hook-and-line gear. Although there is little data on the release mortality of these gears, the capture methods would intuitively seem to enable live release. Additional studies of the release mortality rates of these gears should be conducted.

2.2 Regulating Catch in Selective Fisheries

Regulating catch in selective fisheries may be accomplished by placing limits on landings of marked and/or unmarked fish. Time and area restrictions may also provide managers with some measure of stock selective catch regulation if the timing, migration or rearing patterns of marked and unmarked stocks differ sufficiently. Such restrictions were not evaluated in this assessment.

Fisheries could be managed by a combination of selective and nonselective restrictions. Depending on the degree of selectivity desired, some retention of unmarked fish could be allowed. For example, separate limits could be placed on the number of marked and unmarked fish retained by fishers. In situations where marked fish were less plentiful, some degree of retention of unmarked fish might be considered acceptable to achieve a satisfactory angling experience.

Fishery managers currently employ two general types of catch limits to achieve a range of fishery and resource objectives: (1) catch limits are applied to individual fishers or boats (e.g., as daily or seasonal bag limits for recreational fisheries); or (2) limits are defined for entire fisheries (e.g., a seasonal catch quota). These approaches are discussed in more detail below.

2.2.1 Regulation Applied to Individual Anglers or Effort Units

Restrictions applied to individual units of effort are most likely to be used for managing recreational fisheries. The most commonly employed controls are the daily, trip, or seasonal limit on landed catch. Daily bag limits are used to limit catch rates and to maximize economic benefits associated with recreational fishing by distributing harvest among anglers participating in the fishery and extending season lengths. Daily bag limits may be applied to marked and/or unmarked fish. For example, a fishery can be completely selective, requiring release of all unmarked fish, with bag limits applying to marked fish only. Alternatively, if harvestable unmarked fish are available, managers may wish to consider a mixed, marked and unmarked daily limit.

The application of effort and/or gear restrictions to commercial fisheries is not discussed in detail in this report. Daily catch limits per boat, similar to the recreational fishery application, could be developed for hook-and-line (troll) or net gear types. It is also possible that individual boat quotas on marked or unmarked fish could be applied. Management of fisheries on an individual boat basis would cost more than application of catch controls to entire fisheries. Commercial fisheries could also be managed on the basis of allowable landing ratios of unmarked to marked fish.

2.2.2 Regulation on a Fishery Basis

Limits on total catch may be applied to fisheries when the objective is to ensure that a particular stock impact is achieved or at least not exceeded. Without the capability to directly measure stock specific impacts, managers have defined stock impact limits in terms of the total catch of all stocks. Quotas and ceilings are two types of fishery catch limits currently employed in managing nonselective fisheries. Catch quotas and ceilings could be applied to marked fish with no retention of unmarked fish. However, the stock specific impacts of those controls could differ markedly from ceilings or quotas applied to nonselective fisheries.

Allowable total impacts for a fishery are most often defined in terms of the wild stocks, or stocks that can sustain relatively lower harvest rates and/or total catch. In completely selective fisheries, wild stocks are unmarked and regulations would prohibit their retention. Hence, catch limits would not relate directly to the impact of the fishery on wild fish. The impact on wild stocks would be limited to release and/or drop-off mortalities, and mistaken retention of unmarked fish, except in those cases where some retention is allowed (e.g., mixed bag or landing limits). These sources of mortality would offset to some degree the effectiveness of quotas or ceilings used with selective fisheries. The uncertainty surrounding the effectiveness of such regulations underlines the need for information on unmarked fish encounter rates. Data necessary to make accurate estimates of encounter rates in a selective fishery might be obtained from on-the-water sampling, angler surveys or log-books.

2.3 Examples of Selective Mark Fisheries

Currently, many recreational fisheries are regulated to allow retention of marked fish only. Steelhead salmon fisheries in the U.S. and Canada are managed by retention regulations where hatchery fish are identified by the absence of the adipose fin (and no fresh scar). In B.C., when the selective fishery for steelhead salmon was first implemented, considerable discontent was initially expressed by anglers, and license sales declined. The anglers' major concern was an erroneous belief that caught-and-released fish suffered a high rate of mortality. A public education program effectively defused this concern.

Compliance was also a significant problem in B.C. for this selective fishery. Extra staff were hired for the first year to deal with enforcement problems on some rivers and, while some wild fish are still retained, compliance has improved. Angling ethics may be changing as selective fisheries become more common. Today, 50% or more of marked hatchery steelhead salmon are also released by anglers (B. Ward, B.C. Ministry of Environment, Lands and Parks, Pers. Comm.). Most B. C. anglers feel this selective fishery is very successful and is effective in protecting wild steelhead salmon. However, data for quantitative assessments are not yet available.

In Washington State, WDW initiated adipose clipping of hatchery steelhead salmon in 1981 in the Columbia Basin. Coordinated programs soon followed throughout the Columbia River basin with Oregon and Idaho. By 1992, all hatchery steelhead salmon released by Washington State were marked by adipose clip. Similar to the Canadian experience, U.S. anglers were slow to accept selective fishing, but acceptance has grown due to familiarity with regulations and public education programs. Information related to wild steelhead salmon release regulations, collected in 1992 and 1993 by WDW enforcement agents indicates that over 95% of anglers contacted were in compliance (R. Gibbons, WDFW, Pers. Comm.).

Today, wild steelhead salmon release regulations are in effect in Washington for all summer-run steelhead salmon, and on nearly 50% of winter-run streams for all or part of the season. Steelhead fishing generates a large annual economic activity in the state of Washington. For example, Gibbons (1994) estimated that the 1992-93 recreational steelhead salmon season generated approximately 50 million dollars of economic activity. Managers of these fisheries believe a significant portion of the total angling opportunity associated with these benefits would have been lost without the selective mark fishery regulations (B. Crawford, WDFW, Pers. Comm.).

2.4 Discussion and Summary

Management of selective fisheries requires definition of the allowable gear types and imposition of regulations to control catch. Various gear types and approaches to fishery regulation have been considered to facilitate the following fishery management objectives:

1) Provide for adequate escapement from fisheries;

2) provide for meaningful fishing opportunity;

3) ensure orderly fishery conduct; and

4) ensure information is collected to enable evaluation of fishery performance.

A variety of gear types may be employed successfully in fisheries that require live release. Gillnet gear release mortality rates are relatively high, hence the feasibility of using this gear for selective fisheries is low. Mortality rates associated with purse seines are also high, though some instances of lower mortality have been reported when special handling of the gear and/or fish was employed. Release mortality rates associated with net gears may be reduced under certain conditions, that may include modifications to net gears currently available. Other capture methods such as traps, reef nets, beach seines and fish wheels may prove to be practical, low cost gears for selective fishing, but further research and development is needed before we can determine if these methods can be successfully applied in selective fisheries. The effects of selective fishing with net gears are analyzed in Chapter 6, assuming that release and drop-off mortality rates are relatively high.

Hook-and-line gears, traps, reef nets, beach seines, and fish wheels have typically lower release mortalities than gillnets and purse seines, and are the most promising for successful selective fisheries. Recreational fishery release mortality rates for adult coho and chinook are approximately 10%, while mortality rates for the troll fishery are in the range of 20% to 30%.

Some selective fisheries may be regulated by restricting catch on the basis of individual units of gear, whereas others could be managed on total catches for a season. Recreational fishery managers need to consider the effects of selective fisheries on angler compliance, regulation complexity and changes in effective effort. Management of fisheries by total catch will be more difficult to assess since both landed and incidental mortalities must be considered when determining stock-specific impacts of the fishery. Implementation of selective fisheries will require additional sampling to produce acceptably precise estimates of catch and incidental mortality.

CHAPTER 3. USER GROUP PERCEPTIONS AND EXPECTATIONS

Most fishers for Pacific salmon are aware of the need for conservation and some know that hatcheries produce a significant proportion of their catch. Measures that are perceived to maintain fishing opportunity while protecting wild fish will likely be accepted. Many fishers have expressed support for the concept of selective fisheries. The successful implementation of selective fishery initiatives will require a clear demonstration that sufficient numbers of marked fish will be available for harvest, that released fish will survive at acceptable rates, and significant numbers of wild fish will reach the spawning grounds. Continued support for selective fishery regulations will depend on the perceived catch success and improvement in the health of wild stocks.

3.1 Recreational Fisheries

Extensive consultation with B.C. sportfishers clearly indicate support for the concept of a selective fishery for coho salmon in the Strait of Georgia. The B.C. Wildlife Federation, which represents organized anglers, has strongly endorsed this concept as has the Sport Fishing Advisory Board, the official advisory body to CDFO on recreational fisheries.

Recreational fisheries advisors in B.C. strongly advocate that any fin mark should designate a fish that may be retained (W. Otway, Recreational Fishery Ombudsman for CDFO, Pers. Comm). Confusion will result if one mark is used to designate a fish that can be retained, and another one to designate a fish with a CWT (which may or may not be retained, depending on whether or not it has an additional mark). A selective fishery with complicated regulations will not be acceptable to most fishers, enforcement personnel, or fisheries managers.

In B.C., the recreational fishing community will certainly accept a selective fishery based on the adipose clip as the selective mark coupled with direct sampling and electronic detection of CWTs. Organized anglers have also stated their willingness to pay for some of the costs associated with a selective fishery.

In Washington, two general conclusions emerged from a recent WDFW survey about selective fisheries at a 1994 Seattle Sportsman show. Many of those interviewed had no knowledge of the selective fishery concept and were likely to have no opinion. However those who were knowledgeable were generally supportive (M. Alexandersdottir, WDFW, Pers. Comm.). Surveys of anglers after implementation are recommended to measure their perceptions regarding selective fisheries.

A number of groups representing recreational fishers provided testimony at a hearing (June 3, 1994) in the Washington State Senate Natural Resources Committee regarding a proposed bill to mass mark and selectively harvest coho and chinook salmon. These groups included the Northwest Steelhead and Salmon Council of Trout Unlimited, the Puget Sound Recreational Fisheries Enhancement Oversight Committee, the Northwest Marine Trade Association, The Recreational Fishing Coalition, and the Northwest Sport Fishing Industry

Association. Each of these groups supported the proposed bill, generally with the expectation that mass marking and selective fisheries would rebuild wild stocks, maintain recreational fishing opportunities, and contribute to the economic viability of the recreational fishing businesses of Washington.

3.2 Commercial Fisheries

The Washington legislative hearing previously discussed also provided representatives of commercial fishing groups an opportunity to present their views on mass marking and selective fisheries. Groups which presented testimony included the Willapa Bay Gillnetters, the Northwest Gillnetters Association, the Purse Seine Vessel Owners Association, and Salmon For Washington. A diversity of opinions were expressed, but general themes included the following:

1) The money required to implement selective fisheries could be more usefully applied in the renovation and protection of habitat and the production of more fish through enhancement;

2) commercial fisheries are currently managed in a manner which makes them highly selective toward the harvestable or target stocks and species; and

3) selective fisheries may be used to re-allocate catch from the commercial fishery to the recreational fishery.

Several groups have suggested that selective fisheries might increase fishing opportunities for commercial fisheries, either indirectly as a result of a reduced need to protect wild stocks, or directly through the implementation of selective commercial fisheries. The latter viewpoint was echoed by Mr. Zeke Grader, Executive Director of the Pacific Federation of Fishermen's Associations, at a forum sponsored by the PSMFC (October 2, 1994). Mr. Grader suggested that one option might be to establish a selective troll fishery on a trial basis off the coast of northern California, where fisheries are currently closed.

3.3 Treaty Indian Fisheries

Representatives of the Northwest Indian Fish Commission (NWIFC) also provided comments on mass marking and selective fisheries at the Washington legislative hearings and at the PSMFC forum. The representatives indicated that before formulating a position on selective fisheries, the treaty tribes of western Washington were waiting to examine the results from the PSC assessment. Tribal support of mass marking and selective fisheries would likely be dependent upon:

1) A demonstrable benefit to the escapements of wild stocks, particularly those classified as threatened or endangered under the U.S. Endangered Species Act (ESA);

2) maintenance of the viability of the CWT system;

3) implementation with full coordination and agreement among affected management agencies;

4) benefits to tribal fisheries commensurate with the additional uncertainty introduced into stock assessment and the additional costs of marking, management, and enforcement; and

5) securing funding for the additional costs of marking, sampling, management, and enforcement without decreasing current agency funding levels for existing tagging, sampling, enhancement, and management programs.

The Columbia River Inter-Tribal Fish Commission (CRITFC) has not been fully supportive of mass marking and selective fisheries for the reasons listed by NWIFC and for additional reasons. It is clear that significant increases in funding would be required to enact selective fisheries and maintain the viability of the CWT programs. CRITFC believes that maintaining current funding levels for sampling, enhancement, and management programs would not be adequate. CRITFC also believes that the causes of decline of wild fish stocks must be addressed and corrected. This involves not only changes in harvest, but also in hatcheries, habitat, and hydroelectic power generation practices as well. Selective fisheries should only be considered as a part of a more comprehensive restoration plan which addresses the causes of decline of the wild stocks.

CHAPTER 4. OVERVIEW OF THE COASTWIDE CWT SYSTEM

It is imperative that any selective fishery program not compromise the viability of the current CWT system as used for fisheries research and management. The coastwide CWT system is reviewed below to demonstrate the massive scale of the program and the role that it plays in salmon research and fisheries management. Much of the discussion below is drawn from a previous report prepared by the PSMFC (1992) which reviewed alternatives for mass marking anadromous salmonids.

4.1 Historical Sketch

CWTs were introduced in 1971 as a method to easily mark large numbers of salmonids. The adipose fin clip was later sequestered as the external flag for CWT marked salmon. Advantages of CWTs included large numbers of possible codes, relatively low cost per tag, ease of application, and low mortality.

Coastwide usage of CWTs quickly followed and led to the establishment of ocean sampling and recovery programs by ADFG, CDFG, CDFO, ODFW, and WDF in the early 1970s. Regional coordination of the numerous tagging studies was provided by PSMFC's Regional Mark Committee. In addition, the Regional Mark Processing Center established a centralized database for coastwide CWT release and recovery data, and the associated catch and sample data. CDFO maintains an equivalent database on the Pacific Biological Station's Vax computer. Data are shared using procedures and formats established by the PSC.

4.2 Current CWT System

The CWT program has steadily expanded over the past two decades, with over 55 state, federal, provincial, tribal, and private entities in the U.S. and Canada now releasing tagged salmonids for assessment and research. An estimated 47 million juvenile salmon are tagged annually. Chinook tagging levels are highest (32 million), followed by coho (11 million). Steelhead, chum, pink, and sockeye salmon tagging levels are lower, at approximately two million, one million, 0.5 million, and 0.5 million fish, respectively.

This massive tagging effort represents approximately 2,000 new tag codes each year. The total cost of tagging is in excess of four million dollars ($US) annually. The cost per individual fish is about 11 cents (PSMFC 1992). An additional eight to nine million dollars is expended annually for tag recovery programs in U.S. and Canadian commercial and recreational fisheries. Tag recoveries from returning adults are on the order of 0.35 million per year.

The coastwide CWT system truly represents a long-term, multi-million dollar investment that lies at the heart of our stock assessment capabilities. The CWT system is the most widely used stock identification technique on the west coast of North America for salmonid research and management (Johnson 1990). Objectives of studies utilizing CWTs include the following:

1) Evaluation of hatchery production (contributions to fisheries);

2) investigations of ways to improve hatchery production (e.g., differential treatment studies on size of fish at release, time of release, diets, disease treatment, and stock differences);

3) evaluation of enhancement alternatives;

4) determination of mitigation effectiveness;

5) determination of wild stock productivity;

6) determination of migration patterns;

7) estimation of fishery contribution rates;

8) estimation of fishery exploitation rates;

9) evaluation of fishery adjustments to increase harvest and/or reallocate harvest; and

10) monitoring interceptions and providing information for negotiation of international agreements.

All fishery management agencies on the west coast utilize the CWT for stock identification for the following reasons:

1) The CWT program includes fully integrated tagging, sampling, and recovery operations along the entire west coast of North America;

2) the CWT provides sufficient resolution for stock-specific assessments; and

3) the CWT is the only stock identification technique for which a historical record (generally back to the mid-1970s) of stock-specific assessments may be computed.

4.3 Obligations

Provisions of the Pacific Salmon Treaty underscore the important role that CWT data play in the management of salmon fisheries. The necessity of maintaining a viable coastwide CWT program was explicitly recognized in the Pacific Salmon Treaty's accompanying Memorandum of Understanding, Section B (Data Sharing): "*The Parties agree to maintain a coded-wire tagging and recapture program designed to provide statistically reliable data for stock assessments and fishery evaluations*". No other data and/or methods exist that are currently capable of providing the information required to evaluate the effectiveness of chinook and coho salmon fishery management actions undertaken by the PSC.

The explosive coastwide growth seen in the use of the CWT made it imperative that a single fin mark be reserved as the external flag for CWT marked salmonids. Therefore, in 1977, the Regional Mark Committee agreed to sequester the adipose fin clip for tagged chinook and coho salmon. This coastwide restriction was later expanded to include chum, sockeye, steelhead and pink salmon, with some exceptions made for the use of multiple fin clips. Steelhead salmon were later exempted from the restriction so that the adipose fin clip could be used to indicate hatchery fish for selective fisheries. This latter usage did not pose a problem for agencies with ocean recovery programs since there was no coastwide sampling program for steelhead salmon.

4.4 Sampling and Monitoring Programs

Over 55 agencies in the U.S. and Canada participate in the coastwide CWT program, but the burden of marine tag recoveries falls mainly on five agencies: ADFG, CDFO, WDFW, ODFW and CDFG. A complete description of the coastwide CWT database, tagging and sampling programs is given by Johnson (1990). He defines several common elements of these major recovery programs:

1) Sampling of commercial and recreational fisheries and escapement;

2) a 20% sampling goal; and

3) universal sampling for adipose fin-clipped chinook and coho salmon.

Chum, pink and sockeye salmon fisheries are not sampled universally for CWTs as major CWT programs do not exist for these species. Steelhead salmon are also not universally sampled coastwide for adipose finclips or CWTs (Johnson 1990).

4.4.1 Sample Design for CWT

The major goal of the sampling program for CWTs is to estimate the total number of CWT marked salmon killed by fisheries or escaping into rivers or hatcheries. In most cases, the total number of salmon with CWTs is estimated by directly expanding recoveries observed by a sample fraction.

The basic sample design for recovery of CWTs coastwide is to randomly sample 20% of the harvest of coho and chinook salmon in fisheries and 30% to 100% of hatchery escapements. This goal was set in an effort to achieve statistically acceptable estimates of total recoveries (Johnson 1990). The sampling effort is stratified by statistical areas, gears and time periods, which are defined by the agencies responsible for the sampling program. Strata are also defined for expansion of observed recoveries to total recoveries, and are not always the same as the sampling strata (Johnson 1990). However, since 1980, 20%-60% of the sampling strata defined coastwide have been under-sampled at the 20% sampling goal level (PSC Data Sharing Committee, report in preparation). Information is not currently synthesized to permit an evaluation of the extent to which hatchery and wild escapement sampling have achieved the goal levels.

4.4.1.1 Voluntary Tag Recovery Programs in Marine Recreational Fisheries

In Puget Sound and B.C., marine recreational fishery sampling depends wholly or in part on anglers voluntarily returning heads of fish with adipose finclips. In B.C., the CWT recoveries originate solely from voluntary returns. In Puget Sound, the marine recreational fisheries are sampled, but at rates averaging 5% to 10% of total harvest of coho and chinook salmon. These sampled recoveries are supplemented with voluntary returns.

CDFO and WDFW expand voluntary recoveries using awareness factors. The awareness factor is an estimate of the proportion of tagged fish taken by anglers which are voluntarily returned. Awareness factors are calculated by dividing the number of tags returned by the estimated total number caught as determined by port sampling or creel census programs. They are calculated on an area and time period basis, usually statistical area and month.

4.4.1.2 Freshwater Recreational Fisheries

In general, freshwater recreational fisheries are not sampled for CWTs in B.C., Washington or Oregon, and the only recoveries are those returned voluntarily by anglers. However, these recoveries cannot be expanded to the total catch unless there is a creel census program for the fishery. As such, these recoveries are rarely used in analyses.

CHAPTER 5. MASS MARKING FOR SELECTIVE FISHERIES

5.1 Potential Mass Marks

Desirable attributes of mass marks used to identify hatchery salmon for selective fisheries include:

1) Easy and inexpensive to apply;

2) easily identified by an untrained observer;

3) low marking mortality; and

4) stable over the life of the fish.

The PSMFC Subcommittee on Mass Marking (1992) reviewed a total of 10 marking techniques and 13 marks for their potential as mass marks to identify hatchery fish. The marks included fin clips (adipose, ventral), fluorescent filament and elastomer Visual Implant tags (V.I.), branding, body tagging, fluorescent sprays, Passive Integrated Transponder (PIT) tags, CWTs, elemental marks, otolith banding, and genetic marks. Of these, only the adipose and ventral fin clips were recommended as potential mass marks for chinook and coho salmon on the basis of the above five attributes.

The Subcommittee also suggested that the V.I. fluorescent marks could serve as a third possible identifier for selective fisheries or CWTs. However, this method is not considered feasible due to the inability to effectively mark salmonids below 80mm body length. This size restriction combined with the need to mark large numbers of juvenile salmon effectively eliminates V.I. tag use since only about 10% of chinook salmon and 50% of coho salmon are large enough to be marked by this method at the time of release.

5.2 Comparison of the Adipose and Ventral Marks

5.2.1 Ease of Application

Removal of the adipose fin is easier and less expensive than removal of the ventral fin, primarily because it is smaller, not bony, and easily accessible from either side because of its dorsal position. In contrast, the ventral fin is more difficult to remove because markers must rotate the fish into the proper position in order to slip the scissors carefully under the bony fin and clip it at its base. Application rates (based on 5g, 80mm fish) for the adipose are 800 fish/person/hour versus 600 fish/person/hour for the ventral mark (PSMFC 1992).

5.2.2 Cost of Application

Application costs are directly related to fin clipping and tagging rates. PSMFC (1992) reported the cost of applying different fin clips and CWT. An adipose clip costs $25/1,000 fish, while a single ventral clip costs $28/1,000 fish. The insertion of a CWT adds another $81/1,000 fish. These costs were based on using a self contained tagging trailer with a travelling supervisor. Individual agency costs may vary. The single fin marking costs could be lower in a large marking program if the responsibility of marking could be transferred to the hatchery manager. The costs in this latter case are $15/1,000 fish for the adipose mark and $16/1,000 fish for the ventral mark.

Additional trailers would probably be necessary for a large marking program. Costs for each new fin marking trailer would be approximately $60,000.

5.2.3 Ease of Recognition

Fishers should have little difficulty recognizing either the adipose or ventral mark as long as the fin clip is complete. However, a major advantage of the adipose mark is that experienced anglers can recognize the mark without having to land the fish for examination. Further, identification of the mark status of landed fish is likely to be faster for the adipose mark than for the ventral. The ability to release unmarked fish without bringing them on board, or more quickly decide whether to release a landed fish, may reduce the release mortality of unmarked stocks. Adipose fin clips are now associated with hatchery fish by most chinook and coho salmon fishers in B.C. and the U.S. As a result, a selective fishery for adipose marked salmon could likely be implemented with less confusion than one for ventral marked fish.

5.2.4 Fin Mark Induced Effects

There are very few published studies on the effects (e.g., growth or mortality) of either the adipose or ventral fin clips with chinook or coho salmon released into marine waters. The few studies available are confounded by the addition of other marks such as the maxillary or pectoral clip. The results from these studies are highly variable and conflict with each other. This may be due to variables that are not easily evaluated, small sample sizes, or poor study design. Studies often lacked adequate controls, and did not account for fish straying into or out of the study population, or for fin regeneration.

However, the available literature on fin marking of all salmonids have shown two general patterns. First, the effects of fin clips on survival and growth occur after release. Studies have shown that the mortality of fin clipped fish is negligible while fish are held in captivity (Shetter 1952; Parker et al., 1963).

Second, the mortality associated with the removal of the adipose fin is the lowest of any fin clip (Bergstedt 1985). Based on an extensive literature review, Jacobs (1990) estimated that ventral clipping fish reduced their post-release survival 20% to 50% compared to unclipped fish. WDFW data are consistent with this pattern. Blankenship et al., 1993, found no significant differential mortality of adipose marked spring chinook salmon with a CWT (Ad-CWT), compared to unhandled controls. In a second WDFW study, Ad-CWT coho salmon were compared to ventral clipped coho salmon with a CWT (Ven-CWT) using two brood years from three different Puget Sound hatcheries. Relative to the Ad-CWT fish, the Ven-CWT fish had lower survivals of 6%, 12% and 19% for the first brood year and 19%, 25% and 15% for the second (L. Blankenship, WDFW, Unpub. Data). In addition, for the one hatchery where the comparison was made, there was no survival or growth difference of AD-CWT fish compared to CWT-only fish. No differential growth between fish with or without the ventral clip was found in this study (L. Blankenship, WDFW, Unpub. Data).

5.2.5 Mark Stability

Stability of a fin clip over the life of a salmon is related to the amount of fin removed at the time of marking and the likelihood that the excised fin will fully or partially regenerate. In the Puget Sound coho study cited above (L. Blankenship, WDFW, Unpub. Data), the ventral fin regenerated such that the mark was not recognized by trained observers in 3-4% of the fish the first year and in less than 1% the second year. Another 20% and 8% regenerated more than half of the ventral fin in the first and second years of the experiment, respectively. The adipose fin regenerated such that the mark was not recognized in less than 1% of the fish each year. More than one half of the adipose fin regenerated in 3% of the fish the first year and 1% the second. The decrease in regenerated fins in the second year is likely due to improved clipping in the second year. Although partially regenerated ventral and adipose fins would be recognizable to trained observers, they would likely be ambiguous to most fishers.

5.2.6 Summary of Adipose and Ventral Mark Attributes

In summary, the adipose fin clip is superior to the ventral fin clip as a mass mark for hatchery chinook salmon and coho salmon in all of the four attributes examined (Table 5.1). The adipose clip is especially desirable over the ventral clip given that very large numbers of hatchery salmon will likely be marked if selective fisheries are initiated. In addition, the ventral clip has major problems with regeneration (i.e. misidentification in the fisheries) and post-release mark mortality.

5.3 Coded Wire Tag Recovery in a Selective Fishery Regime

If the adipose or ventral fin clip is used to identify hatchery chinook or coho salmon for selective fishery purposes, the alternate fin or electronic detectors could be used to identify fish with CWTs. This presents three possible mass/CWT mark options. The same criteria examined to determine the best fin clip for mass marking apply to determining the best fin clip to use as a visible indicator of CWTs. Each of the three options is discussed below with advantages and disadvantages. This is preceded by a review of electronic CWT detection since it is critical to Option 1.

Table 5.1. Comparison of adipose and ventral marks for desirable mass mark attributes.

Criterion	Adipose Clip	Ventral Clip
Ease of application	Easy to apply; Dorsal site; fleshy lobe	More difficult side clip; bony fin structure
Application rate	800/person/hr	600/person/hr
Recognition	Recognizable without landing fish; presently associated with CWT tagging	Requires landing to observe; problems with regeneration
Mark induced mortality	Low	Significant and highly variable
Mark stability	High	Low; significant and highly variable regeneration

5.3.1 Electronic Detection of Coded Wire Tags

Elimination of a fin clip indicator for the CWT will necessitate electronic screening of whole fish during sampling. For example, to maintain the desired sampling rates, 20% of the chinook and coho salmon commercial catch would have to be screened electronically for the presence of a CWT. Feasibility of this approach will depend on the ability of detectors to accurately detect the presence of a CWT in large bodied fish and to process samples at an acceptable rate.

There are currently three basic types of electronic detectors: wand, tubular, and field sampling. Wand detectors are hand-held devices that are passed over the fish's head while holding the fish stationary. Heads or whole fish can be passed through tubular detectors. Field sampling detectors are stationary "V" shaped devices. Fish heads are quickly passed back and forth through the "V" for tag detection.

The ability of the wand detector to detect CWTs is constrained by factors such as CWT location, depth in the fish, and magnetic moment of the tag. Initial testing of the wand detector by WDF on coho salmon in 1992 resulted in an 80% detection rate; the wand generally failed to detect CWTs in large coho salmon. This raised serious concerns about being able to successfully detect tags in the larger adult chinook salmon. However, increases in the detection rate of tagged salmon using a wand detector have become possible by increasing the magnetism of CWTs. Tags with a higher magnetic moment were sold by Northwest Marine Technology after February 1993; tags with even higher magnetic moments were sold after April 1994. On average, the latest version of CWTs have a 70% greater magnetic moment than those sold prior to February 1993.

Tag location and depth factors were investigated by WDF and CDFO. They recorded location and depth of CWTs in 650 returning coho salmon adults in 1993. The average depth was 14mm, with 2.0% of the tags being deeper than 25mm and 0.3% deeper than 30mm. The electronic wand detected standard-length (1.1mm long) tags (issued since February 1993) to a depth of 31mm. Length-and-a-half (1.5mm long) tags were detectable to 41mm. Length-and-a-half tags are recommended for use in coho and chinook salmon if electronic detection is to be used since they are typically tagged at a large enough size to receive the larger tag. WDFW and CDFO tagging supervisors believe that length-and-a-half CWTs can be easily placed in 60mm (2.2 gram) salmon.

WDFW and CDFO personnel recently demonstrated the ability of the wand detector at the 1994 PSMFC Mark Coordinators meeting. They showed a 100% detection rate with a wand in a blind test with 100 adult coho salmon that were injected with the higher magnetic moment standard-length CWTs sold after February 1993. The CWTs were placed 50% deeper and in more varied locations than typically found in tagged coho salmon adults. CDFO and WDFW are currently examining the depth and location of CWTs in large adult chinook salmon and the ability to detect CWTs using electronic wands. If wands do not prove feasible for detecting CWTs in chinook salmon, field sampling detectors could still be used. However, field sampling detectors are cumbersome and may limit access to CWT samples from recreational fisheries. They may also be affected by extraneous magnetic fields common at commercial processing plants.

Half-length tags would probably not be reliably detected with the wand. However, this is not a major concern since only modest numbers of coho and chinook salmon have been released with half-length CWTs coastwide in the last three years (average of 55 chinook and 12 coho tag groups for the years 1991 through 1993). Of these, all but a very small number have been released in California and Alaska.

Tubular detectors are currently used in CWT recovery laboratories coastwide to verify the absence of a CWT in heads found to be negative using a field sampling detector. About 10% of all the heads sampled do not contain a CWT based on field sampling detector results. Subsequent examination using a tubular detector generally finds CWTs in 1-2% of these fish. Tubular detection was found to be as effective as X-ray detection. The tube is up to six inches in diameter, over four feet long and weighs 100 pounds. The manufacturer (Northwest Marine Technology) is designing a smaller, more portable model with a rectangular tube which allows passage of large whole fish with no loss of detection capability. Cost of the basic unit is estimated at $10,000, with automatic sorting of tagged or untagged fish for an additional $5,000. One additional option is an automated delivery system enabling handling of large volumes of fish.

Choice of electronic CWT detectors will be determined by the desired processing rate and sampling environment. Recreational fishery samplers and stream surveyors for CWT fish would probably use wand detectors. Tube detectors may be appropriate for high volume applications such as sampling commercial fisheries and hatchery rack returns.

Concern has been expressed that the increased magnetic properties of the newer CWTs might impair the migratory capability of tagged salmon. Quinn and Groot (1983) found no orientation disruption with juvenile chum salmon tagged with the older CWTs. Theoretically, the increased magnetic moment and tag length is insufficient to interfere with an internal compass that might be contained in a salmon's brain (K. Jefferts, NMT, Pers. Comm.), since the magnetic field declines proportionally to the inverse of the cubed separation distance. CDFO and WDFW are presently undertaking studies to investigate the effects of the increased magnetic moment and wire length of the new CWTs on hatchery returns.

5.4 Mark Options for Selective Fisheries and the CWT System

Three mark options exist:

1) Adipose fin clip as the selective mark with no visible external identifier for the CWT (electronic detection would be used to determine presence of CWTs);

2) adipose fin clip as the selective mark with the ventral fin clip as the visible identifier for CWTs; and

3) ventral fin clip as the selective mark with the adipose fin clip as the visible identifier for CWTs.

The advantages and disadvantages of these options are discussed below:

Option 1. Adipose Fin Clip for Selectivity and Electronic Detection for CWTs

With this option, fishers would selectively harvest adipose-clipped fish. There would be no visible indicator for CWTs.

This option has two key advantages. First, hatchery fish intended for selective harvest would be marked using the least expensive, most easily recognized, most stable and least harmful fin clip. Second, it avoids the more harmful and variable effects expected from using ventral fin clips for selectivity or as a CWT indicator (see Section 5.2.4). Marking costs are lower under this option than the alternatives.

The most significant disadvantage of having no external CWT mark is the added cost for identifying adult fish with CWTs. For the commercial fishery, samplers now screen approximately 20% of the catch visually. A major additional cost of electronic detection will be the need to replace visual screening with electronic screening. Electronic detection will require more time to handle and check each fish as well as substantial capital investments for the detectors. For recreational fisheries, voluntary head recoveries will have to be replaced with a direct sampling program similar to that used for commercial fisheries. The absence of an external marker for the CWT will also necessitate electronic sampling of escapement. Fish heads with tags will be processed in the same manner as they are now.

A disadvantage of using the adipose clip as a mass mark may occur if coho salmon were adipose clipped to indicate hatchery origin for selective harvest, and chinook salmon in the same region were clipped to indicate the presence of a CWT. Some fishers may inadvertently retain adipose clipped chinook salmon and release unmarked chinook salmon due to problems of species identification. If this species identification error was sufficiently large, it could introduce additional error in the extension of chinook salmon CWT results to the associated unmarked chinook population.

Option 2. Adipose Clip for Selectivity and Ventral Clip as CWT Indicator

With this option, fishers would selectively harvest adipose-clipped fish. The presence of a CWT would be indicated by a ventral fin clip which would eliminate the need for electronic screening of catch.

Considering the objectives of selective fisheries, this option shares the major advantages of using the adipose clip cited in Option 1, but would add the complexity of two mark types, each with a different purpose. The overall result of using the adipose rather than the ventral fin clip as a mass mark will be to maximize the number of fish available for harvest (i.e., lower marking mortality and minimal regeneration). The possible occurrence of two different fin clips, only one of which indicates a fish that may be retained, will confuse some anglers and reduce some of the benefits related to mark recognition and expeditious release of non-targeted fish cited for the adipose fin clip (see Section 5.2.3).

The use of the ventral clip as a CWT indicator would negatively impact the CWT program. The higher fin regeneration rate will likely decrease the rate of tag recovery and more importantly, there will be significant and variable mortality due to the removal of the ventral fin (see Section 5.2.4). Variable mark induced mortality will be confounded with natural mortality in comparisons of survival of tag groups. There is also the question whether it is acceptable to use a marking method known to cause added mortality for wild stocks chosen for CWT studies.

The ventral clip CWT indicator would permit sampling of commercial fisheries and the escapement to continue in a manner similar to current practice. The awareness and ability of sport fishers to recognize the ventral fin clip and the possibility that CWTs may be indicated by the ventral fin clip in coho salmon and by the adipose fin clip in chinook salmon are concerns that may require replacement of voluntary head recovery programs with a formal creel sampling program. This would be similar to the sampling program necessary for electronic CWT detection, but without the costs of the detectors.

Option 3. Ventral Clip for Selectivity and Adipose Clip as CWT Indicator

This option uses the ventral fin clip as the selective fishery mark and maintains the adipose clip as the indicator for the CWT.

The disadvantages of using the ventral fin instead of the adipose fin as the selective fishery mark are discussed in sections 5.2.4 and 5.2.5. The overall outcome will be fewer marked fish due to higher mark mortality and fin regeneration. Marking costs will also be higher. More importantly, the variable mark induced mortality associated with the ventral clip negatively impacts the CWT program as discussed in Option 2.

An advantage of using the adipose fin clip as the CWT indicator is that it would reduce confusion that could arise if one mark type means different things for different species. Consider, for example, a selective fishery for coho salmon using the ventral fin, with the adipose as the CWT indicator for both coho and chinook salmon. In this case, the purpose of the adipose clip would be consistent between the species. Under either Option 1 or 2, the adipose clip would indicate a CWT if the fish were a chinook salmon, but would indicate a harvestable fish if it were a coho salmon. The strongest argument for Option 3 is that it is less disruptive to the existing CWT marking and recovery program than the other options.

5.5 Summary

There are three possible marking options for selective coho and chinook salmon fisheries utilizing a combination of ventral clips, adipose clips and electronic detection of CWTs. The combination of the adipose fin clip for selectivity and electronic detection of CWTs stands out as the preferred option. The adipose clip is cheaper to apply, more stable and less lethal than the ventral clip. The technology for electronic detection with wands is presently available and appears adequate for coho salmon, and is currently being investigated for chinook salmon. Tubular detectors provide reliable detection for high volume sampling and stationary field sampling detectors are adequate for use with chinook salmon.

Other options require the use of the ventral fin either for selectivity or as the CWT indicator. This is undesirable because of significant rates of regeneration and the associated problems of misidentification, and significant but variable mortality from ventral fin removal. In the latter case, the variability in mortality from year to year and among stocks could impair our ability to evaluate the effect of selective fisheries.

CHAPTER 6. SHORT-TERM EFFECTS ON HARVEST AND ESCAPEMENT

This chapter addresses three of the primary questions raised by the PSC regarding selective fisheries:

1) Can a selective fishery reduce harvest rates on unmarked fish?

2) Can total exploitation rates be reduced and can spawning escapements be increased as a result of selective fisheries? Under what conditions?

3) How would the catches and incidental mortality in the fisheries be affected?

Given the time and personnel limitations of the committee, the scope of the assessment was narrowed in the following ways:

1) The assessment was limited to coho salmon, for the following reasons. First, estimation of exploitation rates and migration parameters for coho salmon is relatively simple since the harvest is limited to a period of approximately one year. Estimation of the parameters for chinook salmon would be complicated by the more complex life history traits of this species. Second, several proposals for selective fisheries have focused on coho salmon, principally in Puget Sound (WDF 1993) and the Strait of Georgia (Anonymous 1991). Finally, more difficult problems remain for chinook salmon than for coho salmon in developing a workable mass marking, selective fishery, and CWT recovery program (see sections 5.3.1, and 8.1.1).

2) Only the adipose clip and ventral clip were evaluated as potential mass marks. As discussed in Chapter 5, these marks appear to be the only marks which have the potential for use in selective fisheries in the short-term.

The assessment of selective fisheries was divided into three phases with increasing degrees of complexity and realism.

Phase 1. A limited number of stocks and fisheries were modelled in order to develop an intuitive understanding of model processes and to facilitate the completion of a sensitivity analysis.

Phase 2. Additional stocks, fisheries, and processes were incorporated into the model to provide a reasonable representation of stocks and fisheries in Washington and southern B.C. The results from the simulations were expected to be sufficiently realistic to assist managers in the initial development of policies related to the implementation of selective fisheries.

Phase 3. Case studies with actual stocks and fisheries would be analyzed. This phase was not attempted since more staff and resources would have been required than were available to the committee.

The Phase 1 and 2 analyses required the development of a new stochastic simulation model, the Selective Fisheries Model (SFM), specifically designed by the committee to evaluate selective fisheries. Model processes, algorithms, and input structure are described in a separate report (PSC Selective Fishery Evaluation Committee 1995).

6.1 Sensitivity Analysis (Phase 1 Analysis)

6.1.1 Introduction

A high degree of uncertainty often exists in estimates of one or more of the parameters included in a simulation model. Since different parameter values may significantly affect the results obtained from a simulation, a single value for an uncertain parameter may not provide an accurate representation of the range of likely results.

One potential method to evaluate the effect of uncertainty is to run the simulations with multiple values for each uncertain parameter. However, as the number of parameters increases, conducting the model simulation analysis with all possible combinations of parameter values and interpreting the results can become unmanageable.

An alternative method, sensitivity analysis, provides a structured approach to simplify the problem. The sensitivity analysis consisted of:

1) Identifying a range of values for the uncertain parameters;

2) selecting one or more response variables of interest which measured the effect of changes in the parameters; and

3) establishing a criterion for what changes in the response variables were significant.

Results from the sensitivity analysis could then be used to identify parameters to be included at multiple levels in the simulation analyses, and additional research to reduce the range of model parameter values.

6.1.2 Methods

6.1.2.1 Parameters

The committee reviewed the parameters in the model and selected five parameters for inclusion in the sensitivity analysis:

1) Release mortality;

2) dropoff mortality;

3) retention error rate;

4) marked recognition error rate; and

5) mark induced mortality.

Results obtained from the sensitivity analysis depend upon both the sensitivity of the response variables to the parameters and the range of parameter values used. In order to obtain a reasonable values for each parameter, the committee reviewed the available literature and current research. The range of values selected reflect the committee's uncertainty about the values for the parameters. A description of the parameters and the rationale for the values selected for the sensitivity analysis is provided below.

Release Mortality. Release mortality is defined as the probability that a fish brought back to the fisher and released in a selective fishery will subsequently die as a result of the catch-and-release process. The mortality of fish released is likely to depend upon the gear and technique used to capture the fish, the location of capture (e.g., ocean, estuary, or freshwater), and the species and size of the fish released (ChTC 1987b; WDF et al. 1993) (see Section 2.1 for a more complete discussion of release mortality rates). Of these factors, the effect of the type of gear upon the mortality rate has received the greatest study. In this analysis, release mortality was stratified into three categories:

Recreational, trap, and beach seine (7% - 15%); marine recreational hook-and-line fisheries for adult coho and legal-sized chinook (62 cm fork length), traps, and beach seines;

troll and purse seine (20% - 30%); troll fisheries and purse seine fisheries in which a small number of fish are caught per set; and

gillnet and purse seine (30% - 70%); gillnet fisheries and purse seine fisheries in which a large number of fish are caught per set.

Dropoff Mortality. Dropoff mortality is defined as the probability that a fish that encounters the gear and subsequently drops off will die. Within the SFM, the dropoff mortality is controlled by the number of encounters which are not brought to the boat, expressed as a proportion of the landed catch, and the probability that a fish which drops off the gear dies as a result of the encounter. For input into the sensitivity analysis, the product of these two parameters was specified and termed the dropoff mortality rate.

As with release mortality, the dropoff mortality rate is likely to depend upon a number of factors, including the type of gear, the fishing technique, and the number of predators in the vicinity of the gear. Since the fate of the fish lost typically cannot be observed, the parameter is difficult to estimate. The dropoff mortality rate was stratified using categories similar to those previously identified for release mortality:

Recreational (1% - 5%); in developing input data for a simulation model of coho fisheries, Hunter (1985) assumed that the dropoff mortality rate was equal to 5% of the landed catch for recreational fisheries. Discussions with biologists familiar with sport fisheries indicated that the proportion of fish which drop off might range from 1:3 to 2:3 of the fish that are successfully brought to the boat (J. Packer, WDFW, Pers. Comm.; P. Lawson, ODFW, Pers. Comm.). When the range of parameter values was computed for the sensitivity analysis, it was assumed that fish which dropoff are likely to be less severely wounded and/or subject to less handling than fish which are landed. Hence, the dropoff mortality rate was computed by multiplying 50% of the release mortality rate for recreational gear by the range of estimates for the number of fish lost before landing at the boat.

Troll (3% - 9%); the simulation model developed by Hunter (1985) used a dropoff mortality rate of 5% for troll fisheries. For the sensitivity analysis, a range of 3% to 9% was calculated using the same methods as described for recreational hook-and-line fisheries.

Net (10% - 30%); several studies have indicated that the dropoff mortality in net fisheries can be high, particularly if predators remove fish from the net (Geiger 1985; Beach et al. 1981). For example, harbor seal interactions with a gillnet fishery for chinook salmon in South Puget Sound in 1982 resulted in an estimated dropoff mortality rate of 87% (January 18, 1983 letter from Jack Rensel to WDF). A technical team which assessed Puget Sound gillnet fisheries (WDF and NWIFC 1984) indicated that the rate was likely to vary depending upon the predators in the areas, the species, the intensity of fishing, and the type of gear. Depending upon the fishing area, recommended rates in that report for coho salmon ranged from 2% to 23%. The wide range selected by the committee (10%-30%) reflects both the among-fishery variability in this parameter and the uncertainty in the value estimated for any particular fishery.

Retention Error Rate. The retention error rate is defined as the probability that an unmarked fish will be retained in a selective fishery. Failure to release a fish not marked for selective removal could occur if:

1) Naturally occurring marks are identical to the mass mark;

2) a fisher fails to identify the lack of a mark; or

3) a fisher does not comply with regulations.

Within the sensitivity analysis, the low end of the range of values used (2%) was based upon factors (1) and (2). In addition to these factors, the upper end (10%) included predicted noncompliance rates as initially observed for chinook salmon minimum size restrictions in the Strait of Georgia recreational fishery and in selective fisheries for steelhead in British Columbia and Washington (see Chapter 8).

Marked Recognition Error Rate. The marked recognition error rate is defined as the probability that a marked fish will be inadvertently released. The error rate will depend upon the mark which is used to identify fish for selective removal. Fins which are likely to be regenerated or are difficult to observe will result in a higher rate of error. Unpublished studies of ventral-clipped coho salmon by WDFW indicate that at return to the hatchery, 3-4% of the fish had a completely regenerated ventral fin, 20% had less than 50% of the ventral fin missing, and 15% had more than 50% of the ventral fin missing but less than completely removed (L. Blankenship, WDFW, Pers. Comm.). In the sensitivity analysis, a range of 2%-10% was used for the adipose clip and 10%-30% for a ventral clip.

Mark Induced Mortality. Mark induced mortality is defined as the incremental mortality associated with marking fish for identification in a selective fishery. The mortality will vary depending upon the mark which is used and the size of fish at release (see Section 5.2.4). Fish marked at a smaller size will have a higher mortality rate. The sensitivity analysis used two ranges: 0%-8% for an adipose clip and 5%-20% for a ventral clip. For chinook salmon, a higher range (5-40%) would be applicable for a ventral clip.

6.1.2.2 Simulation Runs

The sensitivity analysis was conducted for six cases which combined different types of gears (troll, net or recreational) and marks (adipose clip or ventral clip) (Table 6.1). Within each case, each of the five parameters were assigned three values, resulting in 243 combinations (3^5) per case.

Case 1. Low mortality of fish released (recreational, trap, and beach seine fisheries), ventral clip identifies fish which may be retained in the selective fishery.

Case 2. Low mortality of fish released (recreational, trap, and beach seine fisheries), adipose clip identifies fish which may be retained in the selective fishery.

Case 3. Medium mortality of fish released (troll fishery and some purse seine fisheries), ventral clip identifies fish which may be retained in the selective fishery.

Case 4. Medium mortality of fish released (troll fishery and some purse seine fisheries), adipose clip identifies fish which may be retained in the selective fishery.

Case 5. High mortality of fish released (gillnet and some purse seine fisheries), ventral clip identifies fish which may be retained in the selective fishery.

Case 6. High mortality of fish released (gillnet and some purse seine fisheries), adipose clip identifies fish which may be retained in the selective fishery.

In the simulation, a marked and an unmarked stock of equal size were subjected to a 52 week selective fishery in which all unmarked fish were to be released. Effort in the fishery was set so that 60% of the marked fish were brought to the boat by the end of the year. Although this rate is within the range observed for some chinook and coho salmon stocks, preliminary analyses indicated that the relative importance of the parameters was independent of the effort value used.

Table 6.1. Parameters values for the sensitivity analysis. Recreational category also representative of other gear types (e.g., trap, beach seine) with release mortality rates of 7%-15%. Troll category also representative of other gear types (e.g., purse seine fisheries with a small number of fish per set) with release mortalities of 20%-30%.

Model Parameter	Recreational		Troll		Net	
	Ventral Clip Case 1	Adipose Clip Case 2	Ventral Clip Case 3	Adipose Clip Case 4	Ventral Clip Case 5	Adipose Clip Case 6
Release Mortality	7% 11% 15%	7% 11% 15%	20% 25% 30%	20% 25% 30%	30% 50% 70%	30% 50% 70%
Dropoff Mortality	1% 3% 5%	1% 3% 5%	3% 6% 9%	3% 6% 9%	10% 20% 30%	10% 20% 30%
Retention Error Rate	2% 6% 10%	2% 6% 10%	2% 6% 10%	2% 6% 10%	2% 6% 10%	2% 6% 10%
Marked Recognition Error Rate	10% 20% 30%	2% 6% 10%	10% 20% 30%	2% 6% 10%	10% 20% 30%	2% 6% 10%
Mark Induced Mortality	5.0% 12.5% 20.0%	0.0% 4.0% 8.0%	5.0% 12.5% 20.0%	0.0% 4.0% 8.0%	5.0% 12.5% 20.0%	0.0% 4.0% 8.0%

6.1.2.3 Analytical Procedures

The sensitivity analysis was conducted with a complete block design for each of the 6 cases discussed above using the methods of Swartzman and Kaluzny (1987). The response variables selected for the analysis were the escapement of unmarked fish and the catch of marked fish. Analysis of variance (ANOVA) was used to identify the parameters with the greatest effect upon the response variables. For the ANOVA, the parameter values were recoded from 1 to 3 with a 3 corresponding to the largest value.

The committee established a criterion for determining which parameters had a significant effect upon the response variables over the range of parameter values considered. A parameter was identified for potential inclusion at multiple values in the SFM if the mean response at the high parameter value minus the mean response at the low parameter value exceeded 10% of the mean value for the response variable. The selection of the criterion of 10% was not critical to the conclusions obtained from the sensitivity analysis; the test values obtained were either less than 9% or greater than 17%.

6.1.3 Results

The release mortality parameter resulted in the largest variation in escapement of unmarked fish (Table 6.2). Release mortality accounted for more than 50% of the variation in all cases, ranging from approximately 51% for Case 1 and 2 to 77% for Case 5 and 6. The second most important parameter was generally the retention error rate, which accounted for 28% (Case 3 and 4) to 46% (Case 1 and 2) of the variation in the escapement of unmarked fish. In Cases 5 and 6, the dropoff mortality rate was the second most important parameter.

The most important parameter affecting the catch of marked fish in the sensitivity analysis was always either the marked recognition error or the mark induced mortality. The marked recognition error rate was the most important parameter in all cases in which the mark identifying fish for selective removal was a ventral clip (Cases 1, 3, and 5). The mark induced mortality rate was the second most important parameter. Conversely, the mark induced mortality was the most important parameter in all cases in which the mark for identifying fish for selective removal was a clipped adipose fin. With the exception of Case 6, the marked recognition error rate was the second most important parameter. Case 6 was unusual in that dropoff mortality was the second most important parameter and the two most important parameters accounted for only approximately 71% of the variation. Marked recognition error accounted for an additional 28.1% of the variation in this case.

Table 6.2. The two most important parameters affecting the escapement of unmarked fish. The row titled "% of Variation" is the proportion of the sum of squares of the response variable accounted for by the parameter. The significant parameters (as defined in Section 6.1.2.3) were identified for potential inclusion at multiple levels in the simulation analysis of selective fisheries. Provided in parentheses in the significant parameters row is the mean response at the high parameter value minus the mean response at the low parameter value.

	Recreational [1]		Troll [2]		Net	
	Ventral Clip Case 1	Adipose Clip Case 2	Ventral Clip Case 3	Adipose Clip Case 4	Ventral Clip Case 5	Adipose Clip Case 6
First Parameter	Release Mortality	Release Mortality	Release Mortality	Release Mortality	Release Mortality	Release Mortality
% of Variation	50.8%	50.8%	68.8%	68.8%	77.1%	77.1%
Significant Parameter?	No (6%)	No (6%)	No (8%)	No (8%)	Yes (35%)	Yes (35%)
Second Parameter	Retention Error	Retention Error	Retention Error	Retention Error	Dropoff Mortality	Dropoff Mortality
% of Variation	45.6%	45.6%	28.1%	28.1%	21.9%	21.9%
Significant Parameter?	No (6%)	No (6%)	No (6%)	No (6%)	Yes (18%)	Yes (18%)

1 Also includes other gear types (e.g., trap, beach seine) with release mortality rates of 7%-15%.
2 Also includes other gear types (e.g., purse seines with a small number of fish per set) with release mortality rates of 20%-30%.

Table 6.3. **The two most important parameters affecting the catch of marked fish. The row titled "% of Variation" is the proportion of the sum of squares of the response variable accounted for by the parameter. The significant parameters (as defined in Section 6.1.2.3) were identified for potential inclusion at multiple levels in the simulation analysis of selective fisheries. Provided in parentheses in the significant parameters row is the mean response at the high parameter value minus the mean response at the low parameter value.**

	Recreational [1]		Troll [2]		Net	
	Ventral Clip Case 1	Adipose Clip Case 2	Ventral Clip Case 3	Adipose Clip Case 4	Ventral Clip Case 5	Adipose Clip Case 6
First Parameter	Marked Recognition Error	Mark Induced Mortality	Marked Recognition Error	Mark Induced Mortality	Marked Recognition Error	Mark Induced Mortality
% of Variation	52.6%	67.2%	55.6%	63.9%	55.7%	39.6%
Significant Parameter?	Yes (18%)	No (8%)	Yes (20%)	No (8%)	Yes (22%)	No (8%)
Second Parameter	Mark Induced Mortality	Marked Recognition Error	Mark Induced Mortality	Marked Recognition Error	Mark Induced Mortality	Dropoff Mortality
% of Variation	47.3%	32.2%	44.2%	35.5%	36.3%	31.8%
Significant Parameter?	Yes (18%)	No (6%)	Yes (18%)	No (6%)	Yes (18%)	No (8%)

[1] Also includes other gear types (e.g., trap, beach seine) with release mortality rates of 7%-15%.
[2] Also includes other gear types (e.g., purse seines with a small number of fish per set) with release mortality rates of 20%-30%.

6.1.4 Conclusions

The primary purpose of the sensitivity analysis was to reduce the number of parameters that were modelled at multiple values in the SFM. Given the 10% range criterion described in Section 6.1.2.3, the results from the sensitivity analysis indicated that the following parameters should be included at multiple values:

1) The release mortality rate in net fisheries;

2) the dropoff mortality rate in net fisheries;

3) the marked induced mortality rate for ventral clipped fish; and

4) the marked recognition error rate for ventral clipped fish.

For other parameters, the median was selected for use with the belief that other values within the range used in the sensitivity analysis would not significantly affect the results.

6.2 Effects of Selective Fisheries on Catch and Escapement (Phase 2 Analysis)

6.2.1 Methods

The fisheries and stocks included in the Phase 2 analysis were selected to provide sufficient flexibility to simulate the interactions of multiple gear types, sequential or simultaneous fisheries, multiple stock distribution patterns, and wide variation in the relative contributions of marked and unmarked stocks. The intent was to provide sufficient detail in the SFM configuration to reflect realistic fishery and stock scenarios so that the products of this analysis would be of use in the development of policies related to implementation of selective fisheries. However, due to time and personnel constraints placed upon the PSC Selective Fishery Evaluation, the configuration of the SFM used in the Phase 2 analysis lacked the detail necessary to represent actual stocks and fisheries. A more accurate representation of selective fishery effects applied to actual fisheries and stocks was planned for Phase 3 but was not completed due to the unavailability of the time and staff required for the additional data development and analysis. Below, we provide a brief description of the model and the data used to develop the model inputs. For a more complete description see PSC Selective Fishery Evaluation Committee (1995).

Actual stock and fishery data from 1990 were used to develop the SFM input data. Although data from any recent year could have been used, 1990 was chosen because:

1) CWT data were available for the model's stocks and fisheries;

2) 1990 was not an extreme year in terms of fishery catches or stock abundances; and

3) 1990 was the only year for which trip duration data were available for estimating bag limit effects for the Washington ocean recreational fishery.

6.2.1.1 Model Stocks

The Phase 2 simulation included six stocks with different distribution patterns and, with the exception of the Columbia River, included both hatchery and wild stock components. The pseudonyms used in the SFM and the actual stocks used as guidelines during the development of input data are given below:

OutStk1:	West Coast of Vancouver Island;
OutStk2:	North Washington Coast and Grays Harbor;
OutStk3:	Columbia River;
InStk1:	Strait of Georgia - Lower Fraser River;
InStk2:	North Puget Sound (including Nooksack/Samish, Skagit, and Stillaguamish/ Snohomish regions); and
InStk3:	South Puget Sound.

Four[1] parameters were required to simulate the abundance and distribution of each stock:

1) The initial distribution of the age 3 cohort among fishing areas;

2) survival from smolt to recruitment at age 3;

3) the initial number of smolts; and

4) the migration of fish between geographic regions.

The Phase 2 analysis assumed that the age 3 cohort of each stock was initially distributed among five geographic regions (model acronym provided in parentheses):

1) Strait of Georgia (GEOS);
2) South Puget Sound (SPSD);
3) Strait of Juan de Fuca - San Juan Islands (SJDF);
4) West Coast Vancouver Island (OCNN); and
5) Washington/Oregon Ocean (OCNS).

The migration pathway of each model stock through these five geographic regions is presented in Fig. 6.1.

[1] The estimated length of fish by time was not required since no attempt was made to simulate the effect of minimum size regulations. Other analyses have indicated that current size limits for coho salmon have a relatively minor effect upon catch rates and incidental mortality (P. Ryall, CDFO, Pers. Comm.; Scott 1988).

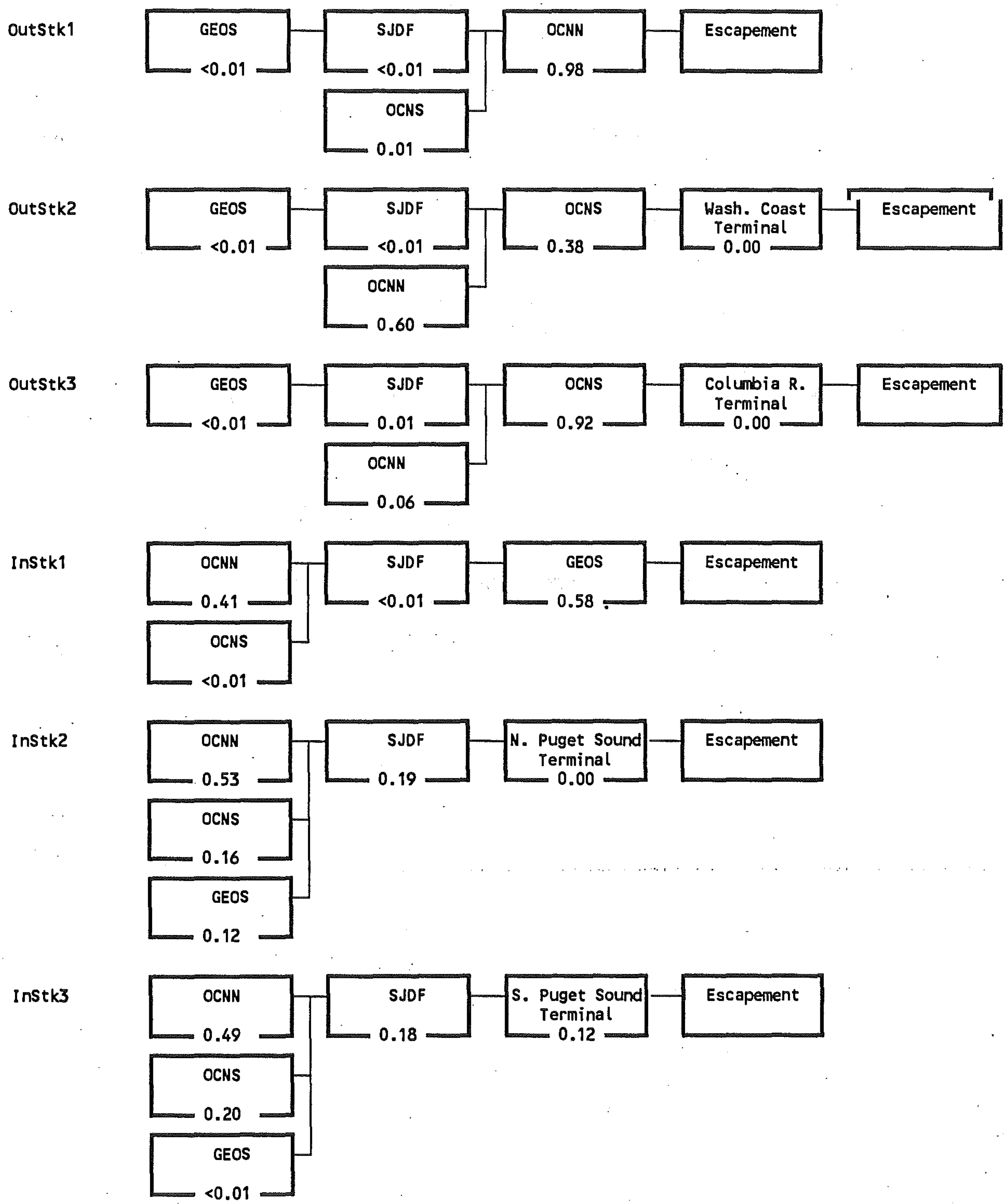


Figure 6.1. Assumed migration pathways for model stocks, by fishery, and the initial distribution. The migration pathway is toward escapement.

6.2.1.2 Model Fisheries

The 13 model fisheries used in the Phase 2 analysis represent a range of potential stock locations (outside, migratory transition, and inside) and gear types. The actual fisheries used as guidelines for input data development and the pseudonyms used in the Phase 2 analysis are detailed in PSC Selective Fishery Evaluation Committee (1995). The Phase 2 analysis required up to five types of information for each fishery:

1) Catch and effort;

2) catchability coefficients;

3) expected annual variability in fishing effort;

4) expected distribution of catch per unit effort; and

5) escapement goals for stocks used to control the terminal area fisheries that were modelled to achieve an escapement goal.

6.2.1.3 Base and Selective Fishery Cases

The effects of the selective fisheries were assessed by comparing the results from simulation runs with one or more selective fisheries with the results from a base case with no selective fisheries. Catches in the base case were controlled by fishing effort with the following four exceptions:

OutTr1: mean effort in OutTr1 fishery was specified for each week and a limitation on the catch for the season was set at 1,708,508 fish;

OutSp1: mean effort in the OutSp1 fishery was specified for each week and a daily bag limit of 2 fish per angler;

OutNt2: catch in the OutNt2 fishery was constrained by the escapement goal (78,396) for the OutStk3H stock;

InNt3: catch in the InNt3 fishery was constrained by the escapement goal (175,607) for the InStk2W stock.

The effect of a selective fishery upon catch and escapement of unmarked fish may be expected to vary depending upon a number of factors including:

1) Values for the parameters discussed in the sensitivity analysis (Section 6.1);

2) the ratio of marked to unmarked fish in the selective fishery;

3) management of fisheries which harvest fish subsequent to the selective fishery; and

4) the percentage of the stock's mortality which occurs in the selective fishery.

With regard to the parameter values, the sensitivity analysis indicated that the median value could be used for all parameters with the following exceptions:

1) Release mortality in net fisheries;

2) dropoff mortality in net fisheries;

3) mark induced mortality; and

4) marked recognition error for ventral clipped fish.

Since the base run included dropoff mortality in net fisheries, modelling the dropoff mortality rate for net fisheries at multiple levels could result in a large increase in the number of cases to be evaluated. For example, using the low and high estimates for the net dropoff mortality rate would result in a doubling of the number of cases to evaluate. Given the limited resources available to the Ad-Hoc Selective Fishery Evaluation Committee, a decision was made to model the net dropoff mortality rate only with the median value from the range of estimates. All other sensitive parameters discovered in the sensitivity analysis were included at both the low and high values in the analysis of the selective fishery cases.

A variety of cases were selected for analysis in order to address factors 1 through 4. The selective fisheries simulations included a variety of locations (inside, outside, and transition), gear types and regulation scenarios (Table 6.4). Parameter values for dropoff, release and mark induced mortality, and for marked recognition error are given in Table 6.5. In each case, an "A" following the case number designates a scenario in which the mass mark was an adipose clip and the parameters were at the median values. Scenarios with a "B" are identical to "A" scenarios except that the release mortality was modelled at the highest value in the range. "B" scenarios are present only in cases with a selective net fishery (Cases 5 and 8). "C" or "D" following the case number designates ventral clip scenarios. Scenarios with a "C" had the mark induced mortality and marked recognition error parameters modelled at their lowest (best) values. Scenarios with a "D" had these two parameters modelled at their highest (worst) values. In Cases 5 and 8, "C" scenarios also had the lowest (best) value for the release mortality in net fisheries and "D" scenarios had the highest (worst) value. Individual cases are listed below:

Case 1. Ocean Recreational Fishery Selective (OutSp1)

Marked Production:

Hatchery substocks of OutStk2, OutStk3, InStk2, InStk3

Identifying Mark:

Ad-Clip Median (Scenario 1A)
Ventral Clip Best (Scenario 1C)
Ventral Clip Worst (Scenario 1D)

Case 2. Ocean Troll Fishery Selective (OutTr2)

Marked Production:

Hatchery substocks of OutStk2, OutStk3, InStk2, InStk3

Identifying Mark:

Ad-Clip Median (Scenario 2A)
Ventral Clip Best (Scenario 2C)
Ventral Clip Worst (Scenario 2D)

Case 3. Transition Recreational Fishery Selective (InSp2)

Marked Production:

Hatchery substocks of InStk1, InStk2, and InStk3

Identifying Mark:

Ad-Clip Median (Scenario 3A)
Ventral Clip Best (Scenario 3C)
Ventral Clip Worst (Scenario 3D)

Case 4. Inside Recreational Fishery Selective (InSp1)

Marked Production:

Hatchery substock of InStk1

Identifying Mark:

Ad-Clip Median (Scenario 4A)
Ventral Clip Best (Scenario 4C)
Ventral Clip Worst (Scenario 4D)

Case 5. Terminal Net Fishery Selective (OutNt1)

Marked Production:

Hatchery substock of OutStk2

Identifying Mark:

Ad-Clip Best (Scenario 5A)
Ad-Clip Worst (Scenario 5B)
Ventral Clip Best (Scenario 5C)
Ventral Clip Worst (Scenario 5D)

Case 6. All Recreational Fisheries Selective (OutSp1, InSp1, InSp2, InSp3)

Marked Production:

All hatchery substocks

Identifying Mark:

Ad-Clip Median (Scenario 6A)
Ventral Clip Best (Scenario 6C)
Ventral Clip Worst (Scenario 6D)

Case 7. All Hook And Line Fisheries Selective (OutSp1, OutTr1, OutTr2, InSp1, InTr1, InSp2, InSp3)

Marked Production:

All hatchery substocks

Identifying Mark:

Ad-Clip Median (Scenario 7A)
Ventral Clip Best (Scenario 7C)
Ventral Clip Worst (Scenario 7D)

Case 8. All Fisheries Selective

Marked Production:

All hatchery substocks

Identifying Mark:

Ad-Clip Best (Scenario 8A)
Ad-Clip Worst (Scenario 8B)
Ventral Clip Best (Scenario 8C)
Ventral Clip Worst (Scenario 8D)

6.2.1.4 Analytical Procedures

In order to evaluate the effect of the selective fisheries, a number of statistics were computed for comparison with the base case. The rationale for presenting these statistics and the computational methods used are provided below.

Fishery Harvest Rates. Reducing the mortality of unmarked fish while maintaining (or increasing) the catch of marked fish is likely to be the primary reason for implementing a selective fishery. Despite reductions in the landed catch of unmarked fish, the harvest rate on unmarked fish might not decline if incidental mortality increases. Harvest rates on marked fish in the selective fishery may also decline due to mark recognition error. Comparison of the median harvest rate in the fishery in the base and selective fishery case provides a measure of the effectiveness of the selective fishery in reducing harvest rates on unmarked fish.

Reduced abundance resulting from mass mark induced mortality could increase harvest rates on marked and unmarked fish in nonselective fisheries with quotas, ceilings (OutTr1), or bag limits (OutSp1) (referred to in later sections as the ceiling effect or bag limit effect).

Increased harvest rates in these fisheries may offset reductions in the mortality of unmarked fish in selective fisheries.

The harvest rate by mark status was computed as:

$$HR_{f,m} = \frac{\sum_{t=1}^{52}\sum_{s=1}^{s^*} M_{s,f,m,t}}{\sum_{s=1}^{s^*} N_{s,g,m,1} + \sum_{t=1}^{52}\sum_{s=1}^{s^*} I_{s,g,m,t}} \tag{6-1}$$

where

s^* : number of stocks in fishery;

$I_{s,g,m,t}$: immigrants by stock (s), mark status (m), geographic region of fishery (g), and time (t);

$M_{s,f,m,t}$: total mortality by stock, mark status, fishery, and time;

$N_{s,g,m,1}$: abundance by stock, mark status, and geographic region at time 1.

Escapement. Since increasing the escapement of unmarked fish may be one goal of selective fisheries, the median value of the predicted escapement in the simulations was a primary statistic of interest. Although the mortality of unmarked fish in the selective fishery may be reduced, escapement might not increase if the fish saved are harvested in a subsequent fishery (referred to as the "transfer effect" in later sections) or if the ceiling and/or bag limit effects increase harvest rates on unmarked fish in other fisheries. The ceiling and bag limit effects may also reduce the escapement of marked components.

Exploitation Rates. Exploitation rates measure the proportion of a stock component that dies as a result of fishing related sources of mortality. An exploitation rate was computed from the simulations by dividing the total mortality (landed catch and incidental mortality) of a stock component by the initial age 3 cohort size. For a given abundance, a reduction in the exploitation rate will result in an increase in escapement.

The exploitation rate statistics complement the escapement statistics in two ways. First, the exploitation rates provide a means to assess whether a change in escapement was due to either a change in abundance or a change in fishery mortality. For example, for a marked stock component, a reduction in escapement with no change in the exploitation rate would indicate that mass mark induced mortality reduced the age 3 cohort size. Second, if selective fisheries are implemented, the effectiveness of the management regime would likely be assessed using exploitation rates since a great deal of uncertainty often exists in escapement estimates for wild stocks (see Chapter 9).

Catch. The median catch in a selective fishery may differ from the base case due to: (1) the release of unmarked fish; (2) marked recognition error; and (3) the reduced abundance of fish caused by mark induced mortality. The median total catch in all fisheries may differ from the base case due to: (1) the reduced abundance of fish caused by mass mark induced mortality; and (2) changes in the availability of marked and unmarked fish due to the prior occurrence of a selective fishery.

Percentage Marked in the Selective Fishery. The effectiveness of a selective fishery will partly depend upon the proportion of fish available to the fishery that is marked. If a small proportion of fish is marked, then catch will drop and incidental mortality will increase. Angler dissatisfaction may be related to the proportion of encountered fish that must be released. Given the average proportion of the encounters which were marked, the geometric distribution was used to estimate the average number of unmarked fish released before the first retention.

Incidental Mortality. Incidental mortalities will increase with selective fisheries. This cost will vary depending upon encounter rates, the marked recognition error, the release mortality rate, and the dropoff mortality rate.

Distribution of Total Mortality and Escapement. Even if implementing a selective fishery reduces the harvest rate on unmarked fish, particular unmarked stock components will benefit only to the extent to which they were harvested in that fishery prior to implementation of the selective regulations. Selective fisheries may also result in a modification of the distribution of mortality among fisheries. This may have important implications for PSC equity, allocations among gear types, and treaty Indian/nontreaty allocations. The average distribution of mortality and escapement was computed for each stock for each of the simulations and compared with the average distribution for the base case.

Monte Carlo simulations with 100 repetitions per case were used to define the distribution of the statistics of interest. This approach was used for a number of reasons.

1) A Monte Carlo simulation facilitates the presentation of a confidence interval rather than a point estimate for statistics of interest. A confidence interval provides managers with an understanding of the uncertainty of the results. It is unlikely that the result in any year would be equal to the point estimate;

2) A Monte Carlo simulation provides a means to evaluate the effect of selective fisheries with respect to other processes affecting the stock. The change in escapement which would result from selective fisheries will be the result of a number of stochastic processes. These processes may have a large affect upon escapement relative to a selective fishery;

3) Due to Jensen's Inequality (Dudewicz and Mishra 1988), the expected (or average) value of a statistic defined by a nonlinear function is not equal to the function evaluated at the expected values of the parameters; and

4) The distribution of a statistic that is the result of a sequence of stochastic processes (e.g., catch by stock in a fishery) may not be adequately defined by the distribution of a higher order statistic that is dependent upon those stochastic processes (e.g., exploitation rate of a stock in a fishery).

In order to avoid confounding the effects of changes in abundance with the effects of the selective fishery, the same set of values for the initial number of smolts were used for each of the simulations.

Results from the Monte Carlo simulations are presented in a number of ways. Box and whisker plots are used to graphically display the distribution of harvest rates, exploitation rates, and escapement in the simulations. The box and whisker plots show the median value of the outcomes, the central 50% of the outcomes (the box), observations that are within 1.5 interquartile range of the box (the whiskers), and individual observations outside of this range (the asterisks) and far outside this range (the empty circles). The 80% confidence intervals for the median percent change from the base case of the harvest rates, exploitation rates, and escapements were computed by bootstrapping the results from the simulations (Efron 1979) 500 times.

The significance of changes in these statistics from the base case were tested using a Wilcoxon signed ranks test (Conover 1980). Significant differences were defined as those where the probability that the observed difference is real is greater than or equal to 95%. There are no objective criteria for determining when a difference between two populations is significant; it is simply a risk analysis. If there is a high cost associated with concluding there is not a difference when in fact there is a true difference, then one should set relatively low significance criteria (e.g., 80%). If on the other hand, there is a high cost associated with concluding there is a difference when in fact there is none, then one should set stringent significance criteria (e.g., 95%). It is our conclusion that there is a higher cost associated with concluding that selective fisheries are effective when in fact they are not than vice versa. Accordingly, we used a relatively strict criterion to conclude that escapements or exploitation rates had in fact changed as a result of the selective fishery.

The significance tests and the box and whisker plots provide alternative means to examine the effect of the selective fishery on the predicted escapements. Since the significance tests are conducted on a pairwise basis for each of the 100 repetitions, the tests are sensitive to the results of the selective fishery regardless of the variations in recruitment between the repetitions. Conversely, the box and whisker plots place the effect of the selective fishery in the context of the total variability of the system. A selective fishery may have a significant effect, but the effect may be small relative to the total variation in the system.

For the catch, incidental mortality, proportion of encounters marked, and the distribution of total mortality, only an average value (or median value for the catch) was computed.

Table 6.4. Modeled fishery regulation scenarios, by case and fishery. An * denotes a selective fishery.

Case	Fishery												
	OutTr1	OutTr2	OutSp1	InSp1	InSp2	InSp3	InTr1	InNt1	InNt2	InNt3	InNt4	OutNt1	OutNt2
Base	Effort-Ceiling	Effort	Effort	Effort	Effort	Effort	Effort	Effort	Effort	Escape Goal	Effort	Effort	Escape Goal
1	Effort-Ceiling	Effort	Effort *	Effort	Effort	Effort	Effort	Effort	Effort	Escape Goal	Effort	Effort	Escape Goal
2	Effort-Ceiling	Effort *	Effort	Effort	Effort	Effort	Effort	Effort	Effort	Escape Goal	Effort	Effort	Escape Goal
3	Effort-Ceiling	Effort	Effort	Effort	Effort *	Effort	Effort	Effort	Effort	Escape Goal	Effort	Effort	Escape Goal
4	Effort-Ceiling	Effort	Effort	Effort *	Effort	Effort	Effort	Effort	Effort	Escape Goal	Effort	Effort	Escape Goal
5	Effort-Ceiling	Effort	Effort	Effort	Effort	Effort	Effort	Effort	Effort	Escape Goal	Effort	Effort *	Escape Goal
6	Effort-Ceiling	Effort	Effort *	Effort *	Effort *	Effort *	Effort	Effort	Effort	Escape Goal	Effort	Effort	Escape Goal
7	Effort-Ceiling*	Effort *	Effort *	Effort *	Effort *	Effort *	Effort *	Effort	Effort	Escape Goal	Effort	Effort	Escape Goal
8	Effort-Ceiling*	Effort *	Effort *	Effort *	Effort *	Effort *	Effort *	Effort *	Effort *	Escape Goal *	Effort *	Effort *	Escape Goal *

Table 6.5. Parameter values used for the base run and each of the selective fishery cases.

Case	Dropoff Mortality			Retention Error Rate	Marked Recognition Error	Mark Induced Mortality	Release Mortality		
	Sport	Troll	Net				Sport	Troll	Net
Base	0.03	0.06	0.20	NA	NA	NA	NA	NA	NA
1A	0.03	0.06	0.20	0.06	0.06	0.04	0.11	NA	NA
1C	0.03	0.06	0.20	0.06	0.10	0.05	0.11	NA	NA
1D	0.03	0.06	0.20	0.06	0.30	0.20	0.11	NA	NA
2A	0.03	0.06	0.20	0.06	0.06	0.04	NA	0.25	NA
2C	0.03	0.06	0.20	0.06	0.10	0.05	NA	0.25	NA
2D	0.03	0.06	0.20	0.06	0.30	0.20	NA	0.25	NA
3A	0.03	0.06	0.20	0.06	0.06	0.04	0.11	NA	NA
3C	0.03	0.06	0.20	0.06	0.10	0.05	0.11	NA	NA
3D	0.03	0.06	0.20	0.06	0.30	0.20	0.11	NA	NA
4A	0.03	0.06	0.20	0.06	0.06	0.04	0.11	NA	NA
4C	0.03	0.06	0.20	0.06	0.10	0.05	0.11	NA	NA
4D	0.03	0.06	0.20	0.06	0.30	0.20	0.11	NA	NA

Table 6.5 (cont'd). Parameter values used for the base run and each of the selective fishery cases (continued).

Case	Dropoff Mortality			Retention Error Rate	Marked Recognition Error	Mark Induced Mortality	Release Mortality		
	Sport	Troll	Net				Sport	Troll	Net
5A	0.03	0.06	0.20	0.06	0.06	0.04	NA	NA	0.30
5B	0.03	0.06	0.20	0.06	0.06	0.04	NA	NA	0.70
5C	0.03	0.06	0.20	0.06	0.10	0.05	NA	NA	0.30
5D	0.03	0.06	0.20	0.06	0.30	0.20	NA	NA	0.70
6A	0.03	0.06	0.20	0.06	0.06	0.04	0.11	NA	NA
6C	0.03	0.06	0.20	0.06	0.10	0.05	0.11	NA	NA
6D	0.03	0.06	0.20	0.06	0.30	0.20	0.11	NA	NA
7A	0.03	0.06	0.20	0.06	0.06	0.04	0.11	0.25	NA
7C	0.03	0.06	0.20	0.06	0.10	0.05	0.11	0.25	NA
7D	0.03	0.06	0.20	0.06	0.30	0.20	0.11	0.25	NA
8A	0.03	0.06	0.20	0.06	0.06	0.04	0.11	0.25	0.30
8B	0.03	0.06	0.20	0.06	0.06	0.04	0.11	0.25	0.70
8C	0.03	0.06	0.20	0.06	0.10	0.05	0.11	0.25	0.30
8D	0.03	0.06	0.20	0.06	0.30	0.20	0.11	0.25	0.70

6.2.2 Results

The results from each selective fishery case are presented below. Tables which summarize the results from all the cases for each stock and fishery are presented in Appendix A. Changes due to selective fisheries in the distributions of mortality for each stock are presented in Appendix B.

6.2.2.1 Case 1

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percentage Marked in Selective Fishery
1A	Adipose	Median	OutStk2H, OutStk3H, InStk2H, InStk3H	62%
1C	Ventral	Best	OutStk2H, OutStk3H, InStk2H, InStk3H	62%
1D	Ventral	Worst	OutStk2H, OutStk3H, InStk2H, InStk3H	59%

Description of Selective Fishery

Fishery	Location	Duration	Gear
OutSp1	OCNS	wks 25-38	Recreational

Stocks Present in the Selective Fishery: OutStk2, OutStk3, InStk2, and InStk3. Fish saved in the OutSp1 fishery of both OutStk2 and OutStk3 are available to OutTr2 and their respective terminal net fisheries. InStk2 is available to OutTr2, InNt1, InNt2, InSp2, and InNt3. InStk3 is available to OutTr2, InNt1, InNt2, InSp2, InSp3, and InNt4.

Effects in the Selective Fishery. The selective fishery significantly reduced harvest rates on unmarked fish in all scenarios of Case 1, with reductions of approximately 78% for each of the mark type and parameter combinations (Table 6.6).

Harvest rates on marked fish increased significantly in Scenario 1A, were unchanged in Scenario 1C, and declined significantly in Scenario 1D (Table 6.6). In Scenario 1A, mark induced mortality reduced the abundance of fish available to the fishery (the mark induced mortality rate was 4% for Scenario 1A, 5% for Scenario 1C, and 20% in Scenario 1D). As a result, the anglers simulated in the model fished for a longer period of time before obtaining the bag limit or quitting for the day. In Scenarios 1C and particularly 1D, increases in the length of the fishing period were offset by increases in the mark recognition error (6% in Scenario 1A, 10% in Scenario 1C, and 30% in Scenario 1D).

Imposition of the selective fishery resulted in reductions in the retained catch. The median reduction in the retained catch ranged from 32% in Scenario 1A to 55% in Scenario 1D (Table 6.6). Reductions in the retained catch resulted from the nonretention of unmarked fish, the mark recognition error rate and the loss in abundance caused by mark induced mortality on the hatchery production of four stocks. The reduction in catch was greatest for Scenario 1D due to the higher marked recognition error rate and the greater mark induced mortality. On average, an angler could expect to release 0.6-0.7 fish prior to encountering the first marked fish.

The incidental mortality increased over the base level by 167% (Scenario 1A) to 224% (Scenario 1D) due to increased dropoff mortality and the mortality of a portion of the marked and unmarked fish released (Table 6.6). Since unmarked fish could not be retained in the selective fishery, an increased number of fish were encountered and dropped-off before the bag limit was reached or the fishing trip ended.

Effects in Other Fisheries. Due to the mark induced mortality and the subsequent reduction in abundance, the harvest rate in fishery OutTr1 increased by 2% (Scenarios 1A and 1C) to 7% (Scenario 1D) relative to the base level (Table 6.7). The greater reduction in Scenario 1D was associated with the higher mark induced mortality assumed for this scenario.

The median catch in the nonselective fisheries increased by 2% and 1% in Scenarios 1A and 1C respectively, and declined by 6% in Scenario 1D (Table 6.7). In Scenarios 1A and 1C the transfer of fish to the nonselective fisheries was slightly greater than the reduction in abundance due to the mark induced mortality. In Scenario 1D, the number of fish saved in the OutSp1 selective fishery was relatively small in comparison to the reduction in abundance due to the higher mark induced mortality and catches declined.

The median change in the total catch across all fisheries was 0%, -1% and 9% in Scenarios 1A, 1C and 1D respectively (Table 6.7).

Table 6.6. **Effects of mass marking and the selective fishery in Case 1 on harvest rates for unmarked and marked fish, catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).**

Statistic	1A Adipose Clip Median	1C Ventral Clip Best	1D Ventral Clip Worst
HR Unmarked Fish	[-79% , -78%]**	[-78% , -77%]**	[-78% , -77%]**
HR Marked Fish	[3% , 7%]**	[1% , 4%]	[-16% , -9%]**
Base Catch	229,838	229,838	229,838
Change after Selective Fishery	- 32%	- 36%	- 55%
Base Incidental Mortality	6,904	6,904	6,904
Change After Selective Fishery	+ 167%	+ 179%	+ 224%
Fish Released Before First Retention	0.6	0.6	0.7

Table 6.7. **Effects of mass marking and the selective fishery in Case 1 on harvest rates in OutTr1, catch in the nonselective fisheries, and the total catch in all fisheries. Confidence intervals for the change in the harvest rate from the base level are at α = 0.20; significance is reported for α = 0.05 (*) and 0.025 (**).**

Statistic	1A Adipose Clip Median	1C Ventral Clip Best	1D Ventral Clip Worst
HR OutTr1	[2% , 2%]**	[2% , 2%]**	[6% , 7%]**
Change in Catch in Nonselective Fisheries	2%	1%	-6%
Change in Total Catch	0%	-1%	-9%

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.8 and 6.9, respectively. Box and whisker plots for escapement of wild stocks in Case 1 are provided in Fig. 6.2.

OutStk1W - The escapements and exploitation rates were not significantly changed in Scenarios 1A and 1C; the escapement was significantly reduced and the exploitation rate was significantly increased in Scenario 1D. This stock does not contribute to OutSp1 and was unaffected by the selective fishery. In Scenarios 1A and 1C, the mark induced mortality on the marked stocks was low and the small increase in the OutTr1 harvest rate (the ceiling effect) was insufficient to significantly reduce escapements. In Scenario 1D, the higher mark induced mortality rates reduced abundance sufficiently in OutTr1 to increase harvest rates and reduce the escapement of OutStk1W (the ceiling effect).

OutStk2W - Escapements significantly increased and the exploitation rates decreased significantly in Case 1.

InStk1W - Escapements and exploitation rates did not change significantly in Case 1. This stock is not harvested in the selective fishery. The increase in the harvest rate in OutTr1 does not affect InStk1W in Scenario 1D as was the case with OutStk1W since a much smaller proportion of InStk1W's catch occurs in that fishery.

InStk2W - Escapements and exploitation rates did not change significantly in Case 1 since the terminal fishery for this stock (InNt3) is managed in the simulation to achieve the escapement goal for InStk2W.

InStk3W - Escapements significantly increased in Scenarios 1C and 1D; exploitation rates were significantly reduced in Case 1.

OutStk1H - Since this stock component was not marked in Case 1, results were similar to those for OutStk1W. Escapements and exploitation rates were not significantly changed in Scenarios 1A and 1C; escapements were significantly reduced and the exploitation rates significantly increased in Scenario 1D.

OutStk2H - Escapements were significantly reduced and exploitation rates were unchanged in Case 1. Escapements declined due to mark mortality.

OutStk3H - Escapements were not significantly changed but exploitation rates were significantly reduced in Case 1. The terminal net fishery for this stock is managed as an escapement goal fishery, so the escapement stays relatively constant. As abundance declines due to mark induced mortality, the exploitation rate declines (via reductions in the catch in OutNt2) to maintain the escapement. Marked recognition error also acted to reduce the harvest rate in OutSp1 in Scenario 1D.

InStk2H - Escapements were significantly reduced and exploitation rates were significantly increased in Case 1. The reduction in the escapement occurred as a result of two factors: (1) harvest rates in the terminal net fishery increased as a result of an increase in the abundance of InStk2W in the terminal area; and (2) mark induced mortality reduced the abundance of InStk2H.

InStk3H - Escapements were significantly reduced, but exploitation rates did not change significantly in Case 1. These results are caused by the reduction in abundance due to mark induced mortality.

Table 6.8. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in escapement in Case 1 from the base case, and the significance of the percent change in escapement (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement		
		1A Adipose Clip Median	1C Ventral Clip Best	1D Ventral Clip Worst
OutStk1W	0%	[-2% , -0%]	[-2% , 0%]	[-8% , -3%]*
OutStk2W	9%	[7% , 15%]**	[10% , 16%]**	[8% , 15%]**
InStk1W	0%	[-0% , 1%]	[-2% , 1%]	[-2% , -0%]
InStk2W	3%	[-1% , 1%]	[-0% , 2%]	[-1% , 1%]
InStk3W	4%	[2% , 9%]	[5% , 11%]**	[5% , 10%]**
OutStk1H	0%	[-2% , -0%]	[-2% , 0%]	[-7% , -3%]**
OutStk2H	9%	[-9% , -4%]**	[-7% , -1%]**	[-22% , -17%]**
OutStk3H	20%	[-3% , 2%]	[-3% , 1%]	[-2% , 2%]
InStk1H	0%	[-1% , 1%]	[-2% , 1%]	[-3% , -1%]
InStk2H	3%	[-9% , -7%]**	[-8% , -7%]**	[-23% , -22%]**
InStk3H	4%	[-8% , -0%]*	[-6% , 0%]**	[-20% , -17%]**

Table 6.9. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 1 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rate		
		1A Adipose Clip Median	1B Ventral Clip Best	1C Ventral Clip Worst
OutStk1W	0%	[0% , 2%]	[0% , 2%]	[2% , 6%]**
OutStk2W	9%	[-4% , -3%]**	[-6% , -3%]**	[-5% , -3%]**
InStk1W	0%	[-1% , 0%]	[-1% , 1%]	[0% , 1%]
InStk2W	3%	[-0% , 0%]	[-1% , -0%]	[-0% , 0%]
InStk3W	4%	[-2% , -1%]**	[-2% , -1%]**	[-2% , -1%]**
OutStk1H	0%	[0% , 2%]	[-0% , 2%]	[3% , 6%]**
OutStk2H	9%	[-0% , 2%]	[-1% , 1%]	[-1% , 1%]
OutStk3H	20%	[-3% , -1%]*	[-3% , -1%]*	[-12% , -8%]**
InStk1H	0%	[-1% , 0%]	[-0% , 1%]	[0% , 1%]
InStk2H	3%	[1% , 2%]**	[1% , 2%]**	[1% , 2%]**
InStk3H	4%	[-1% , 1%]	[-1% , 0%]	[-1% , 0%]

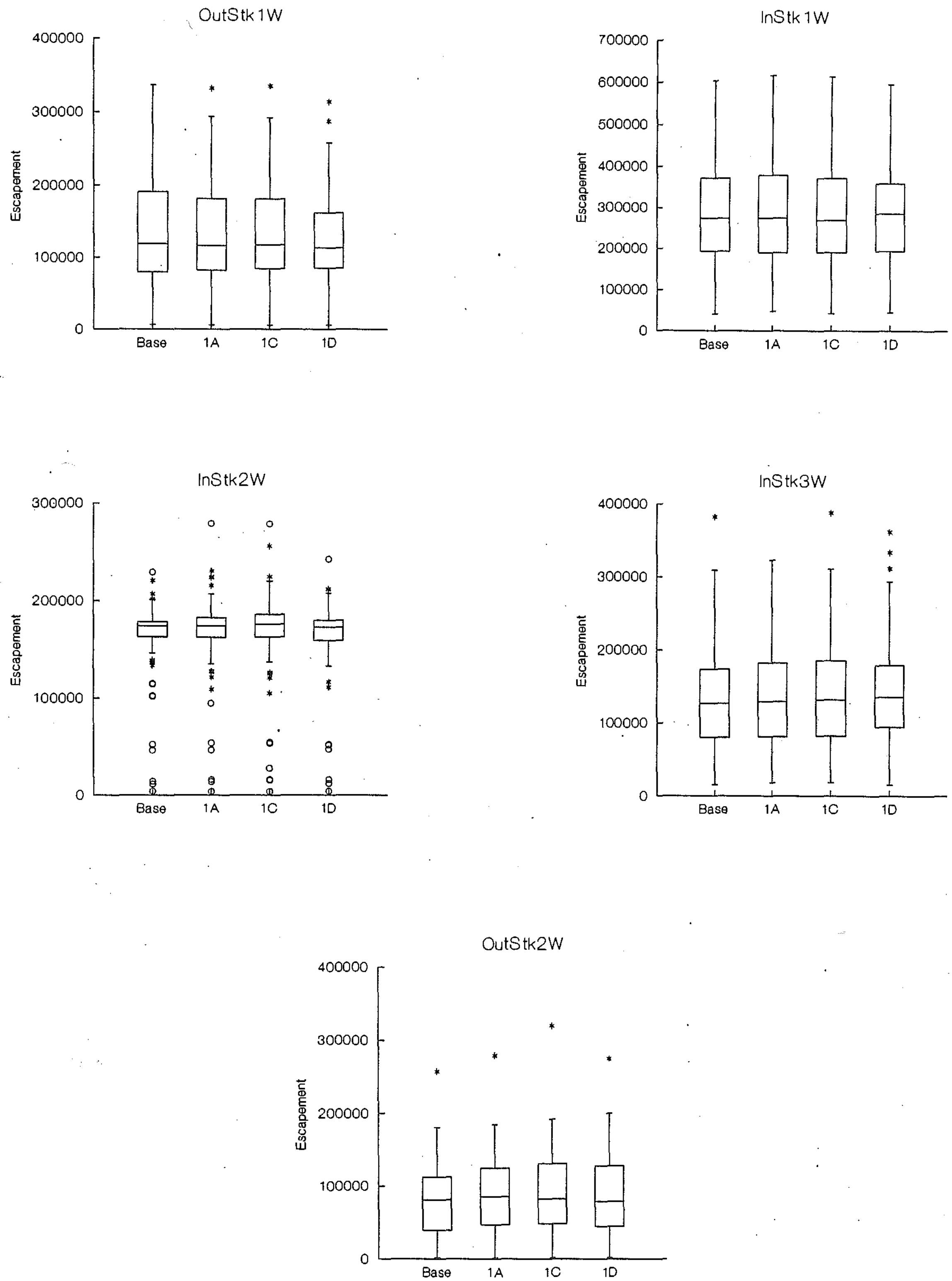


Figure 6.2. Box and whisker plots for the escapement of wild stocks in Case 1.

6.2.2.2 Case 2

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percentage Marked in Selective Fishery
2A	Adipose	Median	OutStk2H, OutStk3H, InStk2H, InStk3H	63%
2C	Ventral	Best	OutStk2H, OutStk3H, InStk2H, InStk3H	63%
2D	Ventral	Worst	OutStk2H, OutStk3H, InStk2H, InStk3H	58%

Description of Selective Fishery

Fishery	Location	Duration	Gear
OutTr2	OCNS	wks 28-41	Troll

Stocks Present in the Selective Fishery. OutStk2, OutStk3, InStk2, and InStk3. Fish from OutStk2 and OutStk3 not harvested in OutTr2 are available to OutSp1 and terminal net fisheries. InStk2 is available to OutSp1, InNt1, InNt2, InSp2, and InNt3. InStk3 is available to OutSp1, InNt1, InNt2, InSp2, InSp3, and InNt4.

Effects in Selective Fishery. Harvest rates on unmarked fish were significantly reduced by the selective fishery in all scenarios of Case 2 (Table 6.10). The 80% confidence interval indicated that harvest rates were reduced by 63% to 68% in Scenario 2A and by a similar amount in Scenarios 2C and 2D. The reduction in the harvest rate was not as great in Case 2 as in Case 1 because of the higher rate of release mortality for the recreational gear in Case 1 versus 25% for the troll gear in Case 2).

Harvest rates on marked fish were significantly reduced in Scenario 2D, but not in Scenarios 2A or 2C (Table 6.10). A higher rate of marked recognition error was assumed for Scenario 2D (30% versus 6% in Scenario 2A and 10% in Scenario 2C) which resulted in a reduction in the harvest rate (80% confidence interval of -12% to -25%).

Median catches in the selective fishery declined by 40% (Scenario 2A) to 61% (Scenario 2D). Reductions in the catch were associated with the release of unmarked fish, the marked recognition error, and the reduced abundance resulting from the mark induced mortality. On average, a fisher could expect to release 0.6 to 0.7 unmarked fish before encountering the first marked fish.

Incidental mortality was increased in the selective fishery because of the mortality associated with releasing unmarked fish and the mark induced mortality (Table 6.10). Incidental mortality increased by 175% (Scenario 2A) to 222% (Scenario 2D), with the greater increase associated with the greater marked recognition error rate.

Table 6.10. Effects of mass marking and the selective fishery in Case 2 on harvest rates for unmarked and marked fish, catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).

Statistic	2A Adipose Clip Median	2C Ventral Clip Best	2D Ventral Clip Worst
HR Unmarked Fish	[-68% , -63%]**	[-67% , -64%]**	[-68% , -61%]**
HR Marked Fish	[-7% , 3%]	[-10% , -3%]	[-25% , -12%]**
Base Catch	154,805	154,805	154,805
Change After Selective Fishery	- 40%	- 44%	- 61%
Base Incidental Mortality	9,294	9,294	9,294
Change After Selective Fishery	+ 175%	+ 189%	+ 222%
Fish Released Before First Retention	0.6	0.6	0.7

Effects in Other Fisheries. Because of the reductions in abundance associated with mark induced mortality, harvest rates in OutTr1, which is simulated as a ceiling fishery, increased significantly in all scenarios of Case 2 (Table 6.11). Increases ranged from approximately 2% in Scenarios 2A and 2C to 8% in Scenario 2D. The larger increase in Scenario 2D was caused by the higher rate of mark induced mortality assumed for this scenario.

Harvest rates also increased significantly in OutSp1 in Scenario 2D, but not in Scenarios 2A or 2C (Table 6.11). Since fishery OutSp1 was fishing on the same pool of fish as the selective fishery, it might be expected that reductions in the catch in the selective fishery would increase the availability of fish to OutSp1, and hence, reduce the harvest rate. However, in Scenarios 2A and 2C, this was apparently balanced by the reduced abundance resulting from mark induced mortality and, in Scenario 2D, the reduced abundance was sufficient to result in an increase in the harvest rate in fishery OutSp1.

Catches in the nonselective fisheries were unchanged in Scenarios 2A and 2C and declined by 4% in Scenario 2D (Table 6.11). In Scenarios 2A and 2C the transfer of fish to the nonselective fisheries was balanced by the reduction in abundance due to the mark induced mortality. In Scenario 2D, the fish saved in the OutTr2 selective fishery were relatively small in comparison to the reduction in abundance due to the higher mark induced mortality and catches declined.

The median change in the total catch across all fisheries was -2%, -1% and -6% in Scenarios 2A, 2C and 2D respectively (Table 6.11).

Table 6.11. Effects of mass marking and the selective fishery in Case 2 on harvest rates in OutTr1, OutSp1, the catch in nonselective fisheries, and the total catch in all fisheries. Confidence intervals for the change in the harvest rate from the base level are at α = 0.20; significance is reported for α = 0.05 (*) and 0.025 (**).

Statistic	2A Adipose Clip Median	2C Ventral Clip Best	2D Ventral Clip Worst
HR OutTr1	[1% , 2%]**	[2% , 2%]**	[7% , 8%]**
HR OutSp1	[- 3% , 1%]	[- 2% , 4%]	[2% , 5%]**
Change in Catch in Nonselective Fisheries	0%	0%	-4%
Change in Total Catch	-2%	-1%	- 6%

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.12 and 6.13, respectively. Box and whisker plots for escapement of wild stocks in Case 2 are provided in Fig. 6.3.

OutStk1W - Results for this stock were similar to Case 1. The escapements and exploitation rates were not significantly changed in Scenarios 2A and 2C; the escapement was significantly reduced and the exploitation rate was significantly increased in Scenario 2D. This stock does not contribute to OutTr2 and was unaffected by the selective fishery. In Scenarios 2A and 2C, the mass mark induced mortality on the marked stocks was low and the small increase in the OutTr1 harvest rate (the ceiling effect) was insufficient to significantly reduce escapements. In Scenario 2D, the higher mark induced mortality rates reduced abundance sufficiently in OutTr1 to increase harvest rates and reduce the escapement of OutStk1W (the ceiling effect).

OutStk2W - Escapements were significantly increased and exploitation rates were significantly decreased in Scenarios 2A and 2C; escapements and exploitation rates were not changed significantly in Scenario 2D. The escapement increased in Scenarios 2A and 2C since OutSp1 and OutNt1 have harvest rates that are too small to harvest all of the saved fish and the bag limit effect in OutSp1 and ceiling effect in OutTr1 were too small to overcome the increase in abundance. In contrast, in Scenario 2D, harvest rates in OutTr1 and OutSp1 are up significantly (8% and 3%) due to the reduced abundance of fish resulting from mark induced mortality. These two fisheries account for 66% of the harvest of this stock. These increases in harvest rates counteract the reduced harvest rate in OutTr1 resulting from the imposition of the selective fishery. This effect was not seen in Case 1 because a higher proportion of OutStk2 is caught in OutSp1 (more saved fish), the bag limit effect was not a factor since OutSp1 was selective, and the number of fished saved was lower in OutTr1 due to the higher release mortality and the smaller proportion of the stock harvested in this fishery.

InStk1W - Escapements and exploitation rates were not changed significantly in Scenarios 2A and 2C; escapements were significantly reduced and exploitation rates significantly increased in Scenario 2D. This stock is not harvested in OutTr2. In Scenario 2D, the ceiling effect in OutTr1 reduced the escapement and increased the exploitation rate.

InStk2W - Escapements and exploitation rates were not changed significantly in Case 2. The terminal fishery for this stock (InNt3) is managed to achieve the escapement goal for InStk2W.

InStk3W - Escapements increased significantly and exploitation rates were reduced significantly in Scenario 2A; escapements and exploitation rates were not changed significantly in Scenarios 2C and 2D. Increases in harvest rates associated with the ceiling effect in OutTr1 and the bag limit effect in OutSp1 prevented the exploitation rates from decreasing in Scenarios 2C and 2D. In addition, there were fewer fish saved than in Case 1 due to the higher release mortality of the troll gear and the smaller proportion of the harvest occurring in OutTr2.

OutStk1H - Since OutStk1H was not marked in this case, the results were similar to those observed for OutStk1W. Escapements and exploitation rates were not changed significantly in Scenarios 2A and 2C; escapements and exploitation rates were significantly reduced in Scenario 2D.

OutStk2H - Escapements were significantly reduced, but exploitation rates did not change in Case 2. Escapements were reduced by the mark induced mortality and the bag limit effect in OutSp1. Insufficient numbers of fish are harvested in OutTr2 for the marked recognition error to reduce the exploitation rate.

OutStk3H - Escapements were significantly reduced in Scenario 2A but were unchanged in Scenarios 2C and 2D; exploitation rates were not changed significantly in Scenarios 2A and 2C but were significantly reduced in Scenario 2D. The exploitation rate was reduced in Scenario 2D without a concomitant change in escapement. The terminal net fishery for this stock is managed as an escapement goal fishery, so the escapement stays relatively constant. As abundance declines due to mark induced mortality, the exploitation rate must decline to maintain the escapement. The reason for the reduced escapement in Scenario 2A is unclear.

InStk1H - This substock is not marked in this scenario and the results were similar to InStk1W. Escapements and exploitation rates were not changed significantly in Scenarios 2A and 2C; escapements were significantly reduced and the exploitation rate was significantly increased in Scenario 2D.

InStk2H - Escapements were significantly reduced and the exploitation rates significantly increased in Case 2. The reduced escapements resulted from both increased terminal net harvest rates (due to greater numbers of InStk2W) and reduced abundance caused by mark induced mortality

InStk3H - Escapements were not significantly changed in Scenario 2A but were significantly reduced in Scenarios 2C and 2D; exploitation rates were not significantly changed in Case 2. The mass mark induced mortality resulted in reduced escapements in Scenarios 2C and 2D. It is unclear why escapements were not reduced in Scenario 2A.

Table 6.12. **Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in escapement in Case 2 from the base case, and the significance of the percent change in escapement (* significant at 0.05; ** significant at 0.025).**

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement		
		2A Adipose Clip Median	2C Ventral Clip Best	2D Ventral Clip Worst
OutStk1W	0%	[-2% , 1%]	[-3% , 0%]	[-9% , -6%]**
OutStk2W	7%	[4% , 11%]**	[4% , 13%]**	[2% , 7%]
InStk1W	0%	[-2% , 1%]	[-1% , 1%]	[-3% , -1%]**
InStk2W	2%	[-1% , 1%]	[-1% , 1%]	[-0% , 2%]
InStk3W	3%	[5% , 9%]**	[1% , 7%]	[1% , 6%]
OutStk1H	0%	[-2% , 1%]	[-3% , 0%]	[-9% , -5%]**
OutStk2H	7%	[-9% , -2%]**	[-8% , -4%]**	[-24% , -20%]**
OutStk3H	13%	[-6% , -0%]**	[-4% , 1%]	[-4% , -1%]
InStk1H	0%	[-2% , 0%]	[-1% , 1%]	[-3% , -1%]**
InStk2H	2%	[-7% , -6%]**	[-9% , -6%]**	[-22% , -20%]**
InStk3H	3%	[-2% , 1%]	[-8% , -3%]**	[-22% , -16%]**

Table 6.13. **Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 2 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).**

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rate		
		2A Adipose Clip Median	2C Ventral Clip Best	2D Ventral Clip Worst
OutStk1W	0%	[-1% , 2%]	[-0% , 3%]	[5% , 7%]**
OutStk2W	7%	[-3% , -2%]**	[-4% , -2%]**	[-2% , -0%]
InStk1W	0%	[-0% , 1%]	[-1% , 1%]	[0% , 2%]**
InStk2W	2%	[-0% , 0%]	[-0% , 1%]	[-1% , 0%]
InStk3W	3%	[-2% , -1%]**	[-2% , -0%]	[-1% , -0%]
OutStk1H	0%	[-1% , 2%]	[0% , 3%]	[4% , 7%]**
OutStk2H	7%	[-1% , 2%]	[-0% , 1%]	[0% , 1%]
OutStk3H	13%	[-1% , 1%]	[-3% , -0%]	[-12% , -8%]**
InStk1H	0%	[-0% , 1%]	[-1% , 1%]	[0% , 1%]**
InStk2H	2%	[1% , 2%]**	[1% , 1%]**	[0% , 1%]
InStk3H	3%	[-1% , -0%]	[-1% , 1%]	[-1% , 0%]

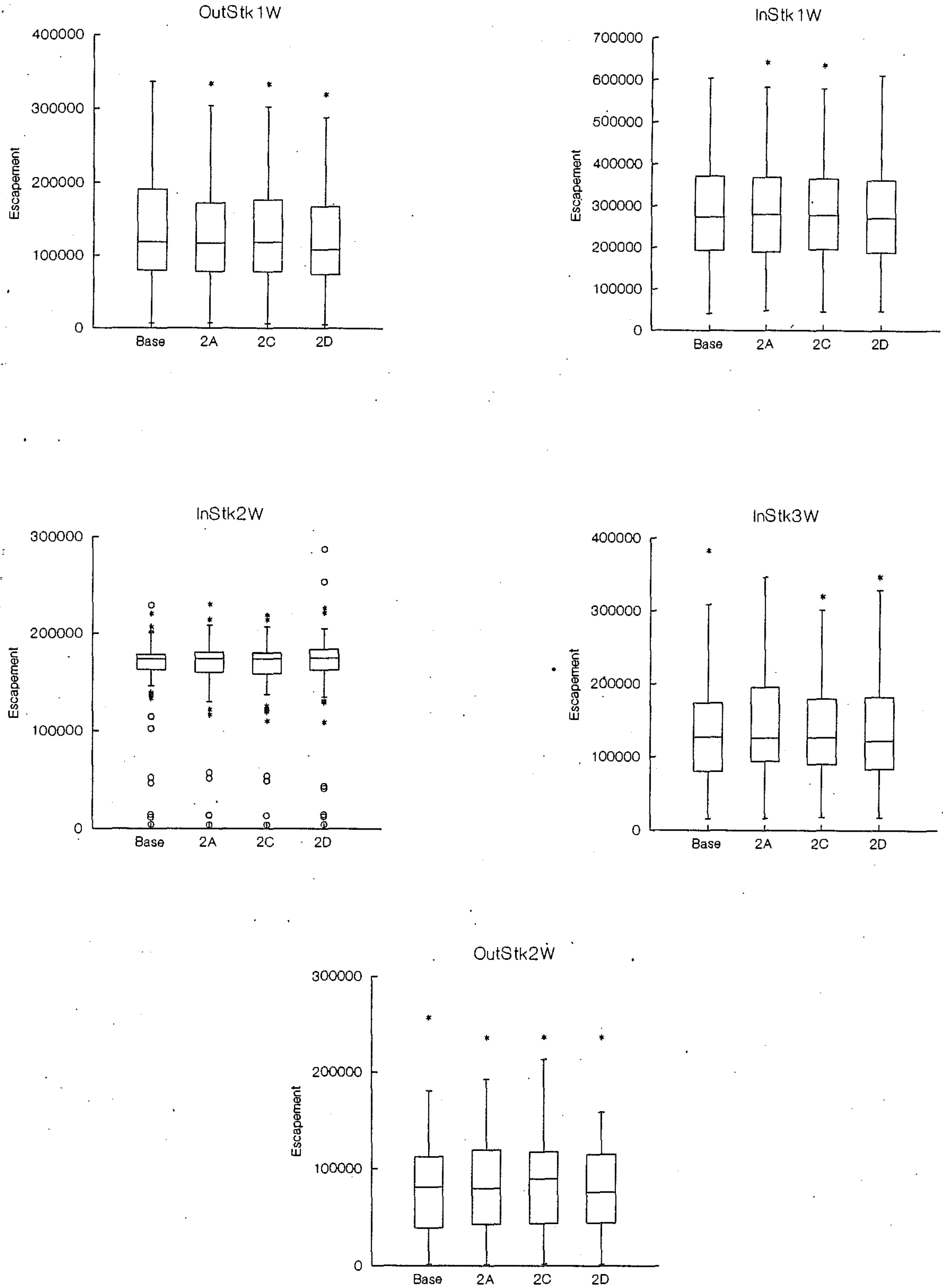


Figure 6.3. Box and whisker plots for the escapement of wild stocks in Case 2.

6.2.2.3 Case 3

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percentage Marked in Selective Fishery
3A	Adipose	Median	InStk1H, InStk2H, InStk3H	54%
3C	Ventral	Best	InStk1H, InStk2H, InStk3H	53%
3D	Ventral	Worst	InStk1H, InStk2H, InStk3H	49%

Description of Selective Fishery

Fishery	Location	Duration	Gear
InSp2	SJDF	wks 1-44	Recreational

Stocks Present in the Selective Fishery: InStk1, InStk2, and InStk3. Fish saved in the InSp2 fishery of InStk1 are available to InNt1, InNt2, InTr1 and InSp1. Saved InStk2 fish are available to InNt1, InNt2, and InNt3. InStk3 is available to InNt1, InNt2, InSp3, and InNt4.

Effects in the Selective Fishery. Harvest rates on unmarked fish in the selective fishery were reduced by approximately 80% in all scenarios of Case 3 (Table 6.14). This significant reduction was slightly greater than the reduction for the recreational fishery in Case 1, perhaps due to the absence of a bag limit in the simulation for fishery InSp2. In Case 1, anglers fished for a longer period of time when the selective fishery was implemented in order to attempt to catch the bag limit. This effect was not present in Case 3 since anglers were assumed to not be constrained by a bag limit in either the base case or upon implementation of the selective fishery.

Harvest rates on marked fish were significantly reduced in Scenarios 3C and 3D, but not in Scenario 3A (Table 6.14). Reductions in the harvest rate on marked fish were greatest for Scenario 3D (approximately 20%) because of the higher marked recognition error rate assumed for that scenario (marked recognition error rates were 6% for Scenario 3A, 10% for Scenario 3C, and 30% for Scenario 3D). As discussed above for the unmarked fish, a greater reduction in the harvest rate for marked fish was apparent in Case 3 relative to Case 1 because of the lack of a bag limit in the simulation of InSp2.

The median catch in the selective fishery was 46% (Scenario 3A) to 65% (Scenario 3D) less than the catch in the fishery in the base case (Table 6.14). The greater reduction in catch in Scenario 3D resulted from the higher rates of mark induced mortality (4% in Scenario 3A, 5% in Scenario 3C, and 20% in Scenario 3D) and marked recognition error assumed for this scenario. The incidence of marked fish in this fishery was lower than in Case 1 or 2, and hence, the average number of unmarked fish released before the first encounter of a marked fish was larger (0.8 to 1.0).

In the simulations, the incidental mortality increased by 175% to 200% following implementation of the selective fishery (Table 6.14).

Table 6.14. Effects of mass marking and the selective fishery in Case 3 on harvest rates for unmarked and marked fish, catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).

Statistic	3A Adipose Clip Median	3C Ventral Clip Best	3D Ventral Clip Worst
HR Unmarked Fish	[-80% , -80%]**	[-81% , -80%]**	[-80% , -80%]**
HR Marked Fish	[-3% , 2%]	[-8% , -3%]**	[-21% , -20%]**
Base Catch	207,350	207,350	207,350
Change After Selective Fishery	- 46%	- 48%	- 63%
Base Incidental Mortality	6,213	6,213	6,213
Change After Selective Fishery	+ 175%	+ 177%	+ 200%
Fish Released Before First Retention	0.8	0.9	1.0

Effects in Other Fisheries. Harvest rates in OutTr1 increased significantly in all scenarios of Case 3, with the greatest increase occurring in Scenario 3D (80% confidence interval of [8%, 9%])(Table 6.15). The increase in the harvest rate resulted from simulating this fishery as a ceiling and the reductions in abundance resulting from mark induced mortality.

Harvest rates in OutSp1 were significantly reduced in Scenarios 3A and 3C, but unchanged in Scenario 3D (Table 6.15). Differences in the results obtained in the scenarios are caused by the interplay of variations in abundance associated with mass mark induced mortality and the effectiveness of the selective fishery in InSpt2. Reductions in the abundance of fish could be expected to result in increased harvest rates in OutSp1 (see Section 6.2.2.5). Conversely, if harvest rates on marked and unmarked fish declined in InSp2, an increased number of fish from OutStk2 and OutStk3 would migrate back through OutSp1 prior to returning to their natal spawning rivers. In Scenarios 3A and 3C, reductions in the mortality of OutStk2 and OutStk3 resulting from the selective fishery were apparently sufficient to counteract the loss in production occurring as a result of mark induced mortality. This was not true in Scenario 3D, in which a greater rate of mark induced mortality was assumed.

Catches in the nonselective fisheries increased by 1% in Scenarios 3A and 3C respectively, and declined by 5% in Scenario 3D (Table 6.15). In Scenarios 3A and 3C the transfer of fish to the nonselective fisheries was slightly greater than the reduction in abundance due to the mark induced mortality. In Scenario 3D, the fish saved in the InSp2 selective fishery were relatively small in comparison to the reduction in abundance due to the higher mark induced mortality and catches declined.

The median change in the total catch across all fisheries was -1%, -1% and -8% in Scenarios 3A, 3C and 3D respectively (Table 6.15).

Table 6.15. Effects of mass marking and the selective fishery in Case 3 on harvest rates in OutTr1, OutSp1, catch in the nonselective fisheries, and the total catch in all fisheries. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).

Statistic	3A Adipose Clip Median	3C Ventral Clip Best	3D Ventral Clip Worst
HR OutTr1	[2% , 4%]**	[2% , 3%]**	[8% , 9%]**
HR OutSp1	[- 5% , - 2%]**	[- 6% , - 2%]**	[- 3% , 1%]
Change in Catch in Nonselective Fisheries	1%	1%	-5%
Change in Total Catch	-1%	-1%	- 8%

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.16 and 6.17, respectively. Box and whisker plots for escapement of wild stocks in Case 3 are provided in Fig. 6.4.

OutStk1W - Escapements and exploitation rates were not changed significantly in Scenarios 3A and 3C; escapements decreased significantly and exploitation rates increased significantly in Scenario 3D. This stock does not contribute to InSp2 and is unaffected by the selective fishery. In Scenarios 3A and 3C, the mark induced mortality is low and the small increase in the OutTr1 harvest rate is not enough to significantly change escapements. In Scenario 3D, reduced abundance associated with the higher mark induced mortality results in an increase in the harvest rate in OutTr1 sufficient to reduce the escapement and increase the exploitation rate.

OutStk2W - Escapements and exploitation rates were not changed significantly in Scenarios 3A and 3C; escapements were significantly reduced and exploitation rates significantly increased in Scenario 3D. As discussed above, the ceiling in OutTr1 acts in conjunction with reduced abundance to increase harvest rates, particularly in Scenario 3D. The increase in the harvest rate is larger than in Case 1 or 2 since a larger fraction of the production is marked. The ceiling effect is most apparent for OutStk1 and OutStk2 since they have the largest proportion of their catch in the OutTr1 fishery.

InStk1W - Escapements and exploitation rates were not changed significantly in Case 3. A very small fraction of this stock is harvested in InSp2. The small number of fish saved in InSp2 are available to the large InSp1 fishery.

InStk2W - Escapements were not significantly changed in Scenario 3A but increased significantly in Scenario 3C (Scenario 3D is marginal at $p = 0.0542$); the exploitation rates were not significantly changed in 3A but were significantly reduced in Scenarios 3C and 3D. Since the terminal fishery for this stock was controlled by an escapement goal, the small changes in the escapement were the result of stochastic processes in the simulated terminal management.

InStk3W - Escapements were significantly increased and exploitation rates were significantly reduced in Case 3.

OutStk1H - This substock was not marked in this case and results are similar to those for OutStk1W. Escapements and exploitation rates were not changed significantly in Scenarios 3A and 3C; escapements and exploitation rates were significantly reduced in Scenario 3D.

OutStk2H - Escapements and exploitation rates were not changed significantly in Case 3. This stock is not marked in this case and should have behaved similarly to OutStk2W. The confidence intervals are very close; the difference is likely the result of randomness.

OutStk3H - Escapements and exploitation rates were not changed significantly in Case 3. This stock is not marked in this case. Since this stock barely contributes to OutTr1 (3%), the ceiling effect is insignificant.

InStk1H - Escapements were significantly reduced, but exploitation rates were not changed significantly in Case 3. The reduction in escapement with no change in exploitation rate results from the reduced abundance due to the mark induced mortality.

InStk2H - Escapements were reduced significantly, and exploitation rates were significantly increased in Case 3. Increased terminal net harvest rate (due to greater numbers of InStk2W) increases the exploitation rate and decreases the escapement. Mark induced mortality also contributed to the decreased escapements.

InStk3H - Escapements were not changed significantly in Scenarios 3A and 3C and were significantly reduced in Scenario 3D; exploitation rates were not changed significantly in Case 3. In Scenario 3D, the mark induced mortality resulted in a reduction in the escapement.

Table 6.16. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in escapement in Case 3 from the base case, and the significance of the percent change in escapement (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement		
		3A Adipose Clip Median	3C Ventral Clip Best	3D Ventral Clip Worst
OutStk1W	0%	[-2% , -0%]	[-3% , -0%]	[-10% , -6%]**
OutStk2W	0%	[-7% , -1%]	[-1% , 1%]	[-9% , -3%]
InStk1W	1%	[-1% , 3%]	[-0% , 3%]	[-3% , 0%]
InStk2W	7%	[-1% , 3%]	[1% , 4%]*	[1% , 4%]
InStk3W	6%	[8% , 16%]**	[10% , 16%]**	[3% , 13%]**
OutStk1H	0%	[-2% , 0%]	[-3% , 0%]	[-10% , -6%]**
OutStk2H	0%	[-6% , -1%]	[-1% , 3%]	[-9% , -3%]
OutStk3H	0%	[-5% , 1%]	[-1% , 2%]	[-4% , 3%]
InStk1H	1%	[-6% , -2%]**	[-6% , -3%]**	[-23% , -21%]**
InStk2H	7%	[-14% , -11%]**	[-13% , -10%]**	[-25% , -23%]**
InStk3H	6%	[-6% , 2%]	[-5% , 1%]	[-22% , -15%]**

Table 6.17. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 3 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rate		
		3A Adipose Clip Median	3C Ventral Clip Best	3D Ventral Clip Worst
OutStk1W	0%	[0% , 2%]	[0% , 2%]	[4% , 8%]**
OutStk2W	0%	[1% , 2%]	[-1% , 0%]	[1% , 3%]*
InStk1W	1%	[-1% , 0%]	[-1% , 0%]	[0% , 1%]
InStk2W	7%	[-1% , 0%]	[-2% , -0%]**	[-1% , -0%]**
InStk3W	6%	[-3% , -2%]**	[-3% , -2%]**	[-3% , -1%]**
OutStk1H	0%	[-0% , 1%]	[-0% , 2%]	[4% , 8%]**
OutStk2H	0%	[0% , 2%]	[-1% , 0%]	[1% , 3%]
OutStk3H	0%	[-0% , 3%]	[-1% , 1%]	[-1% , 1%]
InStk1H	1%	[-1% , 1%]	[-1% , 1%]	[1% , 2%]**
InStk2H	7%	[3% , 4%]**	[2% , 3%]**	[1% , 3%]**
InStk3H	6%	[-1% , 0%]	[-2% , 0%]	[-1% , 1%]

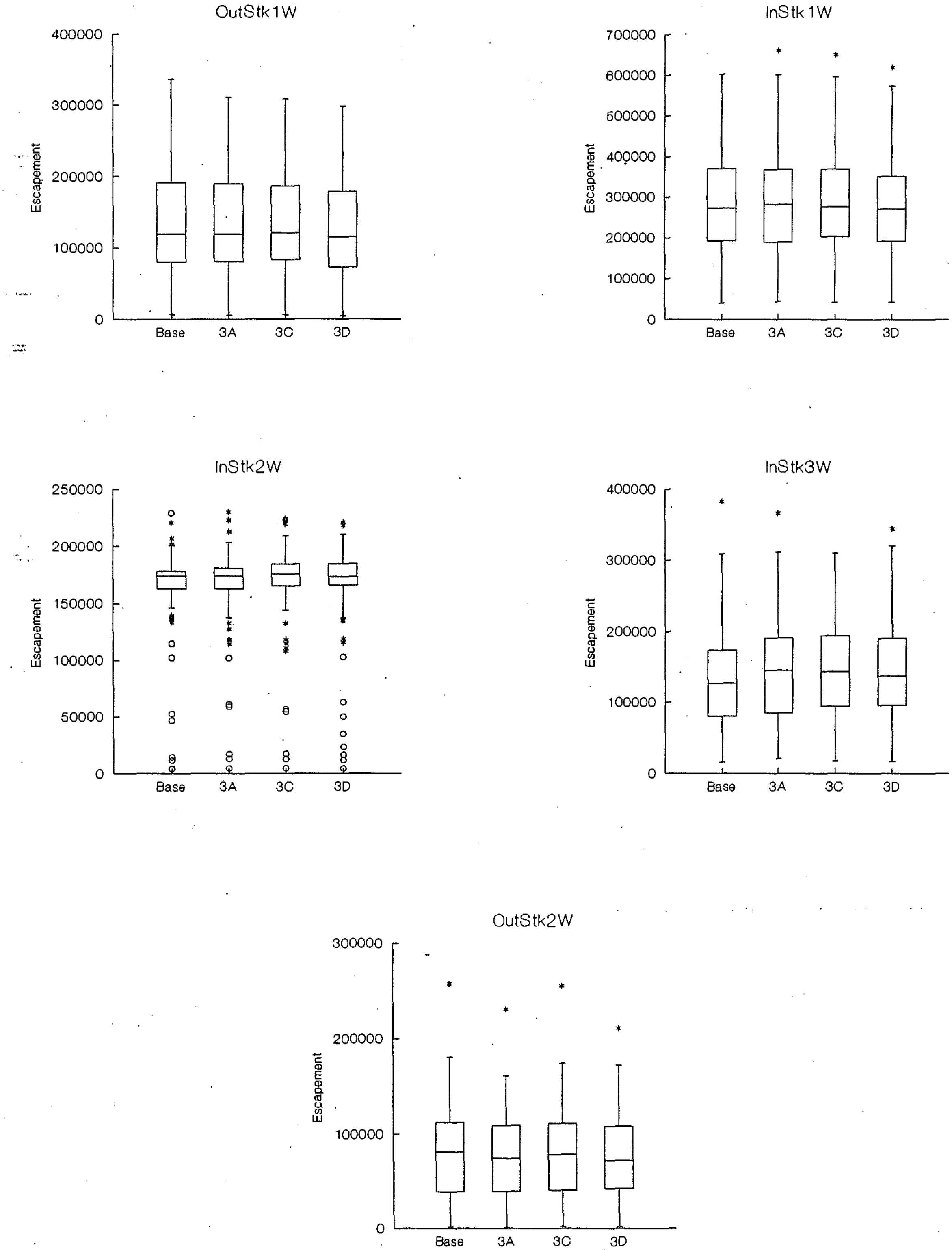


Figure 6.4. Box and whisker plots for the escapement of wild stocks in Case 3.

6.2.2.4 Case 4

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percentage Marked in Selective Fishery
4A	Adipose	Median	InStk1H	23%
4C	Ventral	Best	InStk1H	24%
4D	Ventral	Worst	InStk1H	22%

Description of Selective Fishery

Fishery	Location	Duration	Gear
InSp1	GEOS	wks 10-52	Recreational

Stocks Present in the Selective Fishery. InStk1 and InStk2. Fish saved in the InSp1 fishery of InStk1 are available to InTr1. Saved InStk2 fish are available to InNt1, InNt2, InSp2, and InNt3.

Effects in Selective Fishery. Harvest rates on unmarked fish in the selective fishery were reduced by approximately 74% in each of the scenarios in Case 4 (Table 6.18).

Harvest rates on marked fish were significantly reduced as well, with the largest reduction observed for Scenario 4D (Table 6.18). Reductions in the harvest rate on marked fish resulted from marked recognition error, with the greatest reduction in the harvest rate on marked fish (80% confidence interval of [-20%, -18%] for Scenario 4D) associated with the greatest value for marked recognition error (30% for Scenario 4D).

Catch in the selective fishery declined by 63% (Scenario 4A) to 73% (Scenario 4D) relative to the base fishery level (Table 6.18). The release of unmarked fish, the inadvertent release of marked fish, and the loss of production resulting from mark induced mortality each contributed to the decline in the catch. The decline in catch was greater than in Cases 1-3 because of the smaller proportion of the fish available to the fishery that were marked. The reduced incidence of marked fish also increased the average number of unmarked fish which would be released prior to encountering the first marked fish (3.3 in Scenario 4A, 3.2 in Scenario 4C, and 3.5 in Scenario 4D).

Incidental mortality increased by an average of 371% (Scenario 4A) to 386% (Scenario 4D) in the simulations after the implementation of the selective fishery (Table 6.19). The increase in incidental mortality was caused by the mortality of a portion of the unmarked and marked fish released. The lower incidence of marked fish in this fishery resulted in a larger increase in incidental mortality than the selective fisheries in Cases 1 or 3.

Table 6.18. Effects of mass marking and the selective fishery in Case 4 on harvest rates for unmarked and marked fish, catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).

Statistic	4A Adipose Clip Median	4C Ventral Clip Best	4D Ventral Clip Worst
HR Unmarked Fish	[-74% , -73%]**	[-74% , -73%]**	[-74% , -73%]**
HR Marked Fish	[-5% , -4%]**	[-8% , -6%]**	[-20% , -18%]**
Base Catch	646,962	646,962	646,962
Change After Selective Fishery	- 63%	- 64%	- 73%
Base Incidental Mortality	19,432	19,432	19,432
Change After Selective Fishery	+ 371%	+ 372%	+ 386%
Fish Released Before First Retention	3.3	3.2	3.5

Effects in Other Fisheries. Harvest rates in the OutTr1 and OutSp1 fisheries were generally not affected by mark induced mortality or selective fisheries in Case 4 (Table 6.19). The one exception was Scenario 4D, where the increase of 1% in the harvest rate in the OutTr1 fishery was significant at $\alpha = 0.05$. The stock marked in this case (InStk1H) does not contribute significantly to the OutSp1 fishery, and the loss of production resulting from mark induced mortality was small relative to the total number of fish available to the OutTr1 fishery.

Catches in the nonselective fisheries increased by 5%, 4%, and 4% in Scenarios 4A, 4C and 4D respectively (Table 6.19). The InSp1 fishery is such a large fishery that the fish saved due to the selective harvest increased abundance available to nonselective fisheries despite the mark induced mortality. This is the first case examined where there was a net transfer of fish in Scenario D.

The median change in the total catch across all fisheries was -5%, -6% and -8% in Scenarios 4A, 4C and 4D respectively (Table 6.19).

Table 6.19. Effects of mass marking and the selective fishery in Case 4 on harvest rates in OutTr1, OutSp1, catch in the nonselective fisheries, and the total catch in all fisheries. Confidence intervals for the change in the harvest rate from the base level are at α = 0.20; significance is reported for α = 0.05 (*) and 0.025 (**).

Statistic	4A Adipose Clip Median	4C Ventral Clip Best	4D Ventral Clip Worst
HR OutTr1	[0% , 0%]	[0% , 0%]	[1% , 1%]*
HR OutSp1	[- 4% , 0%]	[- 5% , - 0%]	[- 4% , 1%]
Change in Catch in Nonselective Fisheries	5%	4%	4%
Change in Total Catch	-5%	-6%	-8%

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.20 and 6.21, respectively. Box and whisker plots for escapement of wild stocks in Case 4 are provided in Fig. 6.5.

OutStk1W - Escapements and exploitation rates were not changed significantly in Case 4. This stock is not caught in the selective fishery and since InStk1 is the only stock marked there is not enough change in the abundance available to OutTr1 to cause the ceiling effect to occur.

OutStk2W - Same as for OutStk1W.

InStk1W - Escapements were significantly increased, and exploitation rates were significantly reduced in Case 4. This is the major stock affected by the selective fishery. Affects are large due to the proportion of the stock harvested in InSpt1 and because saved fish are only available to one other fishery (InTr1).

InStk2W - Escapements were significantly increased, and exploitation rates were significantly reduced in Case 4. The selective fishery should save a fairly large number of fish from InStk2W. Because of stochastic processes in the terminal area escapements went up.

InStk3W - Same as for OutStk1W.

OutStk1H - Same as for OutStk1W.

OutStk2H - Same as for OutStk1W.

OutStk3H - Same as for OutStk1W.

InStk1H - Escapements were not changed significantly in Scenarios 4A and 4C but were significantly reduced in Scenario 4D; exploitation rates were significantly reduced in Case 4. In Scenarios 4A and 4C, the marked recognition error reduced the exploitation rate and acted to increase the escapements but the mark induced mortality acted to reduce the escapements. Net result, no change in escapement and reduced exploitation rates. In Scenario 4D, similar processes were acting, but the higher mark induced mortality rate resulted in a reduced escapement.

InStk2H - Escapements were significantly increased and the exploitation rates were significantly reduced in Case 4. Marked recognition error in InSp1 reduced the exploitation rate. Also, for stochastic reasons the terminal fishery did not increase its harvest rate to catch the additional InStk2W fish. Thus, in this case, decreases in non-terminal fishery harvest rates were not compensated for in the terminal area fishery.

InStk3H - Same as for OutStk1W.

Table 6.20. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in escapement in Case 4 from the base case, and the significance of the percent change in escapement (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement		
		4A Adipose Clip Median	4C Ventral Clip Best	4D Ventral Clip Worst
OutStk1W	0%	[-0% , 0%]	[-1% , 1%]	[-2% , -1%]
OutStk2W	0%	[-4% , 1%]	[-3% , 4%]	[-2% , 1%]
InStk1W	38%	[76% , 80%]**	[76% , 80%]**	[76% , 80%]**
InStk2W	7%	[2% , 5%]**	[1% , 4%]	[1% , 5%]**
InStk3W	0%	[1% , 6%]	[-3% , 4%]	[-5% , 0%]
OutStk1H	0%	[-1% , 0%]	[-2% , 0%]	[-3% , -1%]
OutStk2H	0%	[-5% , 1%]	[-2% , 5%]	[-4% , 1%]
OutStk3H	0%	[-5% , 1%]	[-4% , 3%]	[-1% , 4%]
InStk1H	38%	[-3% , -1%]	[-2% , 0%]	[-6% , -5%]**
InStk2H	7%	[2% , 5%]**	[1% , 4%]*	[1% , 4%]**
InStk3H	0%	[2% , 6%]	[-2% , 4%]	[-5% , 1%]

Table 6.21. **Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 4 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).**

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rate		
		4A Adipose Clip Median	4C Ventral Clip Best	4D Ventral Clip Worst
OutStk1W	0%	[-0% , 1%]	[-1% , 1%]	[1% , 2%]
OutStk2W	0%	[-0% , 1%]	[-1% , 1%]	[-0% , 1%]
InStk1W	38%	[-33% , -32%]**	[-33% , -32%]**	[-32% , -32%]**
InStk2W	7%	[-2% , -1%]**	[-2% , -0%]**	[-2% , -1%]**
InStk3W	0%	[-1% , -0%]	[-1% , 1%]	[-0% , 1%]
OutStk1H	0%	[-1% , 1%]	[-0% , 1%]	[1% , 2%]
OutStk2H	0%	[-1% , 1%]	[-1% , 1%]	[-0% , 1%]
OutStk3H	0%	[-1% , 3%]	[-1% , 2%]	[-2% , 0%]
InStk1H	38%	[-1% , -1%]**	[-2% , -2%]**	[-8% , -7%]**
InStk2H	7%	[-2% , -1%]**	[-1% , -0%]**	[-2% , -1%]**
InStk3H	0%	[-1% , -0%]	[-1% , 0%]	[-0% , 1%]

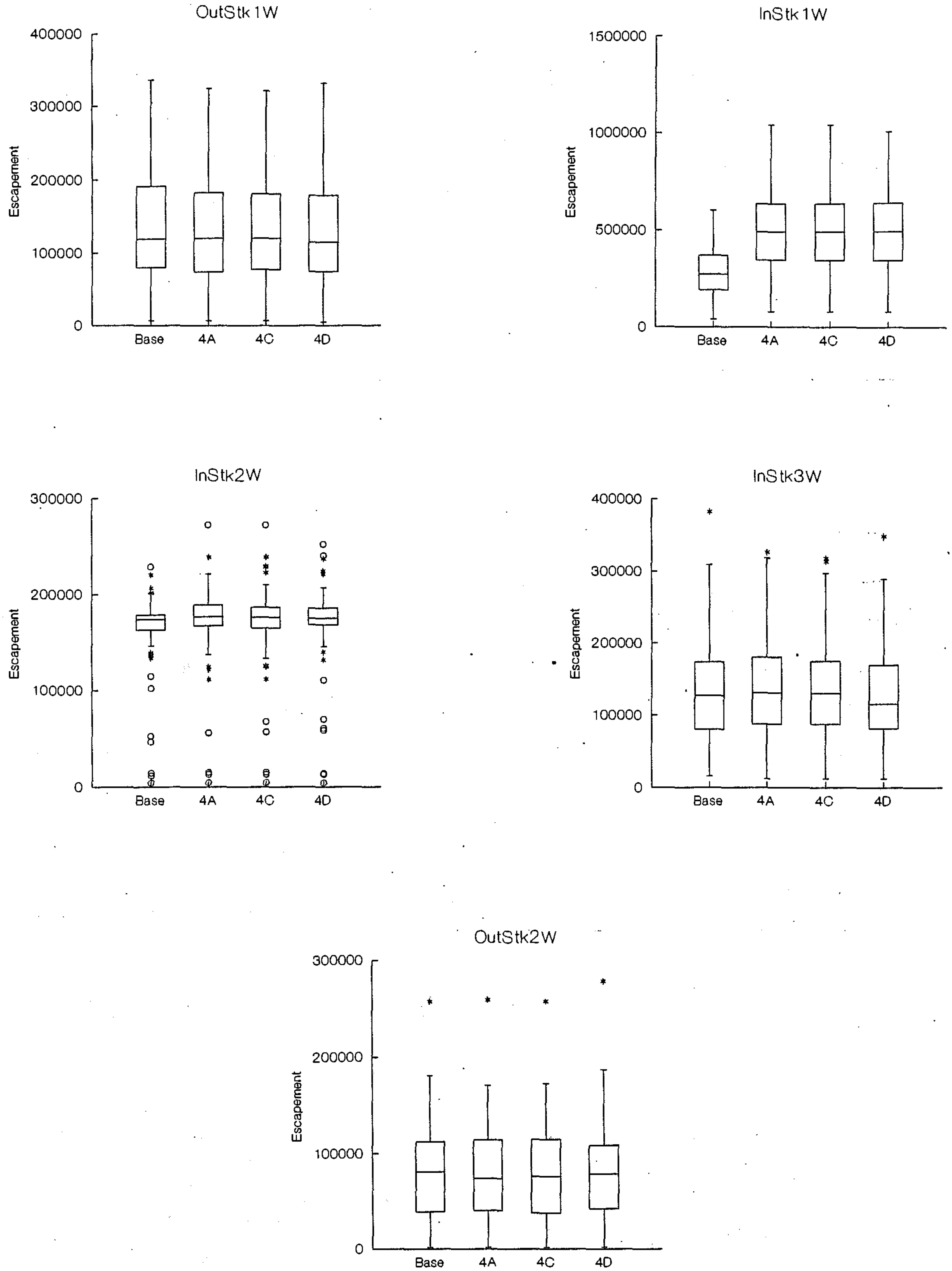


Figure 6.5. Box and whisker plots for the escapement of wild stocks in Case 4.

6.2.2.5 Case 5

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percent Marked in Selective Fishery
5A	Adipose	Best	OutStk2H	44%
5B	Adipose	Worst	OutStk2H	45%
5C	Ventral	Best	OutStk2H	43%
5D	Ventral	Worst	OutStk2H	41%

Description of Selective Fishery

Fishery	Location	Duration	Gear
OutNt1	Washington Coastal Terminal	wks 38-50	Net

Stocks Present in the Selective Fishery. OutStk2. Fish saved in the OutNt1 fishery accrue directly to escapement.

Effects in Selective Fishery. Harvest rates on unmarked fish were reduced significantly in all scenarios of Case 5 (Table 6.22). However, the reductions in the harvest rates were smaller than were observed for the sport and troll fisheries examined in Cases 1-4. The reductions in harvest rates were not as great for this net fishery because of the higher dropoff mortality rate (20% versus 3% for sport and 6% for troll) and the higher release mortality rate (30% or 70% for net gear versus 11% for recreational gear and 25% for troll gear).

Harvest rates on marked fish declined in Scenarios 5C and 5D but were unchanged in Scenarios 5A and 5B (Table 6.22). Reductions in the harvest rate on marked fish resulted from marked recognition error, which was set equal to 6% for Scenarios 5A and 5B, 10% for Scenario 5C, and 30% in Scenario 5D.

Median catches in the selective fishery were reduced by 55% (Scenario 5A) to 70% (Scenario 5D) in the simulations (Table 6.22). The release of unmarked fish, the marked recognition error and the reduced abundance resulting from mortality induced by mass marking each contributed to the reduced catch. The largest reduction of 70% in Scenario 5D was associated with the greatest rate of mark induced mortality (20%) and the greatest rate of marked recognition error (30%). In the simulated fishery, fishers could expect to release 1.2 (Scenario 5B) to 1.4 (Scenario 5D) unmarked fish before encountering the first marked fish.

Incidental mortality increased by 92% (Scenario 5C) to 214% (Scenario 5D) as a result of the subsequent mortality of some of the marked and unmarked fish released (Table 6.22). Larger increases in the incidental mortality occurred in the simulations when release mortality was set at 70% (Scenarios 5A and 5C) versus 30% (Scenarios 5b and 5D).

Table 6.22. Effects of mass marking and the selective fishery in Case 5 on harvest rates for unmarked and marked fish, catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).

Statistic	5A Adipose Clip Best	5B Adipose Clip Worst	5C Ventral Clip Best	5D Ventral Clip Worst
HR Unmarked Fish	[-49%,-46%]**	[-20%,-14%]**	[-50%,-48%]**	[-22%,-18%]**
HR Marked Fish	[-3%, 4%]	[-2%, 5%]	[-6%, -2%]*	[-9%, -4%]**
Base Catch	89,089	89,089	89,089	89,089
Change After Selective Fishery	- 55%	- 56%	- 55%	- 70%
Base Incidental Mortality	17,813	17,813	17,813	17,813
Change After Incidental Mortality	+ 96%	+ 198%	+ 92%	+ 214%
Fish Released Before First Retention	1.27	1.22	1.33	1.44

Effects in Other Fisheries. A significant increase in the harvest rates in the OutSp1 fishery occurred in all scenarios of this case as a result of the reduced abundance associated with mark induced mortality of OutStk2H (Table 6.23). No change occurred in OutTr1, apparently because the change in abundance of OutStk2 caused by mark induced mortality was relatively small compared to the total abundance of fish available to this fishery.

The median catch in the nonselective fisheries was unchanged in Case 5 (Table 6.23). Since OutStk2 was the only stock marked and the terminal net fishery, OutNt1, was the only selective fishery, there was no effect on the nonselective fisheries.

The median change in the total catch across all fisheries was -1%, -1%, -1% and -2% in Scenarios 5A through 5D respectively (Table 6.23).

Table 6.23. Effects of mass marking and the selective fishery in Case 5 on harvest rates in OutTr1, OutSp1, catch in the nonselective fisheries and the total catch in all fisheries. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).

Statistic	5A Adipose Clip Best	5B Adipose Clip Worst	5C Ventral Clip Best	5D Ventral Clip Worst
HR OutTr1	[0%, 0%]	[0%, 0%]	[0%, 0%]	[0%, 1%]
HR OutSp1	[-1%, 6%]**	[-1%, 6%]**	[2%, 6%]**	[1%, 5%]*
Change in Catch in Nonselective Fisheries	0%	0%	0%	0%
Change in Total Catch	-1%	-1%	-1%	-2%

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.24 and 6.25, respectively. Box and whisker plots for escapement of wild stocks in Case 5 are provided in Fig. 6.6.

OutStk1W - Escapements and exploitation rates were not significantly changed in Case 5. This stock is not caught in the selective fishery and since OutStk2 is the only stock marked there is not enough change in the abundance available to OutTr1 to cause the ceiling effect.

OutStk2W - Escapements were significantly increased, and exploitation rates were significantly reduced in Case 5. Affects are large due to the proportion of the stock harvested in OutNt1 and the fact that the saved fish are not vulnerable to any other fisheries.

InStk1W - Same as for OutStk1W.

InStk2W - Escapements were not changed significantly in Scenario 5A, increased significantly in Scenario 5B, and were not significantly changed in Scenarios 5C and 5D; exploitation rates were not significantly changed in Scenario 5A, were significantly reduced in Scenario 5B, and were not significantly changed in Scenarios 5C and 5D. The effects observed in Scenario 5B were likely due to stochastic processes in the simulation of terminal management.

InStk3W - Same as for OutStk1W.

OutStk1H - Same as for OutStk1W.

OutStk2H - Escapements were not significantly changed in Scenarios 5A, 5B and 5C, but were significantly reduced in Scenario 5D; exploitation rates were not significantly changed in Scenarios 5A and 5B but were significantly reduced in Scenarios 5C and 5D. In Scenarios 5A and 5B, escapements and exploitation rates remained unchanged because the magnitude of the marked recognition error, mark induced mortality, and release mortality was small and the effects acted in opposing directions. In Scenario 5C, marked recognition error reduced the exploitation rate; however, escapements did not increase because the benefit of the reduced exploitation rate was negated by the mark induced mortality. In Scenario 5D, escapements and exploitation rates both declined due to the large mark induced mortality and large marked recognition error. The reduction in exploitation rate in 5D is slightly less than that in 5C due to the difference in release mortality.

OutStk3H - Same as for OutStk1W.

InStk1H - Same as for OutStk1W.

InStk2H - Escapements were not changed significantly in Case 5; the exploitation rates were significantly reduced in Scenarios 5A and 5B and not significantly changed in Scenarios 5C and 5D. The effects observed in Scenario 5B were likely due to stochastic processes in the simulation of terminal management.

InStk3H - Same as for OutStk1W.

Table 6.24. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in escapement in Case 5 from the base case, and the significance of the percent change in escapement (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement			
		5A Adipose Clip Best	5B Adipose Clip Worst	5C Ventral Clip Best	5D Ventral Clip Worst
OutStk1W	0%	[-1% , 0%]	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]
OutStk2W	19%	[30% , 38%]**	[8% , 18%]**	[32% , 43%]**	[11% , 18%]**
InStk1W	0%	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]	[-2% , 0%]
InStk2W	0%	[0% , 2%]	[0% , 2%]*	[0% , 2%]	[0% , 3%]
InStk3W	0%	[2% , 9%]	[2% , 9%]	[-1% , 8%]	[-3% , 3%]
OutStk1H	0%	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]	[-2% , 1%]
OutStk2H	19%	[-7% , 1%]	[-8% , 0%]	[-2% , 5%]	[-18% , -15%]**
OutStk3H	0%	[-1% , 3%]	[-1% , 4%]	[-3% , 0%]	[-2% , 1%]
InStk1H	0%	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]	[-2% , 1%]
InStk2H	0%	[0% , 2%]	[0% , 2%]	[0% , 2%]	[-0% , 3%]
InStk3H	0%	[2% , 9%]	[2% , 9%]	[-1% , 7%]	[-3% , 3%]

Table 6.25. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 5 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rates			
		5A Adipose Clip Best	5B Adipose Clip Worst	5C Ventral Clip Best	5D Ventral Clip Worst
OutStk1W	0%	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]
OutStk2W	19%	[-14% , -11%]**	[-6% , -3%]**	[-15% , -13%]**	[-6% , -4%]**
InStk1W	0%	[-0% , 1%]	[-0% , 1%]	[-0% , 1%]	[-0% , 1%]
InStk2W	0%	[-1% , -0%]	[-1% , -0%]**	[-1% , -0%]	[-1% , -0%]
InStk3W	0%	[-2% , -0%]	[-2% , -0%]	[-1% , 0%]	[-1% , 1%]
OutStk1H	0%	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]	[-1% , 1%]
OutStk2H	19%	[-2% , 1%]	[-1% , 1%]	[-3% , -1%]**	[-2% , -0%]**
OutStk3H	0%	[-1% , 1%]	[-1% , 1%]	[-0% , 1%]	[-1% , 1%]
InStk1H	0%	[-0% , 1%]	[-0% , 1%]	[-0% , 1%]	[-0% , 1%]
InStk2H	0%	[-1% , -0%]*	[-1% , -0%]**	[-1% , -0%]	[-1% , 0%]
InStk3H	0%	[-2% , -0%]	[-2% , -0%]	[-1% , 0%]	[-1% , 0%]

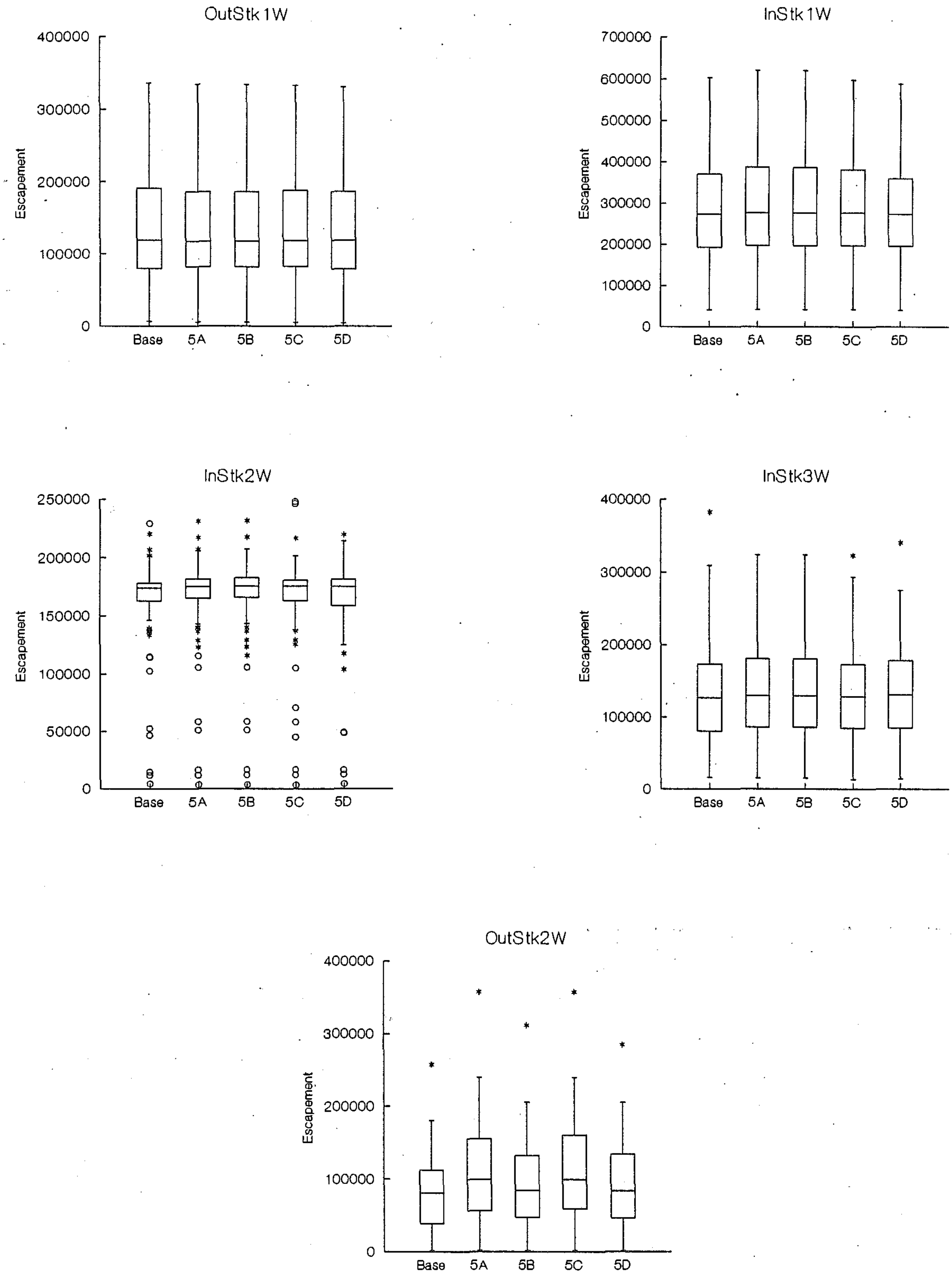


Figure 6.6. Box and whisker plots for the escapement of wild stocks in Case 5.

6.2.2.6 Case 6

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percent Marked in Selective Fishery
6A	Adipose	Median	All Hatchery	41%
6C	Ventral	Best	All Hatchery	41%
6D	Ventral	Worst	All Hatchery	38%

Description of Selective Fishery

Fishery	Location	Duration	Gear
All Recreational	OCNS, GEOS, SJDF, SPSD	Varies by fishery	Recreational

Stocks Present in the Selective Fisheries. OutStk2, OutStk3, InStk1, InStk2, and InStk3.

Effects in Selective Fishery. The change in the harvest rate from the base level was not computed for this case because of an error in the computer code which was used to compute the harvest rates over multiple fisheries. However, based upon Cases 1-5, it is apparent that reductions in the harvest rates on marked fish can be expected in these selective fisheries.

Catches in the selective fisheries dropped by 51% (Scenario 6A) to 66% (Scenario 6D) due to the release of unmarked fish in the selective fisheries, marked recognition error in the selective fisheries, and the loss in production associated with mark induced mortality of all the hatchery stocks (Table 6.26). The greatest reduction in catch was evident for Scenario 6D, in which the mark induced mortality was set equal to 20% (versus 4% in Scenario 6A and 5% in Scenario 6D) and the marked recognition error was set to 30% (versus 6% for Scenario 6A and 10% for Scenario 6D). Fishers could expect to release an average of 1.4 (Scenario 6A) to 1.6 (Scenario 6D) unmarked fish before encountering the first marked fish.

Incidental mortality increased by an average of 264% (Scenario 6A) to 296% (Scenario 6D) as a result of the subsequent mortality of a portion of the fish released in the selective fishery (Table 6.26).

Effects in Other Fisheries. The harvest rates significantly increased in the OutTr1 fishery for all scenarios in this case as a result of reductions in abundance resulting from mark induced mortality of all hatchery stocks and simulating this fishery with a ceiling for the catch (Table 6.27). The greatest increase was for Scenario 6D (80% confidence interval of [8%, 10%]), since this scenario had the greatest value for the mark induced mortality parameter. Increases in the harvest rate in the OutTr1 fishery were greater than for Cases 1 to 5 because of the marking of all hatchery production in Case 6.

Median catches in the nonselective fisheries increased by 8% and 6% in Scenarios 6A and 6C respectively, and were unchanged in Scenario 6D (Table 6.27). In this case, all recreational fisheries were selective and there were substantial transfers of fish due to the savings from selective harvest when the mark induced mortality was low. However, this was also the first case in which all six stocks were marked. As with Cases 1-3, the high mark induced mortality in Scenario 6D negated any benefits to the nonselective fisheries from fish saved by the selective fisheries.

The median change in the total catch across all fisheries was -9%, -10% and -18% in Scenarios 6A, 6C and 6D respectively (Table 6.27).

Table 6.26. Effects of mass marking and the selective fishery in Case 6 on catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish.

Statistic	6A Adipose Clip Median	6C Ventral Clip Best	6D Ventral Clip Worst
Base Catch	1,123,044	1,123,044	1,123,044
Change After Selective Fishery	- 51%	- 53%	- 66%
Base Incidental Mortality	33,713	33,713	33,713
Change After Selective Fishery	+ 264%	+ 276%	+ 296%
Fish Released Before First Retention	1.4	1.4	1.6

Table 6.27. **Effects of mass marking and the selective fishery in Case 6 on harvest rates in OutTr1, catch in the nonselective fisheries and the total catch in all fisheries. Confidence intervals for the change in the harvest rate from the base level are at $\alpha = 0.20$; significance is reported for $\alpha = 0.05$ (*) and 0.025 (**).**

Statistic	6A Adipose Clip Median	6C Ventral Clip Best	6D Ventral Clip Worst
HR OutTr1	[2% , 2%]**	[2%, 3%]**	[8% , 10%]**
Change in Catch in Nonselective Fisheries	8%	6%	0%
Change in Total Catch	-9%	-10%	-18%

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.28 and 6.29, respectively. Box and whisker plots for escapement of wild stocks in Case 6 are provided in Fig. 6.7.

OutStk1W - Escapements were not significantly changed in Scenarios 6A and 6C but were significantly reduced in Scenario 6D; exploitation rates were not significantly changed in Scenario 6A, but were significantly increased in Scenarios 6C and 6D. Since this substock is primarily harvested in OutTr1, these results are similar to the results obtained in Cases 1, 2 and 3. However, the ceiling effect in OutTr1 is greater in Case 6 due to mark induced mortality on a larger number of stocks.

OutStk2W - Escapements were significantly increased, and exploitation rates were significantly reduced in Case 6. Escapements did not increase as much in Scenario 6D due to the increase in the OutTr1 harvest rate (9%) from the ceiling effect. These results are similar those obtained in Case 1 except that the mark induced mortality of additional stocks increased the exploitation rate in OutTr1.

InStk1W - The results were the same as for OutStk2W. Since this stock is primarily harvested in the InSp1 fishery, the results were similar to those obtained in Case 4.

InStk2W - Escapements were marginally up in Scenario 6A (p=0.0521), not significantly changed in Scenario 6C, and significantly increased in

Scenario 6D; exploitation rates were significantly reduced in Scenarios 6A and 6D, but did not change significantly in Scenario 6C. Significant changes in the escapement and exploitation rates likely resulted from stochastic processes in the simulation of terminal area management.

InStk3W - Same as for OutStk2W.

OutStk1H - Escapements were significantly reduced, and exploitation rates were significantly increased in Case 6. OutStk1H was affected by: (1) mass mark induced mortality reduced the abundance of this substock; and (2) the ceiling effect in OutTr1 increased exploitation rates.

OutStk2H - Escapements were significantly reduced in Case 6; exploitation rates were not changed significantly in Scenarios 6A and 6C, but increased significantly in Scenario 6D. In all scenarios, the mark induced mortality acted to reduce escapements. In Scenarios 6A and 6C, increases in exploitation rates resulting from the ceiling effect were balanced by reductions in exploitation rates associated with marked recognition error. In Scenario 6D, the ceiling effect was larger than the effect of marked recognition error. These results are similar to the results obtained in Case 1, except that the increased number of stocks mass marked in Case 6 increased the ceiling effect in OutTr1.

OutStk3H - Escapements were not significantly changed in Case 6; the exploitation rates were not significantly changed in Scenarios 6A and 6C, but were reduced significantly in Scenario 6D. The terminal net fishery for this stock is managed as an escapement goal fishery, so the escapements remain relatively constant. In Scenario 6D, abundance was reduced by the mark induced mortality and exploitation rates declined due reduction in the harvest rates in the terminal net fishery. It is unclear why exploitation rates were not reduced in Scenarios 6A and 6C, as occurred in Scenarios 1A and 1C.

InStk1H - Escapements were not significantly changed in Scenarios 6A and 6C, but were reduced significantly in Scenario 6D; the exploitation rates were significantly reduced in Case 6. In Scenarios 6A and 6C, the mark induced mortality was compensated for by the marked recognition error, so escapements were unaffected and exploitation rates were reduced. In Scenario 6D, the marked recognition error reduced the exploitation rates but the mass mark induced mortality was large enough to still reduce escapements. Results in this case are similar to those observed in Case 4.

InStk2H - Escapements were significantly reduced, and exploitation rates were significantly increased in Case 6. Mark induced mortality, the ceiling effect, and the increase in the abundance of InStk2W in the terminal area acted to reduce escapements and increase exploitation rates.

InStk3H - Escapements were significantly reduced, and exploitation rates were not significantly changed in Case 6. Mark induced mortality reduced abundance which led to reduced escapements. Exploitation rates did not change as increases in exploitation rates associated with the ceiling effect in OutTr1 were offset by marked recognition error in the selective fisheries.

Table 6.28. Proportion of each stock's initial mortality in the selective fishery, the confidence interval for the percent change in escapement in Case 6 from the base case, and the significance of the change in escapement (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement		
		6A Adipose Clip Median	6C Ventral Clip Best	6D Ventral Clip Worst
OutStk1W	0%	[-4% , -1%]	[-4% , -1%]	[-11% , -7%]**
OutStk2W	9%	[9% , 13%]**	[9% , 14%]**	[0% , 8%]**
InStk1W	39%	[77% , 82%]**	[75% , 79%]**	[73% , 78%]**
InStk2W	17%	[1% , 4%]	[-1% , 2%]	[2% , 5%]**
InStk3W	12%	[15% , 23%]**	[12% , 30%]**	[13% , 22%]**
OutStk1H	0%	[-9% , -5%]**	[-11% , -7%]**	[-30% , -26%]**
OutStk2H	9%	[-7% , -4%]**	[-9% , -5%]**	[-27% , -21%]**
OutStk3H	20%	[-5% , 0%]	[-5% , -2%]	[-6% , -1%]
InStk1H	39%	[-2% , 1%]	[-2% , -0%]	[-8% , -6%]**
InStk2H	17%	[-22% , -19%]**	[-23% , -22%]**	[-31% , -28%]**
InStk3H	12%	[-6% , 0%]**	[-9% , 5%]*	[-21% , -14%]**

Table 6.29. **Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 6 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).**

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rate		
		6A Adipose Clip Median	6C Ventral Clip Best	6D Ventral Clip Worst
OutStk1W	0%	[1% , 3%]	[1% , 3%]*	[6% , 9%]**
OutStk2W	9%	[-5% , -3%]**	[-5% , -3%]**	[-3% , -0%]**
InStk1W	39%	[-34% , -33%]**	[-34% , -32%]**	[-33% , -32%]**
InStk2W	17%	[-2% , -0%]**	[-1% , 0%]	[-2% , -1%]**
InStk3W	12%	[-5% , -4%]**	[-6% , -3%]**	[-5% , -3%]**
OutStk1H	0%	[1% , 3%]	[2% , 4%]**	[6% , 8%]**
OutStk2H	9%	[0% , 1%]	[-0% , 1%]	[1% , 3%]**
OutStk3H	20%	[-2% , 1%]	[-2% , 0%]	[-11% , -9%]**
InStk1H	39%	[-2% , -1%]**	[-2% , -1%]**	[-7% , -6%]**
InStk2H	17%	[6% , 7%]**	[6% , 8%]**	[4% , 5%]**
InStk3H	12%	[-1% , 1%]	[-2% , 1%]	[-2% , 0%]

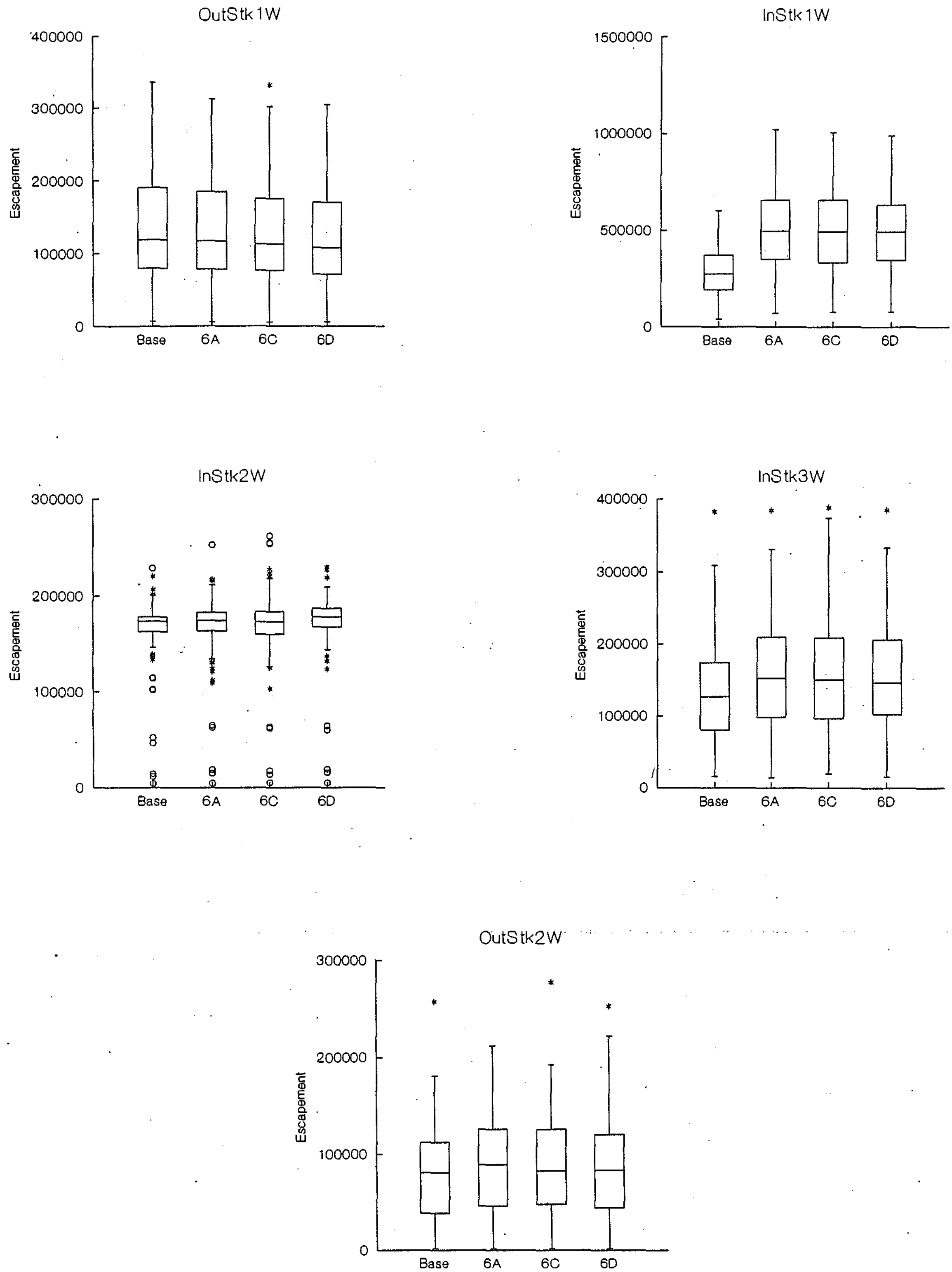


Figure 6.7. Box and whisker plots for the escapement of wild stocks in Case 6.

6.2.2.7 Case 7

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percent Marked in Selective Fishery
7A	Adipose	Median	All Hatchery	38%
7C	Ventral	Best	All Hatchery	38%
7D	Ventral	Worst	All Hatchery	36%

Description of Selective Fishery

Fishery	Location	Duration	Gear
All Recreational and Troll	OCNN, OCNS, GEOS, SJDF, SPSD	Varies by fishery	Recreational and Troll

Stocks Present in the Selective Fisheries. All

Effects in Selective Fishery. The change in the harvest rate from the base case was not computed for this case because of an error in the computer code which was used to compute the harvest rates over multiple fisheries. However, based upon Cases 1-5, it is apparent that reductions in the harvest rates on marked fish can be expected in these selective fisheries.

The release of marked and unmarked fish in the selective fisheries and the loss in production resulting from mark induced mortality reduced the median catch by 53% (Scenario 7A) to 67% (Scenario 7D)(Table 6.30). The greatest reduction in catch occurred when the mark induced mortality rate (4% in Scenario 7A, 5% in Scenario 7C, and 20% in Scenario 7D) and the marked recognition error rates (6% in Scenario 7A, 10% in Scenario 7C, and 30% in Scenario 7D) were at their greatest values. Averaged over all selective fisheries, fishers could expect to release 1.6 (Scenario 7A) to 1.8 (Scenario 7D) unmarked fish before encountering a marked fish.

Incidental mortality increased by an average of 333% (Scenario 7A) to 372% (Scenario 7D) as a result of the subsequent mortality of a portion of the fish which were released in the selective fishery (Table 6.30). As discussed previously with Case 1 (see Section 6.2.2.2), dropoff mortality could also be expected to increase in fishery OutSp1 and fishery OutTr1.

Effects in Other Fisheries. Median catches in the nonselective fisheries increased substantially in this case, 32%, 31% and 25% for Scenarios 7A, 7C, and 7D, respectively.

Even though all stocks are marked in this case, the addition of OutTr1 as a selective fishery greatly increased the fish saved relative to Case 6, Thus, even in Scenario 7D, there were large increases in catch in the nonselective fisheries.

The median decline in the total catch across all fisheries ranged from -31% to -43% in Case 7.

Table 6.30. Effects of mass marking and the selective fishery in Case 7 on catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish.

Statistic	7A Adipose Clip Median	7C Ventral Clip Best	7D Ventral Clip Worst
Base Catch	2,956,234	2,956,234	2,956,234
Change After Selective Fishery	- 53%	- 53%	- 67%
Base Incidental Mortality	143,700	143,700	143,700
Change After Selective Fishery	+ 333%	+ 350%	+ 372%
Fish Released Before First Retention	1.6	1.6	1.8

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.31 and 6.32, respectively. Box and whisker plots for the escapement of wild stocks in Case 7 are provided in Fig. 6.8.

All Wild Stocks (except InStk2W) - Escapements were significantly increased in Scenarios 7A, 7C, and 7D; exploitation rates were significantly reduced in Scenarios 7A, 7C, and 7D. Since OutTr1 was selective in this case, there was no ceiling effect for wild fish. The increases in escapement were large with the size of the escapement increases relative to the size of the terminal fishery for each stock.

InStk2W - Escapements were not changed significantly in Scenarios 7A and 7D and increased significantly in Scenario 7C; exploitation rates were not significantly changed in Scenario 7A and were significantly reduced in Scenarios 7C and 7D. Significant changes in escapement or exploitation rates were likely caused by simulation of stochastic processes in the terminal area.

OutStk1H - Escapements were significantly reduced in Case 7; exploitation rates were significantly increased in Scenarios 7A and 7C but were not significantly changed in Scenario 7D. In Scenarios 7A and 7C, mark induced mortality and the ceiling effect reduced both escapements and exploitation rates. In Scenario 7D, escapements went down due to mark induced mortality; the ceiling effect was balanced by the marked recognition error resulting in no change in exploitation rate. The effect of marked recognition error was attenuated by the large release mortality in the troll fishery.

OutStk2H - Escapements were significantly reduced in Case 7; exploitation rates were significantly increased in Scenario 7A, were not significantly changed in Scenario 7C, and were significantly reduced in Scenario 7D. Reductions in abundance associated with mark induced mortality led to reduced escapements in Case 7. Exploitation rates changed for the same reasons as discussed above for OutStk1H.

OutStk3H - Escapements were not changed significantly in Scenario 7A but were reduced significantly in Scenarios 7C and 7D; exploitation rates were not changed significantly in 7A and 7C but were reduced significantly in Scenario 7D. Results observed in this case are similar to those observed in Cases 1, 2 and 6. In each of these cases, the exploitation rates in Scenario D were reduced in order to achieve the escapement goal and compensate for the reduced abundance associated with mark induced mortality. Exploitation rates generally did not change significantly in Scenarios A and C in these cases, since variations in exploitation rates resulting from compensation for mark induced mortality were relatively small in comparison to the simulated stochastic processes in the terminal area. Reductions in the escapement observed in Scenarios 7C and 7D were also likely the result of the stochastic processes in terminal area fisheries.

InStk1H - Escapements were significantly reduced in Scenario 7A, were not changed significantly in Scenario 7C, and were significantly reduced in Scenario 7D; exploitation rates were not significantly changed in Scenario 7A, but were significantly reduced in Scenarios 7C and 7D. In Scenario 7A, mark induced mortality acted to reduce escapements and the combination of the ceiling effect and marked recognition error resulted in no net change in exploitation rate. In Scenario 7C, mark induced mortality was balanced by the reduction in exploitation rates, resulting in no net change in escapements. In Scenario 7D, exploitation rates were reduced enough to outweigh the mark induced mortality and escapements increase. The change in exploitation rates occurred for the same reasons as discussed for OutStk1H, but the balance point has shifted to Scenario 7A. This is because very little catch of InStk1H occurs in nonselective fisheries. As a result the marked recognition error has a much larger effect on InStk1H than on InStk3H, for example, where there are large nonselective terminal fisheries.

InStk2H - Escapements were significantly reduced, and exploitation rates were significantly increased in Case 7. Mark induced mortality, the ceiling effect in OutTr1, and the increase in the abundance of InStk2W fish in the terminal area combined to reduce escapements and increase exploitation rates.

InStk3H - Escapements were significantly reduced in Case 7; exploitation rates were significantly reduced in Scenario 7D. Mark induced mortality acted to reduce the escapements. In Scenarios 7A and 7C, reductions in exploitation rates associated with marked recognition error were negated by increases in exploitation rates associated with the ceiling effect in OutTr1. In Scenario 7D, the effects of the marked recognition error were larger than the ceiling effect and the exploitation rate declined.

Table 6.31. Proportion of each stock's initial mortality in the selective fishery, the confidence interval for the percent change in escapement in Case 7 from the base case, and the significance of the change in escapement (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement		
		7A Adipose Clip Median	7C Ventral Clip Best	7D Ventral Clip Worst
OutStk1W	60%	[74% , 88%]**	[75% , 88%]**	[77% , 91%]**
OutStk2W	53%	[65% , 79%]**	[69% , 83%]**	[62% , 76%]**
InStk1W	70%	[143% , 150%]**	[140% , 149%]**	[144% , 150%]**
InStk2W	48%	[2% , 7%]	[3% , 7%]**	[1% , 7%]
InStk3W	40%	[53% , 63%]**	[45% , 58%]**	[53% , 65%]**
OutStk1H	60%	[-22% , -12%]**	[-21% , -11%]**	[-17% , -9%]**
OutStk2H	53%	[-10% , -3%]**	[-13% , -4%]**	[-15% , -10%]**
OutStk3H	36%	[-5% , -1%]	[-6% , -2%]**	[-6% , -1%]**
InStk1H	70%	[-4% , -1%]**	[-3% , 1%]	[2% , 5%]*
InStk2H	48%	[-40% , -37%]**	[-39% , -36%]**	[-44% , -40%]**
InStk3H	40%	[-8% , -1%]**	[-11% , -3%]**	[-14% , -8%]**

Table 6.32. **Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 7 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).**

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rate		
		7A Adipose Clip Median	7C Ventral Clip Best	7D Ventral Clip Worst
OutStk1W	60%	[-51% , -47%]**	[-51% , -47%]**	[-52% , -48%]**
OutStk2W	53%	[-26% , -23%]**	[-27% , -25%]**	[-25% , -22%]**
InStk1W	70%	[-61% , -60%]**	[-60% , -60%]**	[-61% , -60%]**
InStk2W	48%	[-3% , -1%]	[-3% , -1%]**	[-3% , -0%]**
InStk3W	40%	[-14% , -12%]**	[-12% , -11%]**	[-13% , -12%]**
OutStk1H	60%	[5% , 11%]**	[2% , 9%]**	[-8% , -2%]
OutStk2H	53%	[-0% , 2%]**	[-1% , 2%]	[-4% , -2%]**
OutStk3H	36%	[-1% , 1%]	[-2% , 0%]	[-10% , -8%]**
InStk1H	70%	[-1% , -0%]	[-2% , -1%]**	[-12% , -11%]**
InStk2H	48%	[12% , 15%]**	[11% , 14%]**	[8% , 10%]**
InStk3H	40%	[-1% , 1%]	[-0% , 1%]	[-3% , -2%]**

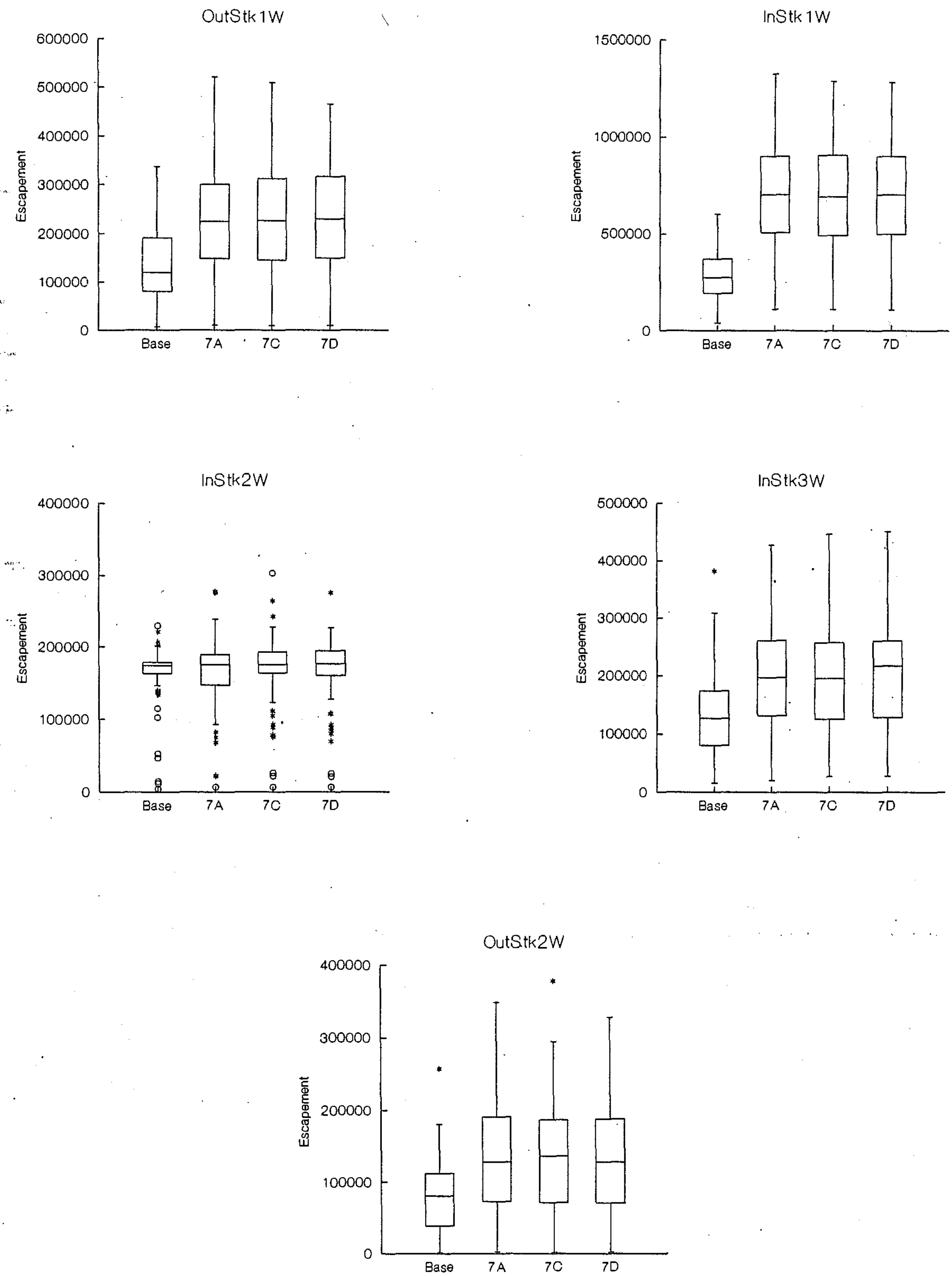


Figure 6.8. Box and whisker plots for the escapement of wild stocks in Case 7.

6.2.2.8 Case 8

Description of case

Scenario	Mark Type	Parameter Values	Stocks Marked	Percent Marked in Selective Fishery
8A	Adipose	Best	All Hatchery	41%
8B	Adipose	Worst	All Hatchery	41%
8C	Ventral	Best	All Hatchery	41%
8D	Ventral	Worst	All Hatchery	39%

Description of Selective Fishery

Fishery	Location	Duration	Gear
All	All	Varies by fishery	All

Stocks Present in the Selective Fisheries. All.

Effects in Selective Fishery. The change in the harvest rate from the base level was not computed for this case because of an error in the computer code which was used to compute the harvest rates over multiple fisheries. However, based upon Cases 1-5, it is apparent that reductions in the harvest rates on marked fish can be expected in these selective fisheries.

Mass marking and the imposition of selective fisheries resulted in reductions in catch that averaged from 42% (Scenario 8A) to 58% (Scenario 8D). The largest reduction in the landed catch was associated with the scenario with the greatest value for the mark induced mortality parameter (4% in Scenarios 8A and 8B, 5% in Scenario 8C, and 20% in Scenario 8D) and the greatest value for the marked recognition error parameter (6% in Scenario 8A, 10% in Scenario 8C, and 30% in Scenario 8D). The average number of unmarked fish which would be released before encountering a marked fish ranged from 1.4 (Scenario 8A) to 1.6 (Scenario 8D).

Incidental mortality increased by an average of 217% (Scenario 8A) to 317% (Scenario 8D) as a result of the subsequent mortality of a portion of the fish released in the selective fisheries. As discussed previously with Case 1 (see Section 6.2.2.2), dropoff mortality could also be expected to increase in fishery OutSp1 and fishery OutTr1.

Table 6.33. Effects of mass marking and the selective fishery in Case 8 on catch, incidental mortality, and the average number of unmarked fish released prior to the retention of the first marked fish.

Statistic	8A Adipose Clip Best	8B Adipose Clip Worst	8C Ventral Clip Best	8D Ventral Clip Worst
Base Catch	4,097,131	4,097,131	4,097,131	4,097,131
Change After Selective Fishery	- 42%	- 44%	- 43%	- 58%
Base Incidental Mortality	371,890	371,890	371,890	371,890
Change After Incidental Mortality	+ 217%	+ 280%	+ 231%	+ 317%
Fish Released Before First Retention	1.4	1.4	1.4	1.6

Stock Effects. Confidence intervals and significance tests for escapement and exploitation rates are provided in Tables 6.34 and 6.35, respectively. Box and whisker plots for the escapement of wild stocks in Case 8 are provided in Fig. 6.9.

All Wild Stocks - Escapements were increased significantly in Scenarios 8A-8D; exploitation rates were reduced significantly in Scenarios 8A-8D. In this case there are no nonselective fisheries; the increases in escapement are very large for all of the wild stocks.

OutStk1H - Escapements were significantly reduced in Case 8; exploitation rates were significantly increased in Scenarios 8A, 8B and 8C and not significantly changed in Scenario 8D. The results obtained in Case 8 were similar to those in Case 7 since this substock is not harvested in any net fisheries in the simulations. In Scenarios 8A, 8B and 8C, mark induced mortality and the ceiling effect in OutTr1 reduced both escapements and exploitation rates. In Scenario 8D, mark induced mortality acted to reduce escapements; the ceiling effect was attenuated by the marked recognition error, resulting in no change in the exploitation rates.

OutStk2H - Escapements were not significantly changed in Scenarios 8A and 8C, but were significantly reduced in Scenarios 8B and 8D; exploitation rates were significantly increased in Scenarios 8A and 8B, not significantly changed in Scenario 8C, and were significantly reduced in Scenario 8D.

OutStk3H - Escapements were not significantly changed in Scenarios 8A, 8B and 8C but were reduced significantly in Scenario 8D; exploitation rates were not significantly changed in Scenarios 8A, 8B and 8C but were significantly reduced in Scenario 8D. Results observed in this case are similar to those observed in Cases 1, 2, 6, and 7. In Scenario D in each of these cases, exploitation rates were reduced in order to achieve the escapement goal and compensate for the reduced abundance resulting from mark induced mortality. Exploitation rates generally did not change significantly in Scenarios A and C since variations in exploitation rates resulting from compensation for mark induced mortality were relatively small in comparison to the simulated stochastic processes in the terminal area. Reductions in the escapement observed in Scenarios 8D were also likely the result of the stochastic terminal processes.

InStk1H - Escapements were not significantly changed in Scenarios 8A and 8C, were significantly reduced in Scenario 8B, and were significantly increased in Scenario 8D; exploitation rates were not significantly changed in Scenarios 8A and 8B, but were significantly reduced in Scenarios 8C and 8D.

InStk2H - Escapements were significantly reduced, and exploitation rates were increased significantly in Case 8. Mark induced mortality, the ceiling effect, and the increase in the returning InStk2W fish combine to reduce escapements and increase exploitation rates.

InStk3H - Escapements were not changed significantly in Scenarios 8A and 8C, but were reduced significantly in Scenarios 8B and 8D; the exploitation rates were significantly reduced in Scenarios 8C and 8D.

Table 6.34. Proportion of each stock's initial mortality in the selective fishery, the confidence interval for the percent change in escapement in Case 8 from the base case, and the significance of the change in escapement (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Escapement			
		8A Adipose Clip Best	8B Adipose Clip Worst	8C Ventral Clip Best	8D Ventral Clip Worst
OutStk1W	61%	[69% , 102%]**	[75% , 89%]**	[68% , 100%]**	[76% , 93%]**
OutStk2W	73%	[106% , 135%]**	[83% , 101%]**	[107% , 151%]**	[84% , 98%]**
InStk1W	70%	[133% , 149%]**	[143% , 149%]**	[134% , 154%]**	[144% , 150%]**
InStk2W	75%	[39% , 62%]**	[3% , 8%]**	[46% , 66%]**	[4% , 7%]**
InStk3W	81%	[128% , 169%]**	[88% , 94%]**	[135% , 173%]**	[87% , 101%]**
OutStk1H	61%	[-24% , -12%]**	[-22% , -11%]**	[-25% , -8%]*	[-16% , -8%]**
OutStk2H	73%	[-17% , -2%]	[-15% , -8%]**	[-18% , -4%]	[-14% , -8%]**
OutStk3H	74%	[-5% , 2%]	[-4% , 1%]	[-5% , 2%]	[-4% , -0%]**
InStk1H	70%	[-8% , 2%]	[-5% , 0%]*	[-9% , 2%]	[3% , 5%]*
InStk2H	75%	[-94% , -90%]**	[-67% , -60%]**	[-93% , -90%]**	[-61% , -58%]**
InStk3H	81%	[-9% , 5%]	[-6% , -1%]*	[-8% , 5%]	[-6% , 1%]**

Table 6.35. Percent of each stock's initial cohort killed in the selective fishery, the 80% confidence interval for the percent change in exploitation rates in Case 8 from the base and the significance of the percent change (* significant at 0.05; ** significant at 0.025).

Model Stock	% of Initial Cohort Killed in Fishery	Confidence Interval and Significance Test For Percent Change in Exploitation Rate			
		Adipose Clip Best	Adipose Clip Worst	Ventral Clip Best	Ventral Clip Worst
OutStk1W	61%	[-52% , -48%]**	[-51% , -48%]**	[-52% , -47%]**	[-53% , -49%]**
OutStk2W	73%	[-46% , -43%]**	[-33% , -31%]**	[-45% , -43%]**	[-34% , -31%]**
InStk1W	70%	[-61% , -60%]**	[-61% , -60%]**	[-61% , -60%]**	[-61% , -60%]**
InStk2W	75%	[-21% , -16%]**	[-3% , -1%]**	[-20% , -15%]**	[-3% , -2%]**
InStk3W	81%	[-35% , -34%]**	[-20% , -19%]**	[-35% , -34%]**	[-21% , -20%]**
OutStk1H	61%	[6% , 12%]**	[5% , 11%]**	[2% , 8%]**	[-9% , -4%]
OutStk2H	73%	[1% , 4%]**	[1% , 4%]**	[0% , 3%]	[-5% , -3%]**
OutStk3H	74%	[-5% , -0%]	[-3% , 0%]	[-5% , 0%]	[-11% , -8%]**
InStk1H	70%	[-2% , 1%]	[-2% , 1%]	[-3% , -1%]**	[-12% , -11%]**
InStk2H	75%	[27% , 35%]**	[21% , 23%]**	[27% , 34%]**	[16% , 18%]**
InStk3H	81%	[-2% , 0%]	[-1% , 1%]	[-2% , -1%]**	[-5% , -4%]**

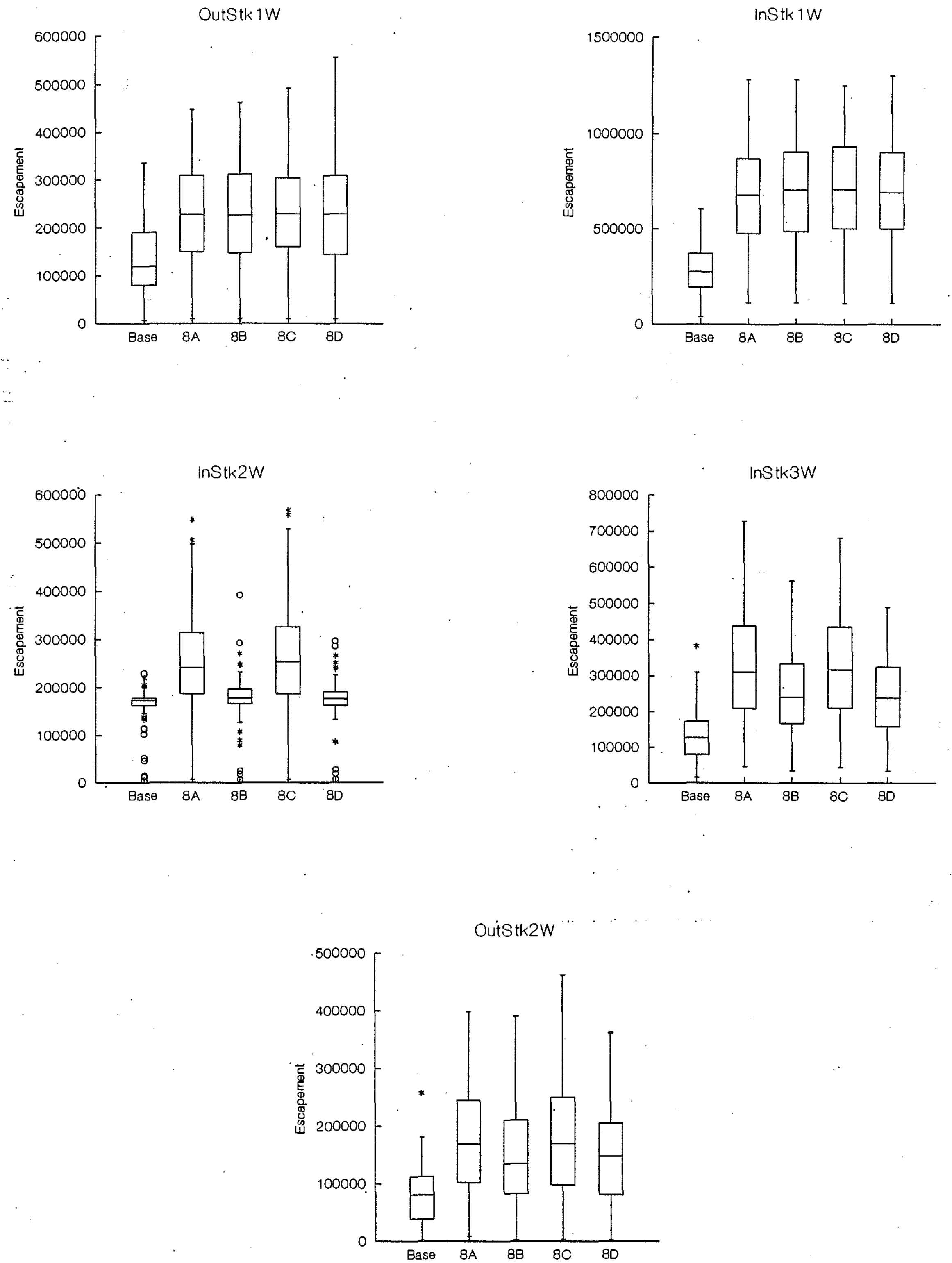


Figure 6.9. Box and whisker plots for the escapement of wild stocks in Case 8.

6.2.3 Conclusions

The analysis reported in Section 6.2 was designed to answer three primary questions:

1) Can a selective fishery reduce harvest rates on unmarked fish?

2) Can total exploitation rates be reduced and can the escapements be increased as a result of selective fisheries? Under what conditions would this occur? and

3) How would catches and incidental mortality in the fisheries be affected?

Eight selective fishery cases were developed to assess a wide range of selective fishery and stock combinations. Although the individual cases are not intended to represent actual case studies, in combination these cases provide a realistic assessment of the effects of selective fisheries both on stock conservation and fishery performance.

6.2.3.1 Can a selective fishery reduce harvest rates on unmarked stocks?

We have clearly shown that selective fisheries are effective at reducing harvest rates on unmarked stocks. In all eight cases modelled, the harvest rates on unmarked fish were significantly reduced in the selective fisheries. However, the magnitude of the reduction was variable, ranging from a high of 70%-80% for gear types with low release and dropoff mortality rates to a low of 10%-50% for gear types with high release and dropoff mortality rates. These rates can be expected to vary, depending upon the manner in which the gear is operated and the time and location of the selective fishery. Recreational gear, traps, and beach seines are believed to have the lowest release mortality rates. Gillnets and purse seine fisheries in which a large number of fish are caught per set are believed to have the highest release mortality rates. Troll and purse seine fisheries in which a small number of fish are caught per set are believed to have intermediate release mortality rates.

This reduction in harvest rate will be modified to the extent that the harvest rate in the fishery actually increases as a result of the selective fishery program. In the SFM, two fisheries were modelled to demonstrate this effect. In both the OutTr1 and OutSp1 fisheries, the harvest rates increased (1%-10%) due to the mark induced mortality. Other mechanisms that increase harvest rates in selective fisheries, such as effort shifts, will reduce the effectiveness of the selective regulations in reducing the mortality on unmarked fish.

6.2.3.2 Can the total exploitation rates be reduced and can the escapements be increased as a result of selective fisheries? Under what conditions would this occur?

We have demonstrated that the ability of selective fisheries to reduce exploitation rates and increase escapements is entirely fishery and stock dependent. The relative effectiveness of different selective fishery configurations in achieving these conservation objectives is dependant upon several, often inter-related, factors. These factors are discussed below in terms of their effect upon escapement. However, the effect on exploitation rates can be inferred, since for unmarked stocks, changes in exploitation rates result from changes in escapement.

1) Effectiveness in increasing escapement is directly related to the proportion of a stock that would be harvested in the selective fishery in the absence of selective regulations.

   For example, in Case 3, InSp2 is selective and approximately 1% of InStk1's mortalities occur in this fishery, while in Case 4, InSp1 is selective and approximately 38% of InStk1's mortalities occur in this fishery. Although harvest rates on unmarked fish were significantly reduced in both case 3 (80%-81%) and Case 4 (73%-74%), there was no change in the escapement of InStk1 in Case 3 and a 76%-80% increase in Case 4.

2) Effectiveness in increasing escapement declines as the availability of saved unmarked fish to nonselective fisheries increases.

   In Case 3, unmarked fish of stock InStk1 saved in InSp2 are available both to InTr1 and to InSp1, which combined harvest 47% of InStk1. In Case 4, fish saved in the selective InSp1 fishery are only available to InTr1, which harvests only 9% of InStk1 and the majority of fish saved accrue to escapement. Therefore, less of the savings of Instk1 would pass through to escapement from an InSpt2 selective fishery than from an InSpt1 selective fishery.

   Case 5 is an extreme example of this point. In this case, the selective fishery is a terminal net fishery (OutNt1) and the fish of OutStk2W saved as a result of selective harvest accrue directly to escapement. From the perspective of availability to nonselective fisheries, this selective fishery is optimal; however, net fisheries may have high release and dropoff mortalities. Case 5 demonstrates both sides of this dilemma. In the best scenarios (5A and 5C) escapements of OutStk2W increase by 30%-40%, while in the worst scenarios (5B and 5D) incidental mortalities increase by 200% and the net increase in escapement was similar to the increases seen in Cases 1 and 2.

3) Effectiveness in increasing escapement declines if harvest rates in nonselective fisheries increase as a result of reductions in overall abundance caused by mark induced mortality.

   There are two components to this factor. The first is that reductions in mortalities for an unmarked stock that is present in a selective fishery can be negated by increased mortalities on that stock in some other fishery. The second is that stocks that do not derive any benefit from a selective fishery - they are either not marked or not present - can experience declines in escapement due to increased mortalities in other fisheries.

Case 2 illustrates the first point. In Scenarios 2A and 2C, the harvest rate in the OutTr2 fishery is substantially reduced and the escapements of OutStk2W - a major contributor to the fishery - are significantly increased. However, in Scenario 2D, the escapements of OutStk2W do not increase. The harvest rate on unmarked fish in OutTr2 declined in this scenario just as in the 2A and 2C, but in 2D, the harvest rate in OutTr1 Fishery increases by 7% - 8% due to the high mark induced mortality. This increase in the harvest rate in Outtr1 negated the reduction achieved in OutTr2.

Cases 1-3, and 6 illustrate the second point. In these four cases, OutStk1 is not marked and is not present in the selective fishery. As discussed above, the harvest rate in OutTr1 is significantly increased in the scenarios with high mark induced mortality (1D, 2D, 3D, 6D). This increased harvest rate results in significant declines in escapement for both the wild and hatchery components of OutStk1 in all four cases.

4) Increases in the escapement of wild stocks resulting from the implementation of selective fisheries were small relative to the variability in the escapements. In cases 1-5, the median escapement differed little from the median escapement in the base case, with the exception of InStk1 in Case 4. Even in Case 6, (all recreational fisheries selective) the median escapement for 4 of the 5 wild stocks was within the range of the central 50% of the escapement's in the base case.

The multiple selective fishery Cases 6, 7, and 8 represent combinations of the above effects illustrated by the individual fishery cases. As the number of fisheries that are selective increases, the proportion of the stock harvested in the selective fisheries increases and the number of nonselective fisheries that can harvest fish saved by the selective fishery decreases. Accordingly, the magnitude of the increases in escapement of unmarked stocks increases from Case 6 through 8.

6.2.3.3 How would catches and incidental mortality in the fisheries be affected?

Landed catch in the selective fishery declined in all modelled cases (-32% to -73%). The magnitude of the declines varied with the proportion marked, the degree of mark recognition error (i.e., the inappropriate release of marked fish) and reduced abundance of marked fish due to marking mortality (Fig. 6.10). For example, in Scenario 1A (4% mark mortality, 6% mark recognition error, 62% mark rate), catch was reduced by only 32% whereas in Scenario 4D (20% mark mortality, 30% mark recognition error, 22% mark rate) the landed catch was reduced by 73%.

Incidental mortality rates in selective fisheries are highest for net fisheries and lowest for recreational fisheries, with troll fisheries having an intermediate rate. These impacts are directly related to the magnitude of release and drop-off mortalities for the gear used in these fisheries. Relative to the base level, incidental mortality increased in selective fisheries from 100% to 400% across all cases and scenarios. Incidental mortality expressed as a proportion of landed catch in selective fisheries ranged from 0.12 in Scenario 1A to 2.09 in Scenario 5D. Incidental mortality in selective fisheries increased in all cases as the proportion of unmarked fish, the release mortality and the mark recognition error increased (Fig. 6.11).

The total catch in nonselective fisheries declined in 3 of 22 scenarios examined. These 3 scenarios (1D, 2D and 3D) involved the ventral worst mark mortality of 20% which produced a low abundance of marked fish. These scenarios also had relatively small selective fisheries that did not save enough unmarked fish for harvest in subsequent fisheries to overcome this mark mortality effect. For seven of the remaining scenarios, redistribution of catch from selective fisheries and reduced abundance of marked fish due to mark mortality balanced each other to produce no change in the total catch in nonselective fisheries. In the remaining 12 scenarios, the redistribution of fish resulted in a net increase in catch in the nonselective fisheries.

The most extreme example of this was seen in the terminal net fishery of InStk2. This fishery was managed to achieve the wild escapement goal of InStk2. As the terminal abundance of InStk2 increased above that necessary to achieve its goal, the harvest rate in the terminal net fishery (InNet3) increased as well. This was not the case for the other model fisheries which had a constant harvest rate. Moderate increases in wild run size as observed in Cases 3 and 6 represented a benefit to InNt3 since the additional wild fish returning to the terminal area allowed the fishery to harvest additional hatchery fish. However, in Case 7, the increase in abundance of wild InStk2 fish was sufficient to harvest all of the hatchery fish and still meet the wild stock escapement goal. In this case, fisheries would need to be redesigned to allow for differential harvest of wild fish. This stock illustrates a situation where selective fisheries designed to benefit a particular set of wild stocks may have unplanned consequences for other wild stocks that are harvested in the same selective fisheries.

CHAPTER 7. ESTIMATION OF STOCK PARAMETERS AND MANAGEMENT MODELS

Stock assessment and management of chinook and coho salmon must contend with harvests by diverse gear types over extensive geographic areas. Until the late 1970's, the total fishing mortalities by age and stock were unknown and the status of our wild chinook and coho populations was uncertain. The development of the CWT fundamentally changed our assessment and management capabilities for these species. Tagged juvenile salmon, usually those released from hatcheries, provided information on the marine distribution of stocks, total mortalities and exploitation rates in fisheries, and variation in marine survival. Under the assumption that the distribution and exploitation rates of hatchery stocks were representative of nearby wild stocks, this information was subsequently applied to their management. Managers could now investigate the population dynamics and status of wild stocks, develop stock-specific abundance predictions, and estimate stock compositions in fisheries. Numerous management agencies, fishery councils, and the PSC technical committees rely on the CWT program to assess and manage chinook and coho salmon.

In order to maximize the value of CWTs, an indicator stock program was established. In this program, a fixed set of representative stocks are tagged on an ongoing basis to provide estimates of stock statistics. Estimates obtained from the indicator stocks are accurate only to the extent that the biological characteristics of the stock are represented by its indicator.

The ability to estimate population abundance and the distribution of stock-specific mortalities is critical to salmon management. CWT-based estimation methods underlie most tools that are currently used for stock-specific assessment of coho and chinook salmon. Stock-specific parameters derived from CWT-based estimates of fishery and escapement contributions include distributional statistics, estimation of exploitation rates by stock, age, fishery and time period and total initial cohort size of stocks at recruitment.

Because the CWT is central to management of chinook and coho salmon, the viability of the CWT program is of vital concern. The viability of the CWT system is defined here as:

1) The ability to use CWT data for assessment and management of wild stocks of chinook and coho salmon;

2) the ability to maintain the program such that the uncertainty in our assessments and their applications does not unacceptably increase management risk; and

3) the ability to estimate stock-specific exploitation rates by fishery and age.

The viability of the CWT system depends critically upon the fundamental assumption that the tagged to untagged ratio within a stock remains essentially constant. Since selective fisheries are intended to affect marked and unmarked stock components differently, this assumption will, by definition, be violated. Thus, selective fisheries have the potential to place the viability of the CWT program in jeopardy. This chapter evaluates the likelihood of that result, and develops tagging, sampling and analytical methods to reduce the risk. Emphasis is placed upon cohort analysis and the coho salmon Stock Composition Model (SCM). This section also addresses the impact on tools that rely upon CWT-based estimates of abundances and exploitation rates derived from cohort analysis, including management planning models and abundance forecasts. We will also examine impacts on management models which do not necessarily rely on CWTs, such as those used to estimate terminal run abundance.

7.1 Cohort Analysis

The application of cohort analysis methods (Gulland 1965) to CWT data was a major development in salmon fishery management and is central to many stock assessment tools (Table 7.1). CWT recoveries currently provide the stock and age specific data necessary to perform a cohort analysis for salmon stocks on the Pacific Coast.

Input to cohort analysis typically includes the following statistics and parameters:

1) The number of tagged fish released;

2) the number of tags recovered in fishery samples by tag group and fishery, expanded to account for the sampling rate in the fishery;

3) incidental mortality parameters, including the assumed rates of dropoff mortality, proportion of each age class which is vulnerable to each fishery, and the release mortality rates;

4) assumed natural mortality rates; and

5) escapement of tagged fish by age.

Using these inputs, cohort analysis reconstructs the life history of a tagged stock for a given brood year. Working sequentially back through time, the catch and incidental mortality are added to the escapement of the oldest age class. If multiple ages or time periods (e.g., 12 months of a year) are incorporated in the analysis, estimates of natural mortality are also added at the start of each time period. The accumulated escapement, catches, incidental mortality, and natural mortality provide an estimate of the initial cohort, or the number of initial recruits to ocean fisheries.

This generalized process of cohort analysis and a specific example are presented in Fig. 7.1. Starting with the age 3 spawning escapement (655 in the example), the initial cohort size (labelled ocean standing stock) would be estimated to be 3,861 coho salmon. The process would be identical for chinook salmon, but would involve multiple age classes for each brood year.

Table 7.1. Applications of cohort analysis in chinook and coho salmon management analyses and computer models.

<table>
<tr><th>Distributional statistics</th><th>Exploitation rate by stock,fishery, and age</th><th>Abundance forecasts</th></tr>
<tr><td>Annual distribution of exploitation rate index stocks, ChTC analyses</td><td rowspan="2">Basic analytical tool for ChTC annual report:
- fishery indices
- stock indices
- brood exploitation rates (ocean & total)
- Brood survival rates</td><td rowspan="2">Allows estimation of annual marine survival rates for tagged stocks;

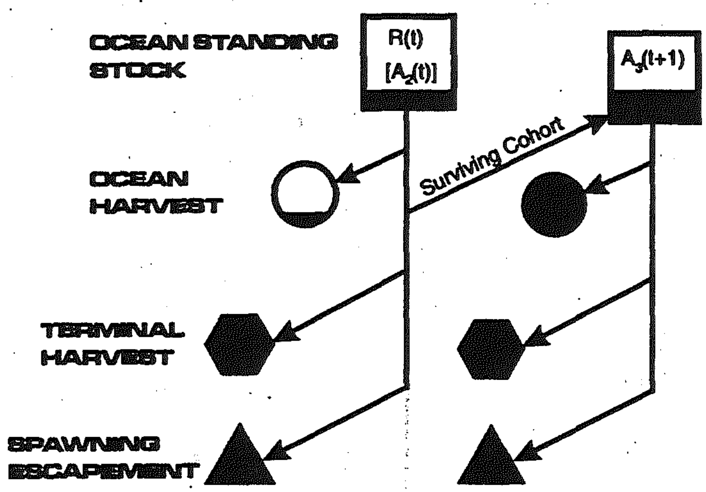
Allows estimation by cohort of age-specific fishery impacts with and without incidental mortalities;

Provides input for ChTC chinook model calibration and forecasts of future ocean abundances;

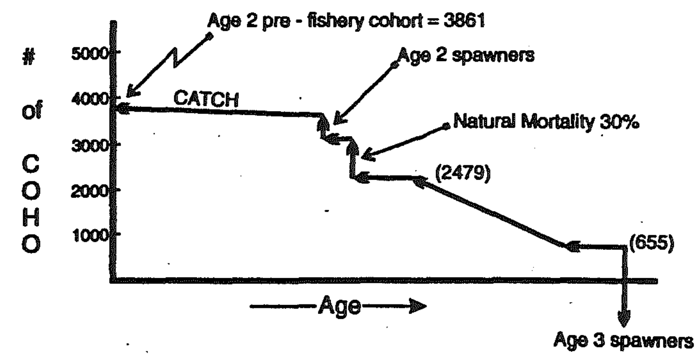
Generates estimates of maturation rates for use in forecast models</td></tr>
<tr><td>Basis of inferred stock distributions in ChTC chinook salmon model, and U.S. Fisheries Regulation Analysis Model (FRAM)</td></tr>
<tr><td rowspan="3">Exploitation patterns used in run reconstructions:
- Georgia Strait chinook and coho salmon model
- WCVI Troll management model
- Columbia River chinook salmon
- Washington State coho salmon for Coastal and Puget Sound stocks</td><td>Input for ChTC chinook salmon model calibration:
- base period exploitation rates by stock
- maturation rates
- fishery indices</td><td>Basis of many sibling regression models (e.g., Robertson Creek & Big Qualicum chinook, Oregon Production Index)</td></tr>
<tr><td rowspan="2">Application in all harvest assessment models:
- ChTC chinook
- FRAM in U.S.
- Georgia Strait and WCVI Troll models
- numerous terminal fishery management models</td><td>Forecasted abundance applied in FRAM; in WCVI Troll model in Canada</td></tr>
<tr><td>Applications in hatchery assessments and marine survival studies</td></tr>
<tr><td>Selective Fisheries Model</td><td>Selective Fisheries Model</td><td></td></tr>
</table>

Age	Estimated Tags Recovered In: WCVI	NCBC	GSTR	GSN	GSPT	WASH.	ALASKA	Returns to Freshwater	Totals
2	0	0	0	0	10	0	0	310	320
3	105	66	376	123	1145	4	4	655	2479

Example of code-wire tag data used in cohort analyses. Example from 1990 brood Coho salmon released from Big Qualicum Hatchery within the Strait of Georgia. Values in table are estimated (i.e. observed recoveries expanded for sampling rates in the fisheries) recoveries.



Diagrammatic representation of life history and fisheries for a cohort of Coho salmon. *R(t)* = recruitment of the cohort at age 2; *Ai* = ocean standing stock at successive ages. Shaded portions of the symbols represent the mature fraction. Ocean standing stock is reduced through ocean harvest (mature and immature fish) and maturation. Mature fish returning to freshwater are either captured in the terminal fishery or escape to spawn.



Schematic example of a cohort reconstruction from Age 3 spawners back to Age 2 pre-fishery cohort.

Figure 7.1. Explanation of cohort analysis, diagrammatic representation of life history, and example of cohort analysis.

7.1.1 What Cohort Analysis Provides

Cohort analysis uses input data and parameter values to estimate the following statistics for individual CWT groups.

1) Initial cohort size recruiting to ocean fisheries and cohort size by time period.

2) Incidental mortalities. Currently, we estimate two types of incidental mortalities: drop-off and sublegal. Estimates of drop-off mortalities are a function of landed mortalities. Estimates of sub-legal mortalities are a function of the relative abundance of the stock and age groups in the sub-legal population, the number of sub-legal encounters per legal encounter and release mortality rates. This assumed relationship between incidental mortality and landed mortality is based upon data collected from fishery sampling and research.

3) Exploitation rates by time period and fishery. Exploitation rates can be computed from cohort analysis for reported catch or total mortality (catch plus incidental mortality). In each instance, the exploitation rate is computed by dividing the mortality by the *cohort size prior to fishing*. In contrast, a harvest rate represents the *proportion of fish available to a fishery* that is killed by that fishery. Given a random harvest of the stocks present, the harvest rate will be the same for all stocks in the fishery, but the exploitation rate will be stock-specific. Harvest rates are not currently estimated using cohort analysis since we have no way of estimating the number of fish available to most fisheries. Exploitation rates reflect both the geographic distribution of the stock and the harvest rate in the fishery.

4) Survival rate from release to recruitment.

5) Maturation rates.

7.1.2 Basis for Current Application of Cohort Analysis

The relationship between salmon and fisheries is complex. Many groups of fish that are currently managed as single stocks are actually comprised of substocks that have different dispersal and migration patterns. For example, a proportion of coho salmon from tributaries to the Strait of Georgia will reside in the Strait and this proportion will vary from year to year, i.e., the residual substock is not the same every year. Furthermore, salmon are vulnerable to fisheries that occur both simultaneously and sequentially in time and space, and fish that encounter these gears, but are not killed, may be re-encountered at some later time.

In the absence of selective fisheries, the complexities of substocks and sequential fisheries can be ignored when inferring exploitation rates of untagged fish from tagged fish. All components of the stock are subject to the same exploitation pattern, and therefore the tagged to untagged ratio remains essentially constant in all fisheries and time periods, and thus exploitation rates of tagged an untagged fish are the same. This point is illustrated in the first two columns of Tables 7.2 (substocks) and 7.3 (sequential fisheries).

Table 7.2. Example of impact of selective fisheries on the distribution of abundances and exploitation rates for marked and unmarked stock components when substocks exist.

	No Fisheries Selective		Second Fishery Selective	
	Tagged	Untagged	Tagged and Marked	Untagged and Unmarked
Initial Cohort	10,000	20,000	10,000	20,000
Distribution to 1st fishery	0.3	0.3	0.3	0.3
Distribution to 2nd fishery	0.7	0.7	0.7	0.7
FIRST TIME PERIOD				
Available to 1st fishery	3,000	6,000	3,000	6,000
Harvest Rate	0.4	0.4	0.4	0.4
Mortality	1,200	2,400	1,200	2,400
Exploitation rate	0.12	0.12	0.12	0.12
Available to 2nd fishery	7,000	14,000	7,000	14,000
Harvest Rate	0.6	0.6	0.6	0.06
Mortality	4,200	8,400	4,200	840
Exploitation rate	0.42	0.42	0.42	0.042
SECOND TIME PERIOD				
Available to 1st Fishery	1,800	3,600	1,800	3,600
Harvest Rate	0.6	0.6	0.6	0.6
Mortality	1,080	2,160	1,080	2,160
Exploitation rate	0.235	0.235	0.235	0.129
Available to 2nd fishery	2,800	5,600	2,800	13,160
Harvest Rate	0.7	0.7	0.7	0.07
Mortality	1,960	3,920	1,960	921
Exploitation rate	0.426	0.426	0.426	0.055
THIRD TIME PERIOD				
Available to 1st Fishery	720	1,440	720	1,440
Harvest Rate	0.6	0.6	0.6	0.6
Mortality	432	864	432	864
Exploitation rate	0.277	0.277	0.277	0.0632
Available to 2nd fishery	840	1,680	840	12,239
Harvest Rate	0.7	0.7	0.7	0.07
Mortality	588	1,176	588	857
Exploitation rate	0.377	0.377	0.377	0.063

Table 7.3. Example of impact of selective fisheries on the distribution of abundances and exploitation rates for marked and unmarked stock components when sequential fisheries exist in a single time period.

	No Fisheries Selective		Second and Fourth Fisheries Selective	
	Tagged	Untagged	Tagged and Marked	Untagged and unmarked
Initial Cohort	10,000	20,000	10,000	20,000
Available to first fishery	10,000	20,000	10,000	20,000
Mortality	5,000	10,000	5,000	10,000
Harvest rate	0.5	0.5	0.5	0.5
Exploitation rate	0.5	0.5	0.5	0.5
Available to second fishery	5,000	10,000	5,000	10,000
Mortality	2,500	5,000	2,500	500
Harvest rate	0.5	0.5	0.5	0.05
Exploitation rate	0.25	0.25	0.25	0.025
Available to third fishery	2,500	5,000	2,500	9,500
Mortality	1,250	2,500	1,250	4,750
Harvest rate	0.5	0.5	0.5	0.5
Exploitation rate	0.125	0.125	0.125	0.238
Available to fourth fishery	1,250	2,500	1,250	4,750
Mortality	625	1,250	625	238
Harvest rate	0.5	0.5	0.5	0.05
Exploitation rate	0.063	0.063	0.063	0.012

Table 7.2 provides an example of how substocks would affect cohort analysis with and without selective fisheries. Fish are distributed to the two fisheries at the beginning of the first time period. They do not mix at the end of each time period, but remain in the fishery to which they were originally distributed, i.e., they behave as substocks. The first two columns demonstrate that substocks have no affect in the absence of selective fisheries. At the beginning of the second time period, 1,800 tagged fish and 3,600 untagged fish remain in the first fishery area and 2,800 and 5,600 remain in the second fishery area. The tagged to untagged ratio is still 0.5 in all fisheries and in the harvest in all time periods, and the tagged and untagged exploitation rates are the same in all time periods and fisheries.

Table 7.3 provides an example of how sequential fisheries would affect cohort analysis with and without selective fisheries. In Table 7.3, the first two columns model a single time period in which four fisheries operate in sequence with harvest rates of 0.5 in each. One tagged fish was initially available for every two untagged fish and this ratio of 0.5 remains constant and the exploitation rates are the same for the tagged and untagged stock components.

In the absence of selective fishing, a sampling program which had access to the landed harvest would sample tagged fish and provide unbiased estimates of the fishery specific exploitation rates on the tagged fish. Incidental mortalities can be estimated from the landed catch using assumptions regarding the proportion of fish encountered that are released and their release mortality rate. For each time period, the estimated exploitation rates (reported catch and incidental mortality) for the indicator tag groups are unbiased estimates of the exploitation rates on untagged stock components associated with that tag group.

7.1.3 The Impacts of Selective Fisheries

Selective fisheries will disrupt our current use of cohort analysis in two ways. First, selective fisheries systematically violate the fundamental assumption that the tagged to untagged ratio remains constant through the entire migration of a stock containing both marked and unmarked components. This is the case because selective fisheries, by definition, selectively retain marked fish (some of which will be tagged) and release unmarked fish (none of which will be tagged). This effectively splits what was a single stock in the absence of selective fisheries into two stocks - marked and unmarked - in the presence of selective fisheries. The tagged and marked hatchery fish will still represent the associated untagged and marked fish, but will no longer represent the untagged and unmarked fish. Estimates of fishery exploitation rates from samples of tagged and marked fish will still be unbiased estimates of untagged and marked fish but *not* of fishery exploitation rates of unmarked fish.

Second, in selective fisheries where unmarked fish can not be retained, there will no longer be landed catch of unmarked fish to sample as a basis for estimating fishery impacts. We will require new techniques for estimating the incidental mortalities of unmarked fish.

The end result of the two problems discussed above is that if selective fisheries are implemented, the existence of substocks, sequential fisheries and multiple encounters (repeated encounters with the same gear within a single time period) can no longer be ignored in the application of cohort analysis. These phenomena will each pose specific tagging and analytical design problems.

7.1.3.1 Substocks

If two or more substocks are distributed to different fishing areas and selective fisheries operate in one or more of these areas, the fishery exploitation rates on the marked stock component cannot be used to estimate the exploitation rates on the unmarked fish. This problem is illustrated in the last two columns of Table 7.2. In this example there are marked and unmarked stock components. All of the marked fish are also tagged and none of the unmarked fish are tagged. Within each component are substocks. As previously described, the substocks distribute to two fisheries, one nonselective and one selective, before the first time period. All surviving fish remain available to the same fishery in the next time period. The initial cohort sizes are 10,000 for the marked fish and 20,000 for the unmarked fish.

During the first time period in the nonselective fishery, the harvest rates (0.4) and exploitation rates (0.12) on marked and unmarked fish are identical. In the selective fishery, the harvest rate on marked fish is 0.6 and this is also the encounter rate of unmarked fish. Since the example assumes a 10% release mortality rate, the mortality rate on unmarked fish is 0.06. The exploitation rate of marked fish in the selective fishery is 0.42 (4,200 over 10,000) and 0.042 (840 over 20,000) for the unmarked fish. In the first time period, the exploitation rate on unmarked fish in the selective fishery is a simple function of marked exploitation rate and the release mortality. However, in subsequent time periods, this simple relationship between the exploitation rates of the marked and unmarked components does not hold even though the relationship between the harvest rates remains constant.

In the second and third time periods, the exploitation rates on unmarked fish in the selective fishery are 13% (0.055 over 0.426) and 17% (0.063 over 0.377) respectively, of the marked exploitation rate. Thus, using the exploitation rate on marked fish in the selective fishery would progressively underestimate the exploitation rate on unmarked fish. This is due to the different rate of removal of the marked and unmarked stock components by the selective fishery during the first time period. In the second time period, 66% (13,160 over 20,000) of the initial unmarked cohort is available to the selective fishery. This contrasts to only 28% (2800 over 10,000) of the initial marked cohort. In the third time period, the relative difference is even greater: 61% of the unmarked cohort and 8% of the marked cohort are available to the selective fishery. At the beginning of each time period, a different proportion of the initial cohort remains alive. Fishery-specific exploitation rates are calculated using the *total cohort* alive at the beginning of the time period. Currently, there is no way to estimate the cohort size at the beginning a time period for a substock. Thus, the combination of selective fisheries and substocks prevents the use of marked exploitation rates to estimate the exploitation rates on unmarked fish.

7.1.3.2 Sequential Fisheries

Our current application of cohort analysis will also be disrupted if fish are available to sequential fisheries within a time period (Table 7.3). This situation creates a problem for cohort analysis under selective fisheries which is similar to the one described above for substocks. Since cohort analysis is frequently performed on data covering lengthy time periods (e.g., 3-4 months), it is likely that sequential migration to different fisheries will occur within the time period. Once the stock components have passed through a selective fishery, the relative proportion of the initial cohort of the two components available to the next fishery changes. The exploitation rate on the marked fish will underestimate the encounter rate of the unmarked fish. At the beginning of the time period the marked to unmarked ratio is 0.5, and remains constant through the first fishery, which is nonselective. But after the second fishery, which is selective, the marked to unmarked ratio has decreased to 0.26 (2,500 over 9,500). In the third fishery, a nonselective fishery, the exploitation rate differs between the marked and unmarked due to the change in relative abundance. The exploitation rate is 0.125 for the marked fish but is 0.238 for the unmarked fish as a larger proportion of unmarked fish have survived the second selective fishery and entered the third nonselective fishery. All these exploitation rates are relative to the initial cohort.

This illustrates that, as in the substock case, after one selective fishery has occurred, the change in marked to unmarked ratio, or the redistribution of the two groups, results in differences in exploitation rates between the two groups in all subsequent fisheries, selective and nonselective. The exploitation rate on the tagged and marked group cannot directly be used to estimate the encounter rate on the untagged and unmarked group.

7.1.3.3 Multiple Encounters

Multiple encounters with the same gear within a time period is a special case of sequential fisheries, in that the unmarked fish encounter the same fishery sequentially instead of a different fishery. Although we have little data on how soon fish that are encountered and released can be encountered again (the recapture interval), the time periods used in cohort analysis are long enough that multiple encounters are likely to occur. Mortalities on unmarked components can be significantly underestimated due to multiple encounters when harvest rates in selective fisheries are high and the recapture interval is small. For example, simple simulations using a 50% harvest rate and a recapture interval of one day, showed that incidental mortalities were underestimated by as much as 45%.

7.1.4 Modification of Indicator Stock Program and Cohort Analysis

Given our current tagging and analytical designs, cohort analysis of individual tagged and marked groups will not provide information for unmarked stocks under selective fishery scenarios that substantially reduce stock-specific exploitation rates. Under these scenarios, to minimize the loss of management information currently provided by cohort analysis, the tagging and analytical programs must be modified.

7.1.4.1 Modification of the Indicator Stock Program

In the current indicator stock program a single stock component is tagged and is used to represent the untagged components of the stock. We have defined this condition as single index tagging (SIT). If selective fisheries are implemented, SIT may no longer provide the necessary information required to manage wild stocks. In this section we discuss the limitations of SIT and introduce a new indicator stock program that we call double index tagging (DIT).

Single Index Tagging (SIT). Once mass marking for the implementation of selective fisheries occurs, there will be two options for SIT: tag only a marked group or an unmarked group. If the tagged group is unmarked, then samples of tagged fish would only be available from nonselective fisheries. No information would be available to estimate impacts in selective fisheries for either the marked or the unmarked stock components, or to estimate total cohort size. If total cohort size cannot be estimated, then exploitation rates cannot be estimated for any fisheries. This would make it impossible to evaluate the effects of selective fisheries and to use either the SCM or cohort analyses for either the marked or unmarked stock component.

If the tagged group is marked, information about all mortalities of marked fish in both nonselective and selective fisheries would be provided. All estimates would be available for the marked stock component from cohort analysis. SIT of a marked group would provide information for use in management models for the marked hatchery stock component. Unfortunately, the unmarked stocks would include virtually all of the wild stocks; these stocks are most in need of accurate management information.

Under some conditions, SIT of the marked group could provide some information about the impacts of nonselective fisheries on unmarked stocks. The exploitation rates in any nonselective fisheries that occur prior to the first selective fisheries could be assumed to be the same for both marked and unmarked components. But, once a selective fishery has occurred, marked and unmarked exploitation rates will differ in subsequent nonselective fisheries. The utility of SIT to account for impacts of nonselective and selective fisheries on unmarked fish will largely depend on the size of selective fisheries. If differences between harvest rates in the selective fisheries for marked and unmarked fish are expected to be small, then the loss of information may be negligible. The difference will be small if release mortality is high or if marked harvest rates are low. In these cases two simplifying assumptions could be made: (1) nonselective exploitation rates are the same for marked and unmarked fish; and (2) the exploitation rate of marked fish in the selective fisheries represents the proportion of the unmarked cohort encountered. However, if differences are small, then the rationale for conducting the selective fishery would be questionable to begin with.

SIT will produce biased estimates of unmarked exploitation rates and the magnitude of the bias will increase as selective fisheries become more effective. *Without recoveries of tagged and unmarked fish, there will be no method for independently estimating the magnitude of this bias or for evaluating the effectiveness selective fisheries.*

Double Index Tagging (DIT). Under DIT, two CWT groups are used to evaluate impacts on a stock, a marked and tagged group to represent the marked component, and an unmarked and tagged group to represent the unmarked component. As both the tagged and untagged fish within each stock component are subject to the same mortality pressures after initial recruitment, *the fundamental assumption of a constant tagged to untagged ratio within each stock component is reasonable*. As a result, DIT will provide estimates from sampled recoveries of all parameters for the marked stock component and for total landed mortalities and total incidental mortalities across all nonselective fisheries, for the unmarked component. However, new assumptions and methods in cohort analysis will be required to estimate incidental mortalities of the unmarked fish in selective fisheries.

7.1.4.2 Modification of Cohort Analysis

Redesigning the indicator stock program allows us to maintain an essentially constant tagged to untagged ratio, but does not solve the second problem associated with selective fisheries: unavailability of landed catch to sample for CWTs. Cohort analysis currently requires landed mortalities in each fishery to estimate the incidental mortalities in that fishery. All of the output from cohort analysis (see section 7.1.1) requires estimates of incidental mortalities. To obtain these estimates after the implementation of selective fisheries will require modification of cohort analysis.

Using DIT, there are three methods to estimate total incidental mortalities in selective fisheries for the unmarked stock component: (1) equal marine survival; (2) equal exploitation rates; and (3) the sum of fishery specific estimates. The first two methods will only provide estimates of the total incidental mortalities while the third method will provide estimates of both the total and fishery specific incidental mortalities.

Equal Marine Survival. This method assumes that: (1) marine survival is equal for both a marked hatchery indicator tag group and an unmarked hatchery indicator tag group; (2) that we know the mortality rate associated with marking fish (immediate and delayed) so that the relative survival of the marked and unmarked tagged groups is known; (3) the post-release tag loss rate is identical for the two tag groups; and (4) we know or can estimate the release size of each tag group. Given this, the size of the initial cohort estimated for the marked tag group can be used to estimate the initial cohort size for the unmarked tag group:

$$N_u = r_{u/m} N_m \qquad (7\text{-}1)$$

where,

N_m = estimate of initial cohort size of marked tag group which is escapement plus all mortalities of marked group in selective and non-selective fisheries estimated from sampled data;

N_u = initial cohort size of unmarked tag group;
$r_{u/m}$ = ratio of unmarked to marked tagged groups at release, adjusted for marking mortality.

The unmarked escapement, total landed mortalities and incidental mortalities in nonselective fisheries are estimated from sampled data for the unmarked tag group. By subtraction, the incidental mortalities in selective fisheries for the unmarked tag group is estimated by:

$$M_{us} = N_u - M_{un} - E_u \tag{7-2}$$

where,

M_{us} = total incidental mortalities in selective fisheries of unmarked tag group;
M_{un} = total mortalities in nonselective fisheries of unmarked tag group;
E_u = total escapement of unmarked tag group.

Equal Exploitation Rates. This method requires the distribution of the marked and unmarked tag groups to be the same. If the distributions are the same, then fishery exploitation rates should be equal for the two tag groups in any nonselective fisheries that occur prior to the first selective fishery. Given this, the initial cohort size for the unmarked tag group can be estimated by:

$$N_u = \frac{M_{uns}}{M_{mns}} N_m \tag{7-3}$$

where,

M_{mns} = total mortalities of a marked tag group in nonselective fisheries prior to the first selective fishery;

M_{uns} = total mortalities of an unmarked tag group in nonselective fisheries prior to the first selective fishery.

This method will work if nonselective fisheries exist prior to the first selective fishery in time or geographical region (if substocks exist) and it will work best if these nonselective fisheries are large and well sampled. Given the initial cohort size, total incidental mortalities and total exploitation rates can be estimated using equation 7-2.

It is important to note that although DIT provides a reasonable basis for the assumption of a constant tagged to untagged ratio under selective fisheries, the independence of individual CWT experiments involving unmarked fish will be lost. Our ability to estimate selective fishery impacts on unmarked stock components will now depend upon relationships between paired CWT groups.

Potential Biases Introduced. Although DIT enables us to estimate total survival and exploitation rates using either of the two methods described above, additional assumptions must be made that are currently unnecessary. These assumptions introduce new sources of variability and bias into the cohort analysis estimates. If the assumptions of equal marine survival or equal distribution after initial recruitment are violated, estimates of initial cohort size for the unmarked tag group will be biased and all subsequent estimates will also be biased.

Under selective fisheries, cohort analysis methods also become more dependent upon unbiased estimates of dropoff and sublegal encounter rates and natural and release mortality for which few definitive data exist. In cohort analysis, fixed natural mortality rates are generally used to adjust the cohort size at the beginning of each time period. The estimates of incidental mortalities for unmarked fish in selective fisheries using either of the above two methods will be confounded with natural mortality because neither source of mortality is measured directly. Thus, if selective fisheries occur over several time periods, the unmarked incidental mortalities in selective fisheries will not be estimated accurately.

Fishery Specific Estimates. Estimates of fishery-specific exploitation rates are most useful for management, but are also the most sensitive to bias introduced by the combination of selective fisheries and substocks, sequential fisheries, and multiple encounters.

Multiple Encounters. Many of the problems introduced by multiple encounters may be addressed by reformulating cohort analysis procedures to incorporate continuous-time catch equations. In a given time period t, the discrete-time exploitation rate (ER) can be computed by dividing the catch in that time period by the cohort size at the beginning of the time period. This exploitation rate can be converted to an instantaneous rate by:

$$f_{mt} = \frac{-\ln(1-ER_t)}{n} \tag{7-4}$$

where,

f_{mt} = instantaneous rate of fishing mortality for the marked stock component;
n = the number of recapture intervals within the time period when a released fish would be available for recapture, e.g., if the time period is 30 days long and released fish are assumed to become available for recapture after one day (recapture interval), n=30.

If substocks are ignored, the exploitation rate for the marked stock can be used as an estimate of the encounter rate for the unmarked stock. Now, the instantaneous rate of incidental mortality for unmarked fish in a selective fishery can be expressed as the product of the instantaneous rate of fishing mortality for the marked stock and the release mortality rate:

$$f_{ut} = f_{mt} * h \tag{7-5}$$

where,

f_{ut} = instantaneous rate of fishing mortality for the unmarked stock component;
h = the release mortality rate.

The incidental mortality for the unmarked stock component can then be expressed as:

$$M_{ut} = N_{ut}*(1-e^{-f_{ut}*n}) \tag{7-6}$$

where,

M_{ut} = incidental mortality for the unmarked stock component;
N_{ut} = cohort size for the unmarked stock component at the beginning of the time period.

This continuous-time formulation enables us to overcome the problem of multiple encounters if substocks do not exist and the recapture interval is known.

Substocks. The methods developed for estimating fishery-specific incidental mortalities of unmarked fish are illustrated through a series of examples. In the first example, a double-index tagged stock is subjected to a single selective fishery in which multiple encounters occur (Table 7.4). We can perform a cohort analysis using recoveries of the marked and tagged (MT) group to estimate the exploitation rate of the fishery (0.4). Now, given an estimate of release mortality of 10%, we can estimate the exploitation rate on the unmarked and tagged (UT) group resulting from incidental mortality by multiplying the estimated exploitation rate for the MT group by the release mortality rate (.4 x .1 = .04). Assuming that the MT and UT groups have equal marine survival, since the same number of tags were released in the MT and UT groups, the initial size at initial recruitment is also the same. Incidental mortality for the UT group can now be estimated at 160 fish by multiplying the initial recruitment of the UT group by our estimated exploitation rate on the UT group (4000 x .04). Incidental mortalities are however, underestimated because of the failure to consider multiple encounters. If the duration of the fishery is 30 days, and we knew that a fish may be available for recapture one day after release, we can estimate an incidental mortality loss of 199 fish using equations 7-4 through 7-6. This correction properly estimates the incidental mortality loss and the exploitation rate on the UT group resulting from the selective fishery.

Table 7.4. Example of single selective fishery with multiple encounters.

ITEM	Value	Comment
Initial Release Size (MT):	5000	Reported
Initial Release Size (UT):	5000	Reported
Catch of MT:	1600	Observed true value
Incidental Mortality Loss (UT):	199	True value, to be estimated
Escapement MT:	2400	Observed true value
Initial cohort size (MT):	4000	Esc+Catch = 1600+2400
Exploitation Rate (MT):	0.40	Catch/Initial Cohort = 1400/4000
Inferred Exploitation Rate (UT):	0.04	Exp Rate (MT) x release mort rate
Est Incidental Mortality (UT):	160	Inf Exp Rate x Init Cohort (UT) = 0.04 x 4000
Est Incidental Mortality (UT):	199	Corrected for multiple encounters

The second example (Table 7.5) illustrates complications introduced by consideration of substocks. Suppose a double-index tagged stock is actually comprised of distinct substocks that migrate to different areas and reside there until the fish return to spawn. Further, suppose that one of these substocks is subjected to a selective fishery. Since we are unable to estimate the size of each substock, we must continue to rely upon estimates of exploitation rates to evaluate fishery-specific impacts. Using the procedures described for the first example, we would estimate the exploitation rate for the fishery at 0.12. This would yield an incidental mortality estimate of 51 fish for the UT group, after correcting for multiple encounters. In this example, our estimate of incidental mortality loss would be 9 percent below the true value.

Table 7.5. Example of substocks on a single selective fishery with multiple encounters.

Item	Value	Comment
Initial Release Size (MT):	5000	Reported
Initial Release Size (UT):	5000	Reported
Number of fish in substock (MT):	1600	True value, but unable to estimate
Harvest rate for fishery (MT):	.30	True value, but unable to estimate
Catch of MT:	480	Observed true value
Incidental Mortality (UT):	56	True value, to be estimated
Escapement MT:	2400	Observed true value - all substocks
Initial cohort size (MT):	4000	catch + escapement = 1600+2400
Exploitation Rate (MT):	0.12	catch/initial cohort = 480/4000
Inferred Exploitation Rate (UT):	0.012	Exp Rate (MT) x release mort rate
Est Incidental Mortality (UT):	48	Inf. Exp Rate x Init cohort (UT) =.012 x 4000
Est Incidental Mortality (UT):	51	corrected for multiple encounters

The third example (Table 7.6) illustrates complications introduced by consideration of sequential fisheries. Suppose a double-index tagged stock sequentially passes through two selective fisheries. Since we are unable to estimate the migratory behavior of fish within the time period, we must continue to rely upon estimates of exploitation rates to evaluate fishery-specific impacts. Using the procedures described for the previous examples, we would estimate the exploitation rate for fisheries 1 and 2 are 0.30 and 0.385, respectively. This would yield incidental mortality estimates for the UT group of 51 fish for fishery 1 and 190 fish for fishery 2, after correcting for multiple encounters. In this example, our estimate of incidental mortality loss for the first fishery would be correct, but our estimate for the second fishery would be 62 percent below the true value.

Table 7.6. Example of sequential fisheries with multiple encounters.

Item	Value	Comment
Initial Release Size (MT):	5000	Reported
Initial Release Size (UT):	5000	Reported
Catch (MT) in fishery 1:	1200	Observed true value
Incidental Mortality (UT) fishery 1:	140	True value, to be estimated
Available to fishery 2 (MT):	3800	True value, but unable to estimate
Available to fishery 2 (UT):	4860	True value, but unable to estimate
Catch (MT) in fishery 2:	1540	Observed true value
Incidental Mortality (UT) fishery 2:	307	True value, to be estimated
Escapement MT:	1260	Observed true value
Initial cohort size (MT):	4000	catch+escapement = 1200+1540+1260
Exploitation Rate (MT) fishery 1:	0.30	catch/initial cohort = 1200/4000
Exploitation Rate (MT) fishery 2:	0.385	catch/initial cohort = 1540/4000
Est Incid. Mort fishery 1 (UT):	140	Corrected for multiple encounters
Est Incid. Mort fishery 2 (UT):	190	Corrected for multiple encounters

The examples presented in Tables 7.5 and 7.6 provide an indication of the types of problems that arise when attempting to estimate fishery-specific incidental mortality losses in the presence of substocks and sequential fisheries. Because of the simplicity of these examples, it is possible to devise some means to correctly estimate incidental mortalities by fishery. For instance, we could easily estimate incidental mortalities for the UT group in the first example through the use of equation 7-2. However, this capability quickly disappears with even slightly increased complexity. The final example is presented to illustrate the difficulty of estimating fishery-specific incidental mortalities when substocks and sequential fisheries exist. Suppose a double index tagged stock is comprised of two substocks, each of which migrates to a different area where it resides until the fish mature for spawning. Further, suppose that these substocks are subjected to sequential selective fisheries. Each fishery removes a portion of the fish that are available, i.e., it operates as a harvest rate fishery. The true distribution of mortalities for the marked and unmarked stocks is depicted in Table 7.7.

Table 7.7. **True distribution of mortalities, two substocks, each subjected to two sequential selective fisheries.**

Initial release (MT):	5000	
Initial release (UT):	5000	
	AREA 1	**AREA 2**
Initial size of substock (MT):	1600	2400
Initial size of substock (UT):	1600	2400
	FISHERY 1	**FISHERY 2**
True harvest rate (MT):	0.30	0.50
Catch (MT):	480	1200
Incidental Mortality (UT):	56	107
	FISHERY 3	**FISHERY 4**
True harvest rate (MT):	0.55	0.20
Catch (MT):	616	240
Incidental mortality (UT):	123	35
Spawning Escapement (MT):	504	960
Spawning Escapement (UT):	1421	2258

However, we do not have access to all this information. The only observational data available on which to perform a cohort analysis is indicated in the boxes in Table 7.8. Initial release sizes of the tag groups are known. For the marked and tagged group (MT), recovery data are available for all fisheries and escapement. For the unmarked and tagged group, recovery data are available only for escapement. The technical problem is to find a means to fill in the missing information (indicated by the question marks).

Table 7.8. **Observed data available for cohort analysis.**

Initial release (MT):	5000	
Initial release (UT):	5000	
	AREA 1	**AREA 2**
Initial size of substock (MT):	?	?
Initial size of substock (UT):	?	?
	FISHERY 1	**FISHERY 2**
True harvest rate (MT):	?	?
Catch (MT):	480	1200
Incidental Mortality (UT):	?	?
	FISHERY 3	**FISHERY 4**
True harvest rate (MT):	?	?
Catch (MT):	616	240
Incidental mortality (UT):	?	?
Spawning Escapement (MT):	1464	
Spawning Escapement (UT):	3679	

The first step is to perform a cohort analysis on the MT group. For simplicity of illustration, assume that natural mortality is negligible and that there is no error in our estimates of recoveries generated from catch sampling programs. The total cohort prior to recruitment is estimated by summing the recoveries in escapements and catches. Since we do not have the ability to estimate the size of substocks or their migration patterns, cohort analysis procedures estimate exploitation rates for each fishery relative to the initial cohort size. The information generated by cohort analysis is depicted in the double-lined boxes of Table 7.9.

Table 7.9. Cohort Analysis on Marked and Tagged (MT) Group.

Cohort at initial recruitment (MT):	4000	
	AREA 1	AREA 2
Initial size of substock (MT):	?	?
Initial size of substock (UT):	?	?
	FISHERY 1	FISHERY 2
Exploitation rate (MT):	0.12	0.30
Catch (MT):	480	1200
Incidental Mortality (UT):	?	?
	FISHERY 3	FISHERY 4
True harvest rate (MT):	0.15	0.06
Catch (MT):	616	240
Incidental mortality (UT):	?	?
Spawning Escapement (MT):	1464	
Spawning Escapement (UT):	3679	

Assuming equal marine survival of the two tag groups, we can estimate the cohort size of the unmarked and tagged group (UT) through equation 7-1. In this example, since the marked and unmarked release sizes were identical (and no differential post release mortality is assumed), the initial cohort size for the UT is 4000 fish. We can now estimate fishery-specific exploitation rates for the UT group by the fishery-specific method. As described earlier, this method is based on the use of estimates of exploitation rates for the MT group as a surrogate measures of encounter rates for the UT group. Exploitation rates on the UT group are estimated by simply multiplying our estimated exploitation rates for the MT group by our estimate of the release mortality rate. The resulting estimates of inferred exploitation rates and incidental mortalities are depicted in double-lined boxes of Table 7.10. A total of 254 (48+120+62+24) incidental mortalities for the UT group is estimated using this method. An independent estimate of 321 total incidental mortalities of the UT group can be estimated through equation 7-2. Thus, the fishery-specific approach underestimates total incidental mortalities by 21%.

Table 7.10. Inferred fishery-specific incidental mortality of unmarked and tagged (UT) Group.

Cohort at initial recruitment (MT):	4000	
Cohort at initial recruitment from Eq. 7-1 (UT):	4000	
Release mortality rate (assumed):	0.10	
	AREA 1	**AREA 2**
Initial size of substock (MT):	?	?
Initial size of substock (UT):	?	?
	FISHERY 1	**FISHERY 2**
Exploitation rate (MT):	0.12	0.30
Catch (MT):	480	1200
Inferred exploitation rate (UT):	0.012	0.030
Incidental Mortality (UT):	48	120
	FISHERY 3	**FISHERY 4**
True harvest rate (MT):	0.15	0.06
Catch (MT):	616	240
Inferred exploitation rate (UT):	0.015	0.006
Incidental mortality (UT):	62	24
Spawning Escapement (MT):	1464	
Spawning Escapement (UT):	3679	

These estimates do not account for the possibility of multiple encounters. In this example, the period used for cohort analysis is 30 days and fish are assumed to be available for recapture one day after release. Results of applying the correction for multiple encounters indicated in equations 7-4 through 7-6 are depicted in Table 7.11. Total incidental mortalities are now estimated as 282, compared to a true value of 321 (see Table 7.7). We still underestimate total incidental mortalities by 12%. One means of eliminating the discrepancy is to distribute our estimate of total incidental mortalities from equation 7-2 in proportion to our estimates of fishery-specific mortalities in Table 7.11. Results of this procedure are depicted in Table 7.12. Our estimates of total incidental mortality are now consistent with each other.

Table 7.11. Inferred fishery-specific incidental mortality of unmarked and tagged (UT) group, corrected for multiple encounters.

Cohort at initial recruitment (MT):	4000	
Cohort at initial recruitment from Eq. 7-1 (UT):	4000	
Release mortality rate (assumed):	0.10	
	AREA 1	**AREA 2**
Initial size of substock (MT):	?	?
Initial size of substock (UT):	?	?
	FISHERY 1	**FISHERY 2**
Exploitation rate (MT):	0.12	0.30
Catch (MT):	480	1200
Inferred exploitation rate (UT):	0.01270	0.03504
Incidental Mortality (UT): (corrected for multiple encounters)	51	140
	FISHERY 3	**FISHERY 4**
True harvest rate (MT):	0.15	0.06
Catch (MT):	616	240
Inferred exploitation rate (UT):	0.01658	0.00617
Incidental mortality (UT): (corrected for multiple encounters)	66	25
Spawning Escapement (MT):	1464	
Spawning Escapement (UT):	3679	

However, the distribution of incidental mortalities is incorrect (compare with Table 7.7). In this example, the error in our estimates of fishery-specific exploitation rates for the UT group ranges from -38% to 49%. Errors of this magnitude could be important when evaluating impacts of proposed selective fisheries on unmarked stocks. We conclude that we are unable to find a means to correctly allocate incidental mortality losses across multiple selective fisheries when substocks and sequential fisheries exist.

Table 7.12. Inferred fishery-specific incidental mortality of unmarked and tagged (UT) group, corrected for multiple encounters and adjusted to total incidental mortality estimate.

Cohort at initial recruitment (MT):	4000	
Cohort at initial recruitment from Eq. 7-1 (UT):	4000	
Release mortality rate (assumed):	0.10	
	AREA 1	**AREA 2**
Initial size of substock (MT):	?	?
Initial size of substock (UT):	?	?
	FISHERY 1	**FISHERY 2**
Exploitation rate (MT):	0.12	0.30
Catch (MT):	480	1200
Inferred exploitation rate (UT):	0.01447	0.03993
Incidental Mortality (UT): (corrected & adjusted)	58	160
% Error from True Value:	3%	49%
	FISHERY 3	**FISHERY 4**
True harvest rate (MT):	0.15	0.06
Catch (MT):	616	240
Inferred exploitation rate (UT):	0.01890	0.00703
Incidental mortality (UT): (corrected & adjusted)	76	28
% Error from True Value:	-38%	-20%
Spawning Escapement (MT):	1464	
Spawning Escapement (UT):	3679	

7.1.4.3 Impact of Selective Fisheries on Wild Stock Tagging Programs

Wild stock tagging programs provide estimates of total survival, survival from initial recruitment to escapement and exploitation rates. They are important for wild stock studies of hatchery interactions, population dynamics, harvest management, and marine survival. These programs have enabled us to determine that marine survival of wild stocks is generally higher than marine survival of adjacent hatchery stocks. This differential marine survival poses special problems for our ability to use CWT experiments involving hatchery fish to determine if changes in abundance of wild fish are due to production or survival.

The standard procedures of cohort analysis cannot be used since the incidental mortalities in selective fisheries cannot be estimated directly from recoveries of unmarked wild fish that are tagged. To estimate incidental mortalities, tagged wild stock groups must be paired with tagged hatchery indicator stocks. Estimates can then be made using the following two methods.

First, if a large, well-sampled nonselective fishery occurs prior to the first selective fishery, equation (7-3) can be used to estimate the initial cohort size of the wild CWT group using information from a marked hatchery tag group. Second, if such a nonselective fishery does not exist, then wild stock tagging will have to be paired with DIT involving two representative hatchery groups in order to estimate cohort sizes and total exploitation rates for wild fish. The DIT groups must not only be identical in their marine survival and subsequent migrational behavior, but the unmarked hatchery group must have the same distribution and exploitation pattern as the tagged wild stock. The equal marine survival rate method cannot be applied directly. Instead, we must assume that the exploitation pattern after recruitment is the same for the hatchery unmarked tag group and the wild tag group. Estimates of mortalities in selective fisheries for the unmarked hatchery group can be estimated using equations presented in Table 7.13.

The proportion (p) of the total mortalities occurring in selective fisheries is estimated for the unmarked hatchery group as:

$$p_{us} = \frac{M_{us}}{M_{un} + M_{us}} \tag{7-7}$$

Then, given an estimate of the mortalities of wild fish in nonselective fisheries (M_{wn}) and the assumption that wild fish and the unmarked DIT group have the same exploitation pattern, the mortalities of wild fish in selective fisheries (M_{ws}) is:

$$M_{ws} = \frac{p_{us}}{1-p_{us}} M_{wn} \tag{7-8}$$

and the total initial cohort size is estimated by addition:

$$N_w = M_{wn} + M_{ws} + E_w \tag{7-9}$$

Table 7.13. Estimation of Total Incidental Mortalities with Double Index Tagging for Marked and Unmarked Hatchery Tag Groups and Wild Tag Groups.

	Hatchery, Marked and Tagged	Hatchery, Unmarked and Tagged	Wild, Unmarked and Tagged
Nonselective Fishery 1	M_{m1n}	M_{u1n}	M_{w1n}
Selective Fishery 2	M_{m2s}		
Nonselective Fishery 3	M_{m3n}	M_{u3n}	M_{w3n}
Selective Fishery 4	M_{m4s}		
Escapement	E_m	E_u	E_w
Estimates of Mortalities and Initial Cohort Size			
Nonselective Mortalities	$M_{mn} = M_{m1n} + M_{m3n}$	$M_{un} = \sum_i M_{uin}$	$M_{wn} = M_{w1n} + M_{w3n}$
Selective Mortalities	$M_{ms} = M_{m2s} + M_{m4s}$	$M_{us} = N_u - M_{un} - E_u$	$M_{ws} = \frac{p_{us}}{(1 - p_{us})} M_{wn}$ (1) $M_{ws} = N_w - M_{wn} - E_w$ (2)
Initial Cohort (N)	$N_m = E_m + M_{mn} + M_{ms}$	$N_u = r_{\frac{u}{m}} N_m$ (1) $N_u = \frac{M_{un}}{M_{mn}} N_m$ (2)	$N_w = M_{wn} + M_{ws} + E_w$ (1) $N_w = \frac{N_m}{M_{mn}} M_{wn}$ (2)

(1) Equal marine survivals.

(2) Equal exploitation rates.

7.1.4.4 Conclusions

In this analysis we have identified the risks to our current CWT based management system posed by the implementation of selective fisheries. Where possible, we have also identified new methods and procedures which will negate or minimize those risks. We are unable to overcome problems of substocks on our ability to accurately estimate fishery-specific impacts whenever more than one selective fishery exists.

Under selective fisheries, the current system, or SIT, will no longer be adequate. As explained above, selective fisheries effectively split stocks into a marked and unmarked component. With SIT, only one of the components (usually marked) will be represented by CWTs and the other component (unmarked) will not be represented by any CWT group. The indicator stock program must be redesigned to provide for double index tagging (DIT) where two index tag groups, one tagged and marked and the other tagged and unmarked are released. Estimates of marine survival and total fishery contributions for selective and nonselective fisheries separately will be available under DIT, but not under SIT. Therefore, under DIT, applications that use these estimates, such as abundance forecasting (Table 7.1), will still be available. However, even with DIT, given our current understanding and abilities, if selective fisheries are implemented it will not be possible to use cohort analysis to provide all the estimates the current system provides. Except in special cases, cohort analysis for unmarked fish will no longer be able to provide fishery-specific estimates or estimates on a time scale finer than the life span of the cohort. The impact of selective fisheries on the ability to estimate various types of stock-specific parameters using cohort analysis under SIT and DIT is summarized in Table 7.14. The ability to use cohort analysis for marked hatchery stocks will not be affected.

Under selective fisheries, direct estimation of total exploitation and survival of wild stocks will be lost. Estimates of these parameters will be dependent upon having a tagged and unmarked hatchery group with a similar exploitation pattern. Concern for this loss becomes greater as the scale of selective fisheries increases.

Table 7.14. **Impact of selective fisheries on estimates derived from cohort analysis for single and double index tagging scenarios. A check mark in a box indicates that no loss of information will occur, a shaded box indicates that there is a total loss of information, and boxes with footnotes indicate estimates will be available but will require new assumptions.**

Estimates from cohort analysis	Hatchery Production (Marked)		Wild Production (Unmarked)	
	Single Index Tagging	Double Index Tagging	Single Index Tagging	Double Index Tagging
Total survival to initial recruitment	✓	✓		(1)
Total exploitation rate from initial recruitment to escapement	✓	✓		(1)
Total contribution to nonselective fisheries	✓	✓		✓
Total contribution to selective fisheries	✓	✓		(1)
Fishery and time specific mortalities for nonselective fisheries	✓	✓		(2)
Fishery and time specific mortalities for selective fisheries	✓	✓		(2)
Fishery and time specific exploitation rates for nonselective fisheries	✓	✓	(3)	(2)
Fishery and time specific exploitation rates for selective fisheries	✓	✓	(3)	(2)

(1) Requires that either: (1) marine survivals of the hatchery marked tag group and wild unmarked tag group are equal, or (2) that exploitation rates in initial nonselective fishery are equal for marked and unmarked tag groups.

(2) Would require the assumptions that the marked exploitation rate represents the proportion of the unmarked cohort that is encountered and that multiple encounter rates are negligible. However, these assumptions will not hold in the presence of substocks or sequential fisheries.

(3) Requires same assumption as (2), but there will be no information available to test the assumptions.

7.2 PSC Coho Stock Composition Model (SCM)

The stock composition of individual fisheries is important information for both domestic and international management. Cohort analysis of CWT fish provides estimates of the distribution of the tagged group, but is insufficient to provide total stock composition for a fishery. Total stock composition by fishery requires estimates of the catch of all production (i.e., tagged plus untagged production) for each stock present in the fishery. This is obtained by applying production expansion factors (PEF) to the unbiased estimates of the catch of the tagged groups. The PEF is the ratio of the untagged to tagged fish in the stock and may be estimated using a variety of methods, including:

1) The ratio of untagged to tagged either at release or at adult return for hatchery stocks;

2) the ratio of untagged to tagged in a terminal area fishery for a single stock with hatchery and wild components, assuming no other stock occurs in the terminal fishery; or

3) a generalized mathematical optimization model using CWT recoveries.

The CoTC has decided to use a mathematical optimization model (SCM) to estimate the coho salmon stock composition of fisheries from Oregon to Alaska (CoTC 1994). Stock composition estimates are based on CWT recoveries in recreational and commercial fisheries and the reported catches in those fisheries. The SCM estimates PEFs for each stock. The PEF multiplied by the CWT recoveries produces an estimate of the *landed* catch by stock for each fishery in the model. The SCM model does not account for incidental mortalities. Currently, incidental mortalities are believed to be small relative to landed catches. Under selective fisheries, however, consideration of incidental mortalities could become increasingly important in estimating interception levels.

In descriptive terms, the SCM assumes that indicator stock tag groups are representative of all stocks within their release or production area, i.e., ocean distributions of the tagged group and untagged wild stocks from the same production area are very similar. The estimation procedure is based on the assumption that harvest rates are the same for both stock components in all fisheries. For the SCM to produce useful estimates of stock composition, three criteria must be met: (1) all stocks contributing to the fisheries in the SCM must be represented by CWT groups, (2) the PEFs must be essentially constant across fisheries for each stock, and (3) the CWT recovery profile for each production area or aggregate must be distinct from the CWT recovery profiles of other such groups.

The SCM attempts to find a set of PEFs, such that:

$$C_j=\sum_{i=1} \lambda_j T_{ij} \qquad (7\text{-}11)$$

where,

C_j = reported catch of stock j in all fisheries;
i = fishery (1.., n);
j = stock (1.., s);
λ_j = PEF for stock j;
T_{ij} = number of tag recoveries for stock j in fishery i.

Selective fisheries are likely to increase the probability of violating criteria 2 and 3 described above. Concern for our ability to rely upon the SCM to estimate stock compositions centers about two areas:

1) Since selective fisheries harvest marked and unmarked stock components separately, the tagged to untagged ratio will not remain constant across all fisheries if we continue to use SIT; and

2) As the number of selective fisheries increases, the ability to discriminate among the CWT recovery profiles of unmarked stocks deteriorates since there are fewer fisheries in each profile. To maintain distinct profiles, stocks would necessarily be combined. As a consequence, either stock-specific information would be lost or additional external information would be needed to partition a single PEF into its individual stock component parts.

For the entire coast, estimation of stock compositions typically involves between 35 to 43 stock groups and 50 to 58 fisheries. The SCM relies upon distinct recovery profiles to allocate catch among stock groups. Consequently, it is highly desirable to have as many fisheries as possible that are both distinctive and catch fish from a large number of production areas. For selective fisheries, CWTs representative of unmarked stock components will not be recovered; this situation could increase the similarity of recovery profiles and reduce the ability of the SCM to reliably allocate catches to individual stocks. A comparable problem may also be created for individual fisheries since fish from only a few production areas may be caught. Both of these problems increase the probability the CWT recovery profiles will be confounded with each other, which increases the potential for misallocation of catch among individual stock groups.

Two methods were used to evaluate the impacts of selective fisheries on the performance of the SCM, one based on data generated by the SFM, and the other on historical CWT recovery and catch data.

7.2.1 Evaluation Based on SFM

To determine the magnitude of these potential effects on the performance of the SCM, we used the selective fishery model to generate CWT recovery profiles for several possible selective fishery scenarios and examined the ability of the SCM to estimate accurate and stable PEF's. Estimates of the total catch and contributions of marked and unmarked CWT fish by fishery were obtained from deterministic runs of the SFM for the base case and selective fishery scenarios 3A, 6A, and 7A (see Section 6.2.1.3).

The SFM was run twice for each scenario. Once to simulate selective fisheries with SIT, and once with DIT. For each SFM run, two output files were created. The first file contained the total catch of marked fish and the catch of marked CWTs by fishery, and the second contained the total catch of unmarked fish and the catch of unmarked CWTs by fishery. For the SFM run with SIT, the CWT recoveries were the same in the two files. For SFM runs with DIT, the number of unmarked CWT fish was set equal to the number of marked CWT fish remaining after marking mortality and CWT recoveries were generated by the SFM independently for the marked and unmarked fish.

The selective fishery output files described above were run through the SCM. PEF's and their coefficients of variation (CV, based on 1000 bootstraps) were estimated for each stock. For the base case, a single PEF was estimated for each stock. For each selective fishery scenario, four sets of PEFs were estimated: (1) marked SIT; (2) unmarked SIT; (3) marked DIT; and (4) unmarked DIT. Only nonselective fisheries were used to estimate the PEFs for unmarked fish. True values of the PEFs were calculated using the initial values for age 3 cohort size and number of age 3 CWT fish in the SFM.

7.2.1.1 Results and Conclusions

In this analysis, separate PEF's were estimated for the marked and unmarked stock components since this technique would likely be used if selective fisheries are implemented. *However, the ability to sample fisheries for the marked to unmarked ratio so that the catch can be apportioned between the two components is essential to this technique.* For this analysis, this ratio was known without error from the deterministic runs of the SFM. For actual fisheries, this ratio would be estimated with error, increasing the error about estimates of the PEFs.

The estimated and true PEFs for marked and unmarked fish under SIT and DIT are presented in Table 7.15. The average percent difference, weighted by the recoveries per stock, between these two values was calculated for the base case and for each selective fishery scenario. As a measure of the range, the total number of PEFs that diverged from the true value by greater than 10% were calculated. To summarize the stability of the PEF's, a weighted average of the CV's for each PEF was calculated for the base case and each selective fishery scenario using the same weights described above. The number of CV's greater than 20% is also reported.

Table 7.15. Comparison of true and estimated production expansion factors.

	Single Index Tagged				Double Index Tagged			
	Marked		Unmarked		Marked		Unmarked	
Stock	True	Estimated	True	Estimated	True	Estimated	True	Estimated
Case 3A Transitional recreational fishery selective								
OutStk1		-	131.93	129.38	-	-	131.93	132.76
InStk1	17.03	17.07	31.14	31.07	16.03	16.07	32.14	32.22
InStk2	12.01	11.97	13.88	14.36	11.01	10.97	14.88	14.89
InStk3	18.14	18.00	10.63	10.69	17.14	17.00	11.63	11.60
OutStk2	-	-	25.26	25.02	-	-	25.26	25.16
OutStk3 (1)	-	-	32.05	31.66	-	-	32.05	31.85
Case 6A All recreational fisheries selective								
OutStk1 (2)	13.20	13.41	-	-	12.20	12.34	124.73	122.72
InStk1 (2)	17.03	17.06	-	-	16.03	16.06	32.14	32.35
InStk2	12.01	12.00	13.88	16.87	11.01	11.00	14.88	14.89
InStk3	18.14	18.03	10.63	11.86	17.14	17.03	11.63	11.64
OutStk2	10.79	10.73	15.08	13.69	9.79	9.74	16.08	16.17
OutStk3	32.02	32.03	-	-	32.02	31.02	-	-
OutStk1/InStk1 (2)			38.19	42.86				
Case 7A All hook and line fisheries selective								
OutStk1 (3)	13.20	13.44	-	-	12.20	12.39	-	-
InStk1	17.03	17.07	31.14	-19.54	16.03	16.06	32.14	34.88
InStk2	12.01	12.00	13.88	22.91	11.01	11.00	14.88	14.86
InStk3	18.14	18.03	10.63	14.71	17.14	17.03	11.63	11.61
OutStk2	10.79	10.73	15.08	22.60	9.79	9.73	16.08	16.13
OutStk3	32.02	32.03	-	-	32.02	31.01	-	-
Base Case								
OutStk1	131.93	134.58						
InStk1	46.93	46.86						
InStk2	25.33	25.26						
InStk3	28.36	28.26						
OutStk2	25.26	25.11						
OutStk3	32.05	31.97						

(1) OutStk3 has no wild unmarked component.

(2) OutStk1 and InStk1 were combined in this case because of confounded CWT recovery profiles.

(3) All fisheries that catch OutStk1 in this case were selective, so there was no catch of unmarked fish.

Selective fisheries diminished the ability to discriminate among the CWT recovery profiles in the SIT runs. In scenario 6A, an outside and inside stock had to be combined. This likely would have been necessary in scenario 7A as well, except that there were no unmarked recoveries of OutStk1, since it only contributes to selective fisheries in Case 7. DIT eliminated this problem; no stocks were combined.

Under SIT, selective fisheries reduce the accuracy of the PEFs. In all three scenarios, when only marked fish were tagged, the mean deviation from the true PEF was greater than for the base case and became increasingly greater as the number of selective fisheries increased. The estimated PEFs were different from the true values by an average of 13% when all hook-and-line fisheries were selective (Case 7). In addition, only the SIT scenarios 6A and 7A produced estimated PEFs that differed from the true value by more than 10%.

Using DIT appears to solve this problem. The average difference between the estimated and true PEFs for all three scenarios were no greater than that seen in the base case (Table 7.16). In selective fisheries, marked CWT fish are removed from the fishery while unmarked fish are not. Thus, as the number of selective fisheries increases, the tagged to untagged ratio becomes increasingly different under SIT. In contrast, under DIT, the tagged to untagged ratios remain constant across all fisheries.

The stability of the estimated PEFs was largely unaffected by selective fisheries under SIT and DIT. The average CVs ranged from approximately 2.0 to 2.6 percent across all of the scenarios (Table 7.16). However, the number of Cvs greater than 20% increased as the number of selective fisheries increased. The observed stability of the PEFs may reflect the small dimensionality of the selective fishery model.

Table 7.16. Average difference between estimated and true PEF in single and double index tag scenarios.

Case	Single Index Tagging				Double Index Tagging			
	Avg PEF Difference	No. >10%	Avg CVs	No. >20%	Avg PEF Difference	No. >10%	Avg CVs	No. >20%
Base	0.34%	0	2.069%	0	0.34%	0	2.069%	0
3A	1.02%	0	2.036%	0	0.38%	0	2.031%	0
6A	6.47%	3	2.662%	1	0.37%	0	2.407%	1
7A	12.59%	4	2.485%	2	0.40%	0	2.197%	2

7.2.2 Evaluation Based on Historical CWT Data

To evaluate the effect of selective fisheries upon estimates of stock composition, a second assessment was completed using the 1984 through 1991 data sets that were used in TCCOHO (94)-1. These data sets were manipulated to generate catch and CWT recovery patterns that reflect what we might have expected to happen had there been a selective fishery similar to Case 6. These manipulated data sets provided true values for comparison with estimates of stock compositions generated by the SCM. We investigated both SIT and DIT.

The data and analyses follow closely those used to estimate the interim stock composition estimates (TCCOHO (94)-1), and will only be briefly described here.

7.2.2.1 Default Production Areas

CWT release sites were combined into 43 default production areas. Two default areas have been added since the stock composition estimates were made (TCCOHO (94)-1): Rivers Inlet (RIVR), Columbia River headwaters (HEAD). The lower coastal Washington production area was split into Grays Harbor (GRAY) and Willapa Bay (WAPA). These new groups resulted from the finer subdivision of existing release sites and not from the addition of release sites. After the initial screening, recoveries were combined for release sites to give one recovery profile per default production area. If the distributions of recoveries for two or more of the default production areas are highly similar, then the mathematical model used to estimate stock composition can assign catch to one group at the expense of the others. This problem was minimized by grouping default production areas with similar tag recovery profiles using hierarchical clustering.

7.2.2.2 Estimation Procedures

Simulation of selective fisheries involves the sequential steps outlined below. In each of these steps, years were treated independently.

1) We estimated the catch by stock and fishery using the SCM and methods described in TCCOHO (94)-1 up to, but not including, the step of adjusting the catch accounted for by the model to the reported catch. This analysis provided estimates of the PEF by stock. The PEF's were then multiplied by the stock-specific CWT recovery profiles to produce a "perfect" matrix of catch by stock and fishery. This is the default data set.

2) We then assumed a value for the proportion of production by production area that would be marked. For production areas from the Columbia River to Vancouver Island, the values assumed (Table 7.17) were identical to those used in Case 6 of the SFM. The Upper Fraser and Thompson River production areas which were not simulated in the SFM were assigned a marked proportion of 0.1. Catch from all other production areas were assumed to have a marked proportion of zero. These areas, which included California, southern Oregon, northern B.C. and

Table 7.17. Estimated marked proportions for those default production areas where marking would be done.

Production Areas	m_j, the marked proportion
Columbia - DESC, LOCO, BRGT, WILL, HEAD	1.0
Outer Coastal Washington - LWWA (GRAY & WAPA), UPWA	0.397
South Puget Sound - WA04	0.665
North Puget Sound - WA01, WA02, WA03, WA56	0.27
Strait of Georgia - GSML, GSVI, LWFR, JNST	0.363
Upper Fraser and Thompson - UPFR, THOM	0.1
Outer Vancouver Island - NWVI, SWVI	0.1

Alaska, were considered to be outside of the mass marking area. Using these proportions, the catch within each fishery was partitioned into a marked and unmarked component for each of the production areas.

3) We next assumed that the catch of marked fish in selective fisheries would not be different from the catch observed with no selective fisheries. For the SIT scenario, we assumed that all hatchery production would be marked (for hatcheries in the production areas releasing marked fish). For the DIT scenario, we assumed that all hatcheries releasing marked fish would simultaneously release identical numbers of unmarked and marked CWT fish. The survival to the fishery of marked and unmarked fish and their ocean distributions were assumed to be identical.

4) In the DIT scenario, catches and tag recoveries of marked and unmarked fish in the default data set were adjusted assuming no increase in production from hatcheries involved in mass marking. Therefore, any unmarked fish to be tagged from these hatcheries would have to be subtracted from the marked release. This was simulated by subtracting from the marked catch, a number of fish equal to the number of unmarked tag recoveries (unmarked tag recoveries equals marked tag recoveries) and adding this number to the unmarked catch. Under SIT, no adjustment of catch or tag recoveries in the default data set was required, and unmarked fish were not represented by unmarked tagged fish in all production areas that released marked fish. Under both SIT and DIT, for those production areas not marking fish, unmarked fish were represented by unmarked and tagged fish. We have also assumed that there would be the capability of recovering both marked and unmarked tagged fish in all non-selective fisheries and marked tagged fish in all selective fisheries.

5) To simulate the effect of a selective fishery like Case 6, the catch and tag recoveries of unmarked fish were eliminated from all recreational fisheries within the Southern Panel area. The catch and tag recoveries of marked fish remained unchanged. Since unmarked fish not caught by the selective fishery would be available to subsequent fisheries in time and/or space, the catch in these subsequent fisheries was increased to reflect this re-distribution. We estimated the increase in catch in both the SIT and DIT scenarios and the increase in number of tags recovered in the DIT scenario as follows. We reasoned that catch in fisheries subsequent to selective fisheries would increase directly with the proportion of wild fish observed in each fishery when there were no selective fisheries. For example, no increase in catch would be observed in the Columbia River terminal net fisheries subsequent to selective fisheries because there were no wild fish in the Columbia River net fishery in the absence of a selective fishery. The increase in catch would be greatest in a terminal fishery that contained no hatchery fish (there are no such fisheries in our data set). To get a rough indication of the magnitude of catch inflation we examined preliminary model runs of the selective fisheries model. Changes in the proportion of total mortality of the primary stock in model fisheries were regressed on estimated proportions of wild fish in their corresponding real fisheries (Table 7.18). The catch inflation factor (k_s) was estimated from the proportion wild (p_w) by:

$$k_s = 0.685 \; x \; p_w + 0.930 \qquad (7\text{-}12)$$

The catch in all Southern Panel inside troll and net fisheries was scaled with a fishery and year specific factor. The outside troll fisheries were not scaled because they occurred prior to any selective fisheries.

6) At this point, we had five data sets for each year from 1984 to 1991:

1) the default, observed data with no selective fisheries;

2) marked component, SIT scenario;

3) marked component, DIT scenario;

4) unmarked component, SIT scenario; and

5) unmarked component, DIT scenario.

Since we had matrices of catch by production area by fishery for each data set (from steps 1-5 above), we were able to calculate the true composition of the catch and the tag recoveries, i.e., we knew what the U.S./Canada stock composition was by fishery and Panel area. The effect of the selective fishery on our ability to determine stock composition could, therefore, be estimated by comparing this known stock composition with the estimates derived by applying the SCM to the data sets 2-5 above for each year.

Table 7.18. For designated fisheries that follow selective fisheries, the estimated proportion of the catch comprised of wild fish in 1990 and the catch inflation factors for the corresponding fisheries in the SFM.

Fishery	Estimated Proportion Wild	Catch Inflation
Georgia Strait Troll	0.672	1.5
Johnstone Strait Net	0.707	1.5
Fraser River Net	0.732	1.5
Samish Marine Net	0.740	1.5
Skagit Marine Net	0.714	1.5
WA 4b, 5, 6c Marine Net	0.658	1.5
South Puget Sound Net	0.413	1.15
Coastal WA Net	0.603	1.10
Grays Harbor Net	0.603	1.10
Willapa Bay Net	0.420	1.10
Columbia Marine Net	0	1.0
Columbia Freshwater Net	0	1.0

7) Standardized estimation error (100 x (SCM estimate - true)/true) was calculated by year, nation, and panel for catch and interceptions, and by year and fishery for proportion Canadian catch.

7.2.2.3 Results and Conclusions

Number of Stock Groups. In all but one year, the number of clustered production areas for the unmarked component either was unchanged or increased slightly in the selective fisheries scenarios compared to the default (Table 7.19). In six of eight years, there was one more group under the DIT scenario than under the SIT scenario. When there was an additional group in the DIT scenario, it resulted from the splitting of Thompson and upper Fraser production areas from Georgia Strait production areas. Otherwise there was little or no change in the composition of production area clusters. In all years, the number of clusters remained considerably less than the number of fisheries, which ranged from 43 to 50.

We conclude that the potential loss of information resulting from the exclusion of unmarked CWT recoveries in selective fisheries does not appear to lead to reduced discrimination of the production areas, in so far as the number of clusters is not reduced. We suspect that there was sufficient overlap among the recreational fisheries that were made selective and the commercial fisheries in the same areas, to preserve discriminatory power.

Table 7.19. Numbers of production areas after clustering, for the unmarked and marked components compared to the default. For the unmarked component, N_{UM} is the total number of production areas, "default" is the number of production areas after clustering with no selective fisheries, and SIT_{UM} and DIT_{UM} are the numbers of production areas with single index and double index tagging, respectively. For the marked components, N_M is the number of production areas releasing marked fish and SIT_M/DIT_M are the numbers of production areas after clustering for the two selective fisheries scenarios.

	Number of Production Areas					
	Unmarked Component				Marked Component	
Year	N_{UM}	default	SIT_{UM}	DIT_{UM}	N_M	SIT_M/DIT_M
1984	27	16	16	18	17	8
1985	28	18	19	20	21	10
1986	31	20	20	21	21	11
1987	30	22	22	22	18	13
1988	33	24	22	23	18	13
1989	34	16	17	18	18	7
1990	32	20	20	21	16	10
1991	33	18	18	18	18	7

Interceptions. There are two panel areas, north and south, and four catch components to interception estimates within each panel area: Canadian catch of Canadian and U.S. fish, and U.S. catch of U.S. and Canadian fish.

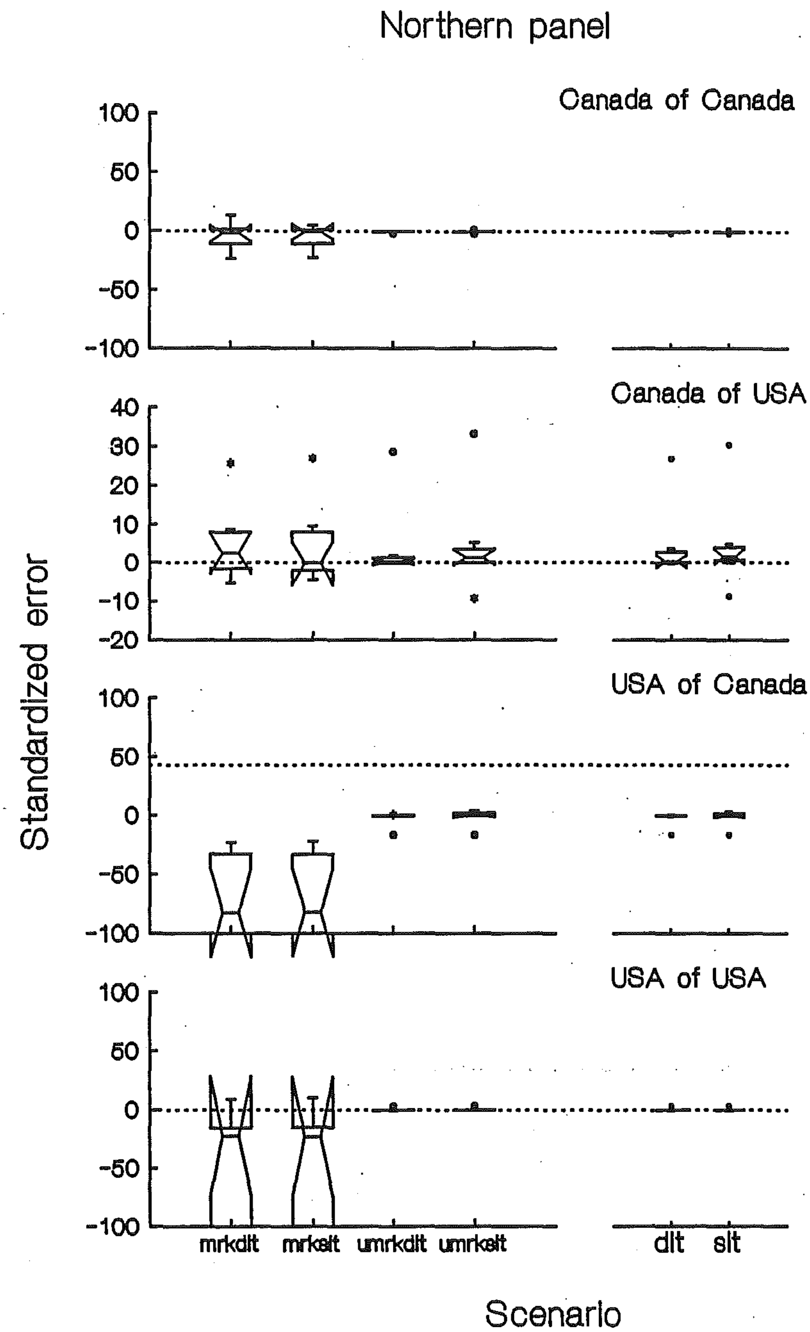


Figure 7.2. **Standardized percent errors in the catch and interceptions in the Northern Panel area by mark type and marking strategy for the period 1987 to 1991. 'Canada of Canada' refers to Canadian catch of Canadian origin fish. 'Canada of USA' refers to Canadian catch of US origin fish.**

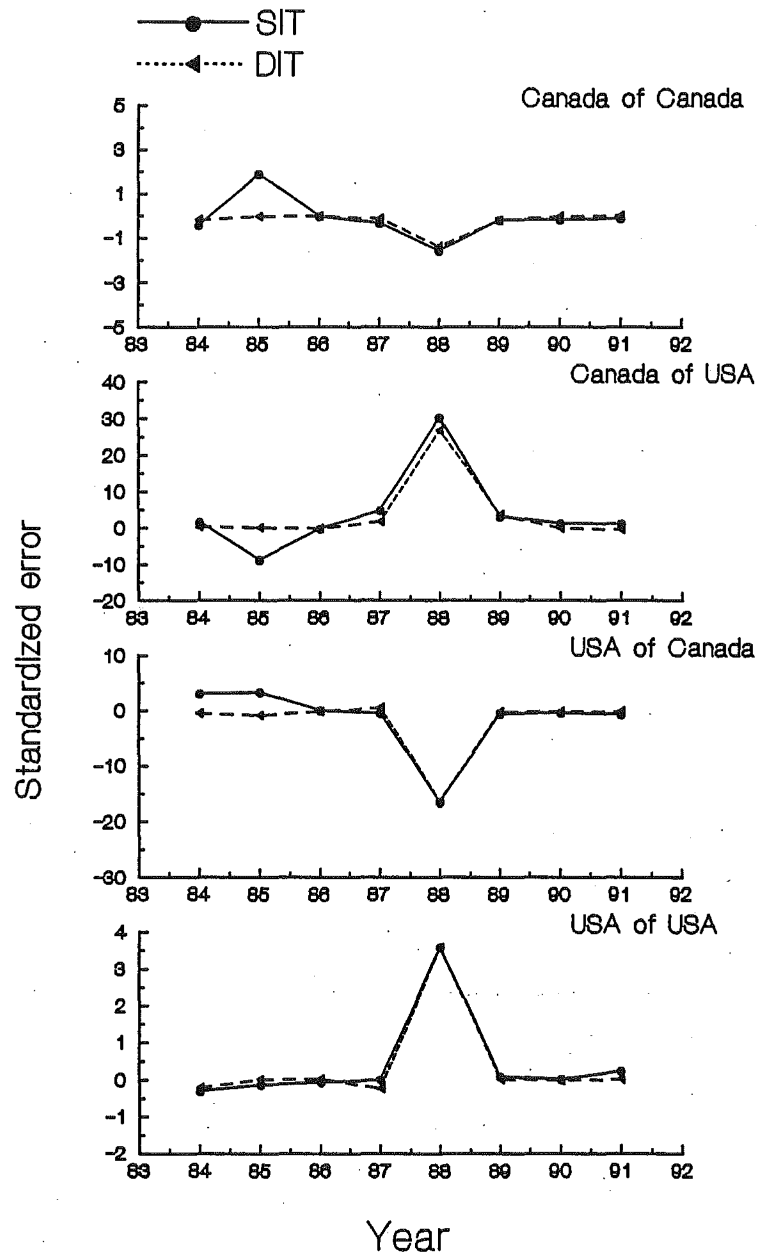


Figure 7.3. Standardized percent errors by year for catch and interceptions in the Northern Panel area for the SIT and DIT tagging scenarios.

Northern Panel. Only a few thousand marked fish would be caught in the Northern Panel fisheries, so we would expect that selective fisheries would have little effect on northern interceptions. Generally, the SCM accurately estimated interceptions (Figs. 7.2 and 7.3). In Fig.7.2, the scenarios indicated on the x-axis are: (1) 'mrkdit' - marked component with double index tagging (DIT), (2) 'mrksit' - marked component with single index tagging (SIT), (3) 'umrkdit' - unmarked component with DIT, (4) 'umrksit' - unmarked component with SIT, (5) 'dit' - marked and unmarked components combined with DIT, and (6) 'sit' - marked and unmarked components combined with SIT. The notched box and whisker figures should be interpreted as follows. The horizontal line at the constriction of the notch is the median value. The horizontal lines above and below the median are the 25% and 75% quartiles. The vertical lines extending from the quartile lines terminate at the 5% and 95% percentiles. Circles or asterisks further out represent outliers. The constriction at the median flares out to meet vertical lines above and below the median. This 'notch' indicates the approximate 95% confidence limits around the median. Where the box appears folded over, indicates that either the 25% or 75% quartile lies within the 95% confidence interval.

In one year (1988), a sizable (15% to 45%) error was observed for unmarked components, but in most years, these errors were relatively small. Although the standardized errors in the estimates of some of the marked components were large (Fig. 7.2), the numbers of fish were quite small. For example, the model estimate of Northern Panel area U.S. catch of marked U.S. fish was often zero when the expected catch was a few hundred fish; a large percentage error with little effect on estimates of total interceptions.

Southern Panel. In the Southern Panel area, some estimates of stock composition have significant errors in the marked components under both SIT and DIT (Figs 7.4 and 7.5) and the unmarked component under SIT. In the marked component, Canadian catch of Canadian fish was significantly underestimated while Canadian catch of U.S. fish was overestimated. (Fig. 7.4). U.S. catch of U.S. fish was estimated well, but U.S. catch of Canadian fish was underestimated. For the unmarked components under SIT, Canadian catch of Canadian fish was significantly underestimated while U.S. catch of Canadian fish was underestimated, but not significantly. U.S. catch of U.S. fish and Canadian catch of U.S. fish were overestimated, but the overestimate was only significant for the Canadian interceptions. With DIT, estimation errors were near zero for all four catch categories (Fig. 7.4). With the marked and unmarked components combined, Canadian catch of Canadian fish was significantly underestimated and Canadian catch of U.S. fish significantly overestimated with both SIT and DIT. The median standardized error was approximately two times greater with SIT than with DIT, however. U.S. catch of U.S. fish was overestimated and U.S catch of Canadian fish was underestimated with SIT but not DIT, although the median errors were not significantly different from zero. Temporal patterns in standardized estimation error were similar for SIT and DIT (Fig. 7.5), although DIT estimates tended to be less variable in their accuracy than SIT estimates.

Stock composition in individual fisheries. The stock composition of key interception fisheries is of considerable interest. The estimated proportions of Canadian fish in six of these key fisheries are shown in Fig. 7.6 under SIT. The box diagrams summarize the range of variation observed over the study period. That range is largest in the two west coast of

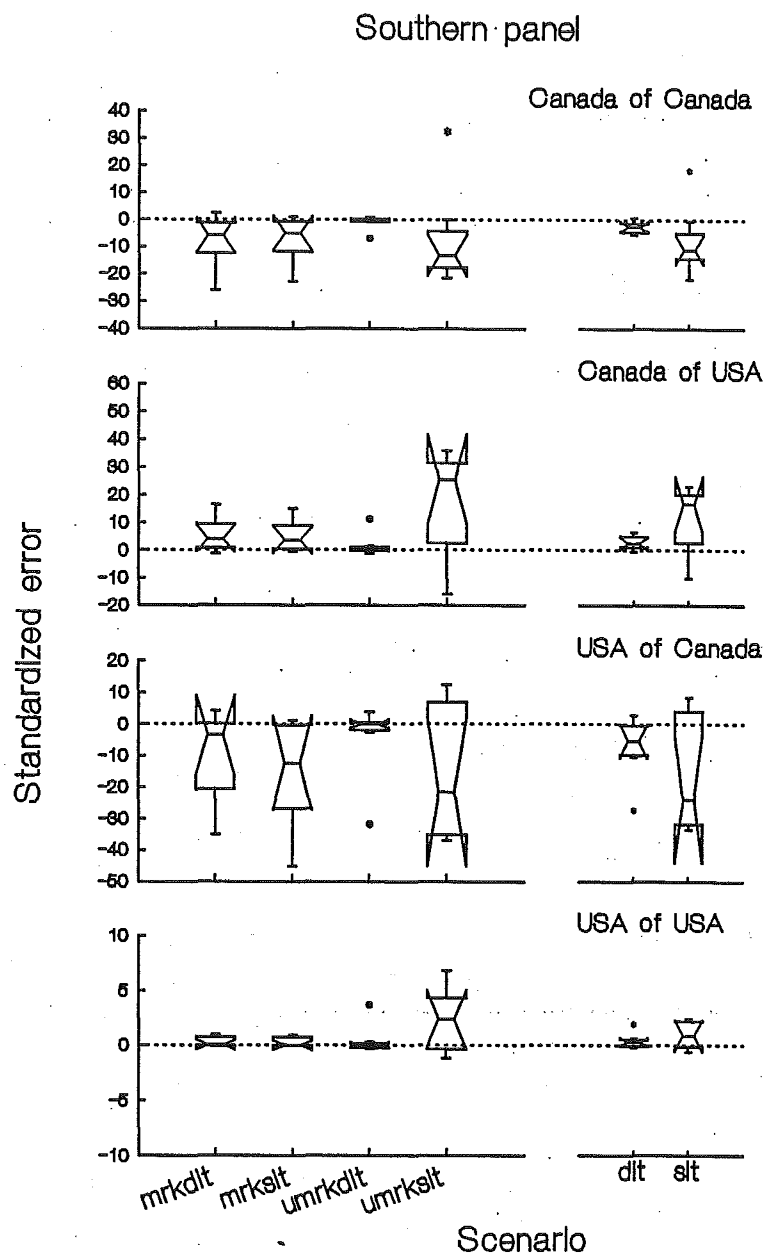


Figure 7.4. Standardized percent errors in the catch and interceptions in the Southern Panel area by mark type and marking strategy for the period 1984 to 1991.

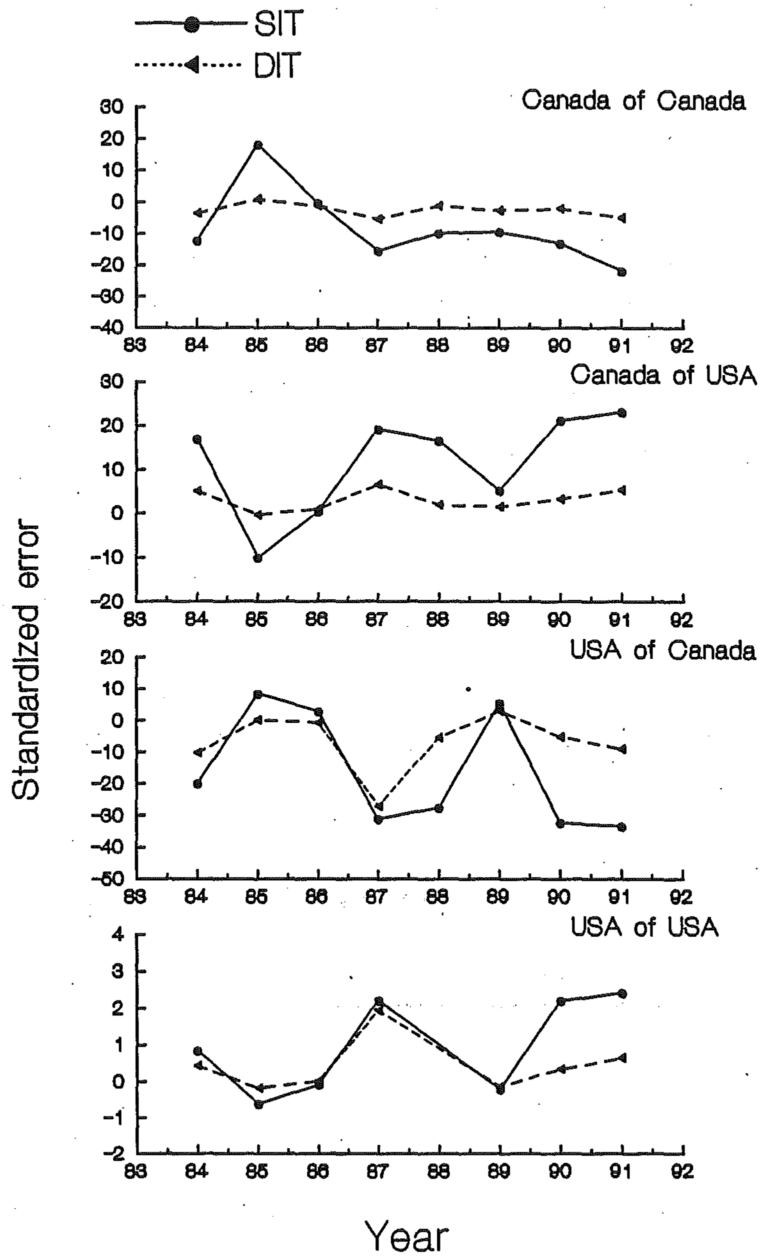


Figure 7.5. **Standardized percent errors by year for catch and interceptions in the Southern Panel area for the SIT and DIT tagging scenarios.**

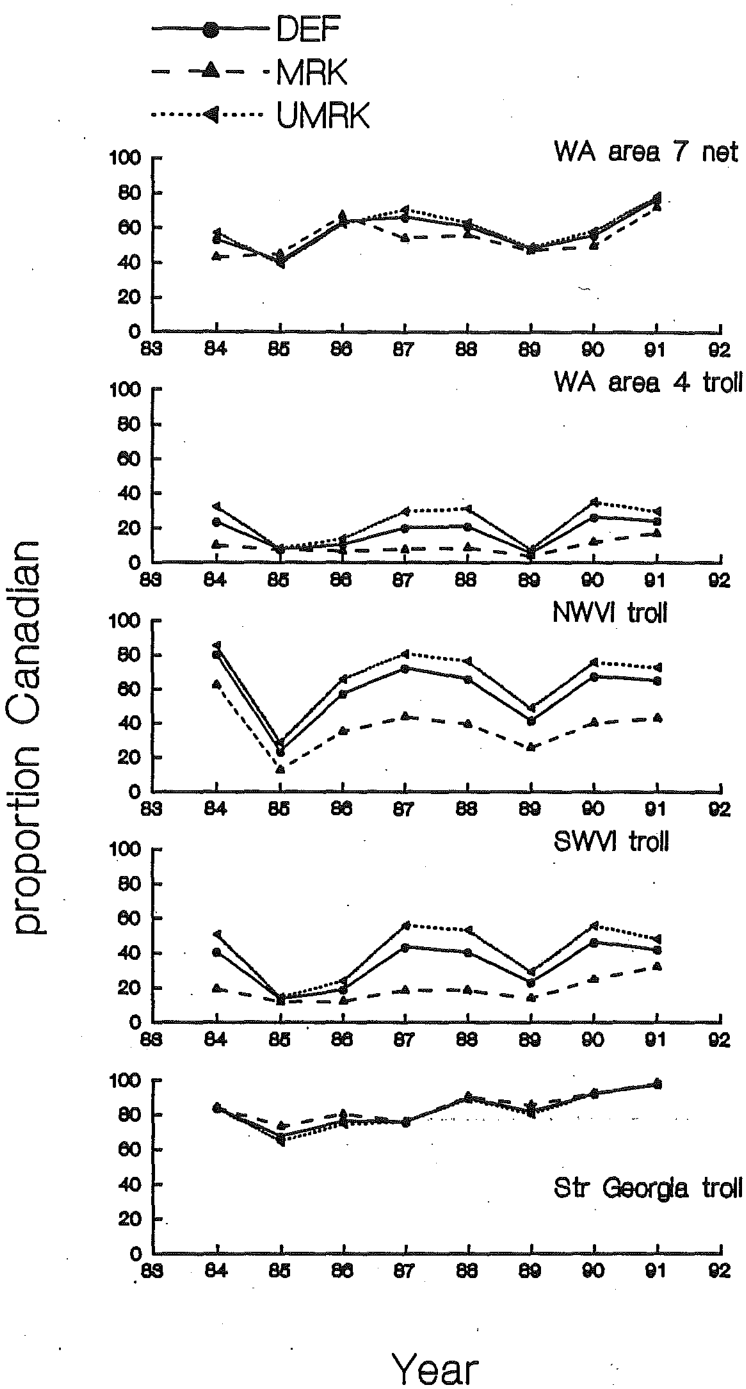


Figure 7.6. **Estimated proportion of Canadian fish in six fisheries in the Southern Panel area by year, for the default and for marked and unmarked components with SIT.**

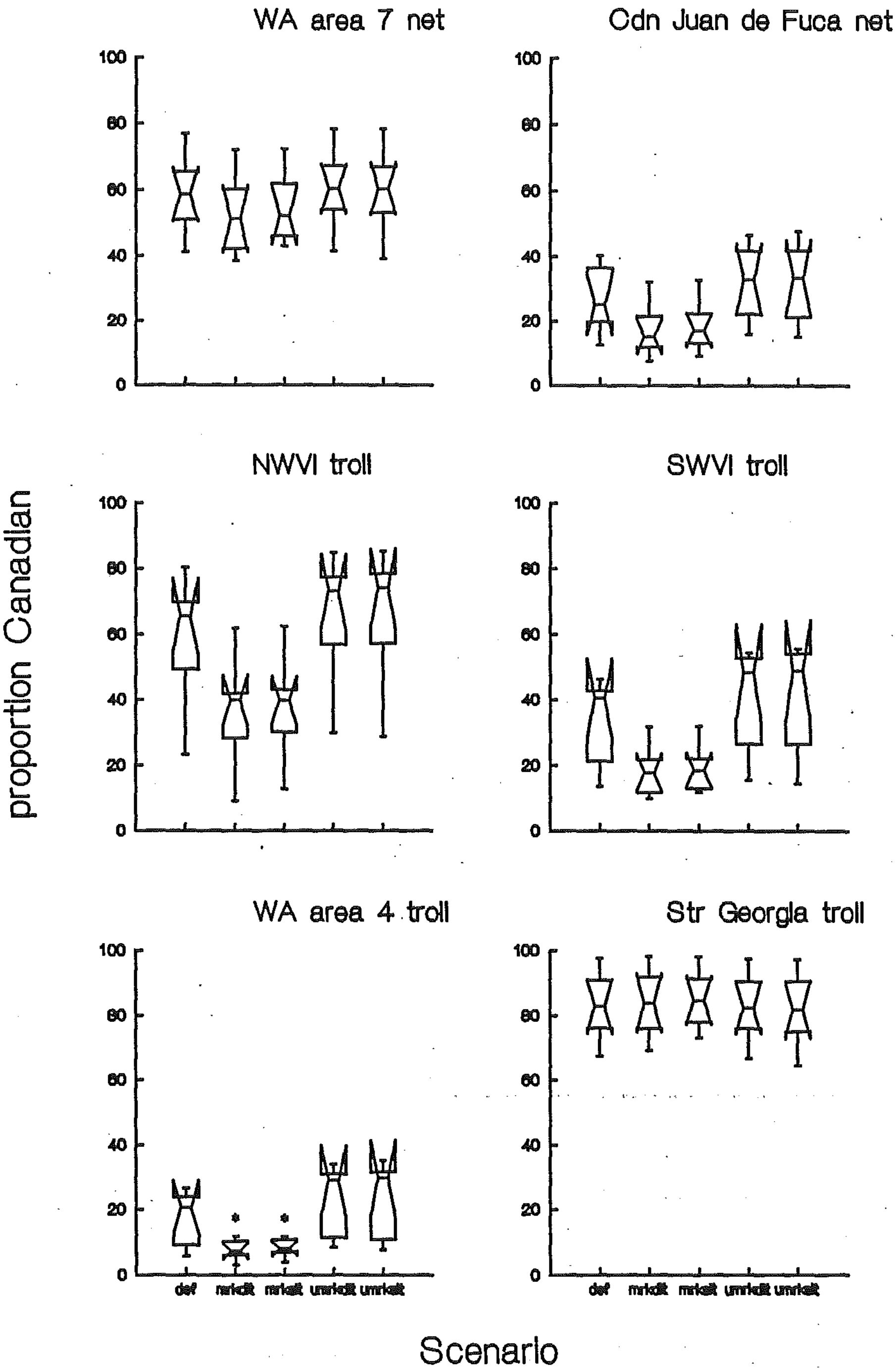


Figure 7.7. Estimated proportion of Canadian fish in six fisheries in the Southern Panel area, for marked and unmarked components with SIT and DIT.

Cohort-based management models are potentially compromised in three ways:

1) Input data do not represent effects of selective fishing;

2) algorithms to account for selective fishing, and the mechanisms of interaction between the fishery and the fish, are not defined in existing models; and

3) time and area resolution may not be sufficient.

We have examined the critical features of these models and the modifications needed to ensure that "the ability to use CWT data for assessment and management of wild chinook and coho salmon" is maintained. The impacts of selective fisheries on management models and the changes needed in their construction and input data are presented in Table 7.20.

In most instances, the required modifications to the models will require a greater understanding of stock population dynamics. Studies and analysis will be required to estimate migration parameters and the likelihood of multiple encounters, and algorithms will need to be developed to model the interactions between these processes and selective fisheries. In the absence of additional knowledge, new assumptions would be required which would increase uncertainty in predictions of the impacts of management actions. A decrease in capabilities for predicting the effects of fishery management actions on unmarked wild stocks will be contrary to the increasing demands for management to conserve these stocks.

7.4 Inseason Abundance Estimations and Run-timing and CPUE Models

The regression models that are used inseason to predict the total terminal run size of chinook and/or coho salmon are based on the historical relationship between: (1) catch-per-unit of effort (CPUE) in terminal fisheries at a particular time in the season and the terminal run size at that time; and (2) the relationship between the terminal run size at a particular time and the total terminal run size. For a single stock, this relationship is:

$$\frac{C_t}{E_t} = qN_t \qquad \textbf{(7-13)}$$

and,

$$N_{tot} = \frac{qN_t}{p_t} \qquad \textbf{(7-14)}$$

where,

C_t = Catch at time t;
q = Catchability;
E_t = Standardized effort at time t;
N_t = Population size at the beginning of time t.
N_{tot} = Total terminal run size;
p_t = The proportion of the total terminal run entering at time t

However, terminal fishery managers must commonly deal with mixtures of hatchery and wild components of a stock such that:

$$\frac{C_t}{E_t} = q\,(N_{ht} + N_{wt}) \qquad (7\text{-}15)$$

where,

$N_{h,t}$ = Population size of the hatchery fish at time t;
$N_{w,t}$ = Population size of the wild fish at time t.

These models assume that q and p_t are constant across years. In addition, for some stocks, the run-timing of the two stock components are assumed to be the same. Selective fisheries, by definition, will differentially affect the exploitation rates on the hatchery and wild stock components. In addition, they may change the catchability and/or run-timing of the stock components. Systematic changes in exploitation rates can change the size and/or age distribution of the returning stock. Catchability, and often run-timing, are related to the size and age distributions. This would obviously be more likely for multiple age-class species, such as chinook salmon, but could also occur in coho salmon. *Systematic changes in the catchability and/or run-timing of a stock will break the continuity with historical data and decrease the predictive power of the inseason models.*

However, the effects of differential preterminal exploitation rates on the two stock components will be stock-specific. To illustrate the effects of differential exploitation rates, three general examples are presented below. In these general examples, the catchability and run-timing remain constant across years. Users of specific inseason abundance models should more fully evaluate the potential impacts of selective fisheries on their models.

7.4.1 Example 1 - One Stock Component

The change in exploitation rate resulting from selective fisheries would change the terminal run size but should not change the historical relationship between CPUE and terminal run size.

7.4.2 Example 2 - Hatchery and Wild Components; Hatchery Component Mass Marked; Same Historical Run-Timing

Although the hatchery-wild composition of the return would change, the historical relationship between CPUE and terminal run size would be maintained because the run-timing is the same for the two components. In this situation, mass marking could actually improve our ability to estimate the return size of the two stock components - the overall terminal run size could still be estimated and now sampling for the mass mark would provide more accurate estimates of the hatchery-wild composition. However, it should be pointed out that techniques for identifying hatchery proportion of catches exist without mass marking (e.g., scale pattern analysis of coho).

7.4.3 Example 3 - Hatchery and Wild Components; Hatchery Component Mass Marked; Run Timing Differs

If the terminal run sizes of the two stock components were predicted independently, selective fisheries would have no impact. Alternatively, if a single prediction had been made based on the assumption that the hatchery/wild ratio is constant across years, then selective fisheries would decrease the predictive power of the inseason model. The differential exploitation rates caused by selective fisheries will change the annual hatchery/wild ratio.

The actual impact of selective fisheries will depend on how variable the hatchery/wild ratio is and the magnitude of the selective fishery effect. The SFM was used to investigate the likely magnitude of the change in the hatchery/wild ratio due to selective fisheries and the ability to detect the change.

7.4.3.1 Selective Fishery Model Evaluation of the Magnitude of Change in Terminal Hatchery/Wild Ratios

The SFM was used to evaluate the impacts of selective fisheries on the hatchery/wild ratio in the terminal run relative to the variability that is present in the absence of selective fisheries. The postseason hatchery/wild ratio in the terminal area was examined for four stocks (Skagit, Stillaguamish-Snohomish, South Puget Sound, and Queets) using a ten year (1984 - 1993) set of run-reconstruction data (Table 7.21). Extreme terminal or river run size was examined for Skagit, Stillaguamish-Snohomish, and Queets stocks. Terminal run size was examined for the South Puget Sound stock aggregate. The ratio of wild to hatchery stock components in the terminal run size was calculated for each year. The selective fishery effect was estimated using the SFM. The North Puget Sound stock (InStk2) in the SFM was used to represent Skagit and Stillaguamish-Snohomish stocks. The South Puget Sound (InStk3) and North Washington Coast (OutStk2) stocks in the SFM were similarly used to represent South Puget Sound and Queets River stocks, respectively. The SFM was run deterministically to generate catch and escapement estimates for each stock for the base case and Cases 1,2, 4, 6, and 7. The wild/hatchery ratio for each stock was estimated for the base case and each selective fishery case. A measure of the selective fishery effect was developed by dividing the wild/hatchery ratios for each stock in the selective fishery cases by the wild/hatchery ratio in the base case (Table 7.22).

Table 7.21. Mean and standard deviation of the wild/hatchery ratios in the terminal area from ten years of run reconstruction data.

Stock	Average Proportion Hatchery	Standard Deviation
Skagit	1.82	0.79
Stilliguamish/Snohomish	4.21	1.15
South Puget Sound	0.40	0.17
Queets	1.01	0.72

Table 7.22. The change in wild/hatchery ratio for different selective fishery cases relative to the base case. A value of one represents no change.

Stocks (1)	Index of Bias				
	Case 1	Case 2	Case 4	Case 6	Case 7
North Sound	na	na	1.00	1.27	1.68
South Sound	na	na	1.00	1.24	1.66
N.Washington Coast	1.20	1.14	na	na	1.94
(1) Cases 1 and 2 were not used to evaluate Puget Sound stocks and Cases 4 and 6 were not used to evaluate the Washington Coastal stock.					

To simulate the directional change in the wild/hatchery ratio due to selective fisheries, the run reconstructed wild/hatchery ratio was multiplied by the selective fishery effect for that stock and case. A single classification analysis of variance was used to test the significance of the difference in the mean wild/hatchery ratios between selective fishery adjusted data and the original run reconstruction data.

In most cases and stocks examined, the change in wild/hatchery ratio due to selective fisheries was not statistically detectible ($P > 0.05$). Significant differences were only detected for Puget Sound stocks in Case 7 (all outside and inside hook-and-line fisheries were selective). Although selective fisheries do change the wild/hatchery ratios of terminal runs (Table 7.22), the magnitude of the change is not significant under most selective fishery cases given the magnitude of current variability in the measurement of the terminal run composition.

7.5 Abundance Forecasting

Abundance forecasts for management planning purposes would also be affected by selective fisheries. Sibling regression models for abundance forecasting, based on terminal runs, presently must account for changes in preterminal fishery exploitation over time but would now also have to account for preterminal selective fishery impacts. In addition, separate estimates would be needed for marked and unmarked components because of differential mortalities caused by selective fisheries.

From a forecasting standpoint, selective fisheries increase complexity because of the need to adjust for the cumulative impacts of differential preterminal fishery impacts on run components in current and prior years. The difficulty of making such adjustments would be especially severe for chinook salmon because of their multiple ages of exploitation and maturation. Or, if a hatchery stock had been used as an index of the expected return to a local wild stock, differential preterminal exploitation rate between stock components would clearly increase the uncertainty in the expected wild returns (at least until corrections to the previous relations could be developed).

For chinook salmon, if mechanisms to adjust for cumulative effects of selective fisheries upon the number and age structure of fish returning to terminal areas cannot be made, then DIT would not be of value for abundance forecasting. Under such circumstances, ocean abundance forecasts would depend almost entirely on estimates of maturation rates and estimates of the age composition of returns. The forecasting model would likely assume the basic form:

$$N_{a+1} = \frac{S_{a+1} * (1 - MR_a) * TR_t}{MR_a} \qquad \textbf{(7-16)}$$

where,

N_t	=	Number of age a fish that are alive before fishing;
S_{a+1}	=	Survival of age $a+1$;
MR_a	=	Maturation rate of age a fish;
TR_t	=	Terminal run at time t.

Such a model is extremely sensitive to the accuracy of estimates of maturation rates. Because sensitivity increases as the magnitude of maturation rates decreases, implications are especially important for younger age classes. For example, if the true maturation rate is 10%, a maturation rate estimate of 9% would result in an overestimate of 12%. Available data series for chinook indicate that substantial variation in maturity rates for age 2 and 3 fish can expected. Inaccurate estimates of maturation rates or high variation in maturation rates would tend to increase uncertainty in preseason forecasts. Techniques can be employed to generate conservative estimates of abundance; for example, an upper limit of a confidence interval on maturation rates could be used in abundance forecasting.

7.6 Summary of Impacts of Selective Fisheries

This chapter has assessed the potential effects of selective fisheries upon many of the stock assessment tools used by management agencies on the Pacific Coast. In general, the assessment indicates that the impacts of selective fisheries will be inversely related to the scope of the selective fisheries. Multiple selective fisheries and/or selective fisheries with high harvest rates on marked fish have the greatest potential for deleteriously affecting current stock assessment tools. Reduced stock assessment capabilities for unmarked stocks is contrary to the increasing demands for better management information to allocate and conserve these stocks. The potential impacts of selective fisheries on each type of management tool is summarized in the following sections.

7.6.1 Cohort Analyses and the Indicator Stock Program

Because the CWT is central to management of chinook and coho salmon, the viability of the CWT program is of vital concern. For this assessment, the viability of the CWT system was defined as:

1) The ability to use CWT data for assessment and management of wild stocks of coho and chinook salmon;

2) maintaining the program such that the uncertainty in our assessments and their applications does not unacceptably increase management risk; and

3) the ability to estimate stock-specific exploitation rates by fishery and age.

Based upon the analyses in this chapter, it is apparent the viability of the CWT program will be impaired if broad scale selective fisheries are implemented. Salient points are summarized below:

1) Selective fisheries disrupt cohort analysis for unmarked fish in two ways. First, exploitation rates of tagged and marked fish are no longer representative of the exploitation rates on unmarked and untagged fish since unmarked fish cannot be retained in the selective fishery. Second, the incidental mortalities of unmarked fish in selective fisheries cannot be directly estimated from the recoveries of tagged and marked fish as the ratio of unmarked to marked fish changes as a result of selective fisheries.

2) The current indicator stock program, which relies on SIT, would provide estimates of exploitation rates only for marked stocks if selective fisheries were implemented. Estimates of exploitation rates on wild stocks, which are the focus of many management actions, could not be estimated directly from recoveries of CWT.

3) Modification of the indicator stock program to DIT, and the use of additional assumptions, makes estimates of fishery-specific brood exploitation rates of

unmarked wild stocks feasible in nonselective fisheries and for the sum of selective fisheries. However, due to the additional assumptions included in the analysis, the estimates may have reduced accuracy and precision.

4) Even with DIT, analytical methods are currently not available to estimate time and fishery-specific exploitation rates on unmarked fish when multiple selective fisheries exist.

5) Indicator tag groups for each unmarked stock component will no longer be independent. Estimates for the unmarked and tagged group will depend upon assumed relationships with the paired marked and tagged group.

6) The utility of wild stock tagging programs will be lost unless paired with a hatchery stock which has an identical migration and exploitation pattern. Representative hatchery stocks may not exist in some areas. For instance, the Big Beef Creek wild stock in Hood Canal, has previously been shown to have a migration pattern unlike hatchery stocks in the region. Maintenance of the tagging program would require marking wild smolts and would still result in analytical limitations.

7.6.2 Coho Stock Composition Model

Selective fisheries would likely compromise our ability to use the SCM to estimate interceptions and stock composition in major fisheries. The magnitude of the effect would be more severe under SIT than DIT.

1) Using simulated data sets, the accuracy, relative to the *status quo*, of stock composition estimates diminished under SIT, as the number and impacts of selective fisheries increase. This was due to two factors: (a) increasing deviation of assumptions regarding constant marked to unmarked ratios as marked fish are selectively removed; and (b) a diminished ability to discriminate between CWT recovery profiles. There was no deterioration in the quality of PEF estimates if DIT was used.

2) DIT alleviated some problems with the SCM for estimating the composition of the landed catch. However, problems still remained in the ability of the SCM to estimate the stock compositions of marked fish in the modified 1984-1991 data sets. Potential resolution of this problem requires further investigation. Estimates of the magnitude and stock composition of incidental mortalities cannot be produced by the SCM under either SIT of DIT.

3) Although the introduction of DIT raises a potential dimensionality problem (too many stocks relative to the number of fisheries to obtain a useful model fit), preliminary evaluation of actual data and strata used by the CoTC for estimation of stock compositions suggests this may not be a problem for estimation of

interceptions. In the years examined, the number of fishery strata increased more than the number of stock groupings.

7.6.3 Management Planning Models

Extensive modification of existing management planning tools would be required for these tools to be useful for representing fishery impacts under selective fisheries. Several new algorithms to evaluate quota management would need to be developed. Additionally, accounting mechanisms including incidental fishing mortalities would be needed.

7.6.4 Inseason Run-size Estimation Models

1) Our ability to estimate total returns of natural stocks could be seriously jeopardized. Stocks managed in terminal areas, based on CPUE models, and subject to selective fisheries may require new prediction models to account for the differential effects of selective fisheries on marked and unmarked stock components. Errors in prediction will vary with the intensity of the selective fishery, consequently, they will require stock-specific evaluation. Selective fisheries could disrupt historical time series used to estimate the total abundance of fish returning to terminal fishing areas. Differential exploitation of stock components with different run timing would lead to bias in estimates of total abundance.

2) The capability to separately estimate the abundance of hatchery and wild components would become more important as selective fishery impacts increase. This capability would require the accrual of estimation databases and a capacity for in-season separation of hatchery and wild run components. If new models are required, several years would be required to collect the necessary data given the inherent variability in biological systems.

3) Sampling for mass marks would provide direct information on the terminal run of marked hatchery stocks.

7.6.5 Abundance Forecasting

Terminal-run based sibling regression models for abundance forecasting would require modification:

1) Forecasts would have to be changed from terminal-run sizes to ocean abundance.

2) Separate estimates would be needed for marked and unmarked components because of differential mortalities caused by selective fisheries.

3) Adjustments to pre-terminal fishery impacts in prior years would be required. Problems in making such adjustments would be especially severe for chinook because multiple-age at maturity and cumulative impacts of selective fisheries

would preclude direct application of differences been terminal return rates for tagged marked and unmarked releases. If adjustments to compensate for cumulative impacts cannot be made, ocean abundance forecasts are likely to be highly dependent on estimates of maturation rates. This may not pose particular problems for stocks that mature predominantly at a single age (e.g., coho in the Southern Panel area); however, problems would be especially severe for chinook, where fish mature at multiple ages and high variability in maturation rates have been observed for younger age classes.

CHAPTER 8. IMPLEMENTATION OF MARKING, SAMPLING, AND COMPLIANCE PROGRAMS

Implementation of selective fisheries will greatly affect current marking, sampling and compliance programs. Participating agencies will mark an increased number of fish which will increase both the costs and complexities of marking. The switch to electronic sampling for CWTs will require additional capital and operational expenditures as well as require substantial modifications to the current CWT sampling programs. As an example, the costs of implementing a selective fishery in the Strait of Georgia and Puget Sound are detailed, since selective fisheries are being considered in both of these areas. Furthermore, since the ultimate success of any selective fishery depends upon compliance with the selective fishery regulations, programs to encourage compliance (enforcement and public education) will be a necessary part of effective implementation of selective fisheries.

8.1 Marking Requirements for the Adipose Only Mark

The adipose clip for selectivity with electronic CWT detection option was highlighted in Section 5.5 as the preferred marking option for implementing selective fisheries. The discussion and costs outlined below are in reference to applying this option at existing production levels.

8.1.1 Marking Logistics

The feasibility of mass marking hatchery salmon depends upon which species is to be marked. However, mass marking may not be desirable for all production. For example, there may be situations where hatchery stocks are depressed, or where hatchery production is being used to supplement natural escapement.

Coho salmon are available for marking in the hatchery for about one year, although not all of the fish are easily accessible during this time. For example, fish transferred from hatchery raceways to large ponds (up to 40% of the production) can be stressed if captured after ponding. These ponds would become extremely muddy with any full-scale fish capture activity, resulting in possible lethal dissolved oxygen levels. These fish need to be marked in mid-April through June, prior to ponding. The remaining fish may be marked from July through to February depending upon fish health, water temperatures, etc. It is assumed that any mass marking would be carried out under the same fish health guidelines employed for CWT application.

Without an automated system, large scale marking of chinook salmon is not practical because of the large numbers of fish to be marked and their short period of hatchery residency (1-3 months). WDFW has started developmental work on an automated marking system with plans for a working prototype by 1997.

8.1.2 Required Changes in Hatchery Practices

There would be minimal changes required in hatchery practices. Due to increased clipping and marking requirements and for the reasons listed in Section 8.1.1, some coho salmon marking would have to be completed prior to ponding. For chinook salmon, marking would be done from raceways.

8.1.3 Expected Cost of Marking ($US)

As noted in Section 5.2.2, the cost of applying a single adipose clip is $25/1,000 fish (PSMFC 1992). Individual agency costs will vary somewhat depending on local labor costs and overhead costs. This cost is based on using a self contained tagging trailer with a travelling supervisor. In a large marking program, the cost would be approximately $15/1,000 fish if the responsibility of marking could be transferred to the hatchery manager. Additional trailers would probably be necessary for a large marking program. Costs for a new fin marking trailer would be approximately $60,000.

Additional costs would be incurred for double index tagging of unmarked (CWT only) and marked (adipose clip and CWT) indicator stocks as described in Section 7.1.3.2. The cost of inserting a CWT is $81/1,000 fish, as compared to $106/1,000 fish for the adipose clip and CWT.

This approach requires electronic detection of tagged fish. Therefore, to insure optimal detection, some agencies will need to upgrade to Northwest Marine Technology's Mark IV model of the CWT injector (Northwest Marine Technology, Pers. Comm.). The Mark IV machine magnetizes the tags prior to the injection process, and guarantees a more uniform magnetization of the tag. The upgrade from the Mark II to the Mark IV machine costs $10,150 per machine.

In addition, recovery agencies will need to purchase a sizeable number of electronic tube and hand wand detectors for sampling their fisheries, escapement, and rack returns. Cost of the tube detectors is $10,000, while the hand wands cost $3,500 each.

8.1.4 Expected Loss of Production Resulting from Marking

Removal of the adipose fin without CWT injection should impose negligible additional mortality (see Section 5.2.4). The same restrictions and protocols described by PSMFC (1992) for CWT application such as healthy fish, low water temperatures, non-smolted fish, etc. should be followed for mass marking hatchery fish.

8.2 CWT Sampling by Electronic Detection

The implementation of selective fisheries with the adipose clip as the selective mark and electronic detection of CWTs will require significant changes in the procedures used to sample and recover tagged fish. The lack of the external adipose fin as the flag for CWT marked fish will be the greatest change. Known portions of the catch will need to be sampled electronically, using detectors appropriate for the sampling environment.

Sampling programs employing electronic detection should be evaluated on a trial basis prior to any implementation of selective fisheries. New electronic detection sampling programs should be performed concurrently with existing sampling programs to evaluate their performance. Once adipose mass marked fish have been released, electronic sampling programs will be needed in all areas where those fish may be recovered.

8.2.1 Sampling Commercial Landings

Presently, commercial landings are sampled directly for CWTs by visually examining each fish in the sample for an adipose clip. After the implementation of selective fisheries, sampled fish will have to be individually examined for CWTs using electronic detectors. Manual electronic sampling will require more time than visual sampling, therefore additional personnel would be required. Automated sampling would not require additional personnel, but would involve greater capital costs.

In some salmon troll fisheries, fish heads are cut off on freezer boats at sea. If the adipose fin became the selective mark, sampling the catch of these boats for CWTs would require that they retain all heads, heads from at least 20% of their catch, or have the capacity to electronically sample for CWTs. On-board electronic sampling would be a new, and potentially significant, cost to the CWT program.

8.2.2 Sampling Recreational Fishery Landings

Contributions of CWT fish to recreational fisheries in the Strait of Georgia and Puget Sound are presently estimated using voluntary returns from recreational anglers. It is estimated that up to 25% of the CWTs are returned in this fashion. Without the visual indicator for the presence of the CWT, the voluntary CWT recovery program would have to be either entirely terminated or considerably modified because fishers would be unaware of the presence or absence of a CWT. In order to recover CWT heads voluntarily from the recreational fishery, head depots would require detection devices that fishers could use to determine the presence of tags. This option is cost prohibitive at this time due to the number of required detectors, vandalism, maintenance, etc. Therefore, direct sampling of the recreational fishery catches would be required to recover CWTs.

Direct sampling of the recreational fishery for CWTs is recommended to minimize risk to the integrity of the existing CWT program. The direct sampling program would attempt to sample a target proportion of the recreational fish catch for CWTs in a manner similar to the commercial fishery. Given a direct sampling approach, calculation of "awareness factors" would become unnecessary. As noted above, fish should also be examined for marks to determine the rate of compliance with the selective fishery regulations. The ChTC has recommended direct sampling of the Strait of Georgia recreational fishery as a research need in a recent report to the PSC Research and Statistics Committee (ChTC 1992) regardless of whether or not selective fisheries are implemented. Legislation may be needed to ensure that CWTs are available for recovery.

8.2.3 Sampling Rates

The precision of estimates from cohort analysis depends on the number of tags recovered. For example, in Washington State, a goal has been set to recover a minimum of 10 coho salmon tags by time period and fishery. The number of CWTs released per tag group necessary to meet a tag recovery goal is inversely related to the rate of CWT sampling.

In order to achieve a 5% CV for the estimate of the total catch, a minimum of 320 total observed tag recoveries must be recovered in all fisheries combined (Table 8.1). The release size of the index tag group required is dependent on the sampling rate and the proportion of the release landed in the fisheries (contribution rate). If the contribution rate is 5% and the sampling rate is 15% (20% for commercial fisheries and 10% for sport fisheries) then a tag release of 43,000 coho salmon is expected to result in a CV of 5% for the estimated total catch. This level of tagging is currently the standard for Puget Sound. If the contribution rate is lower, or the sampling rates are lower, then the tag release group size must be higher.

Table 8.1. Tagged group release size required to meet three levels of precision (CV) given different sampling and contribution rates.

Sampling Rate	Desired CV	Observed Tag Recoveries	Contribution Rates			
			2%	5%	10%	15%
20%	10%	80	20,000	8,000	4,000	2,667
20%	5%	320	80,000	32,000	16,000	10,667
20%	2.5%	1,000	250,000	100,000	50,000	33,333
15%	10%	80	26,667	10,667	5,333	3,556
15%	5%	320	106,667	42,667	21,333	14,222
15%	2.5%	1,000	333,333	133,333	66,667	44,444
10%	10%	80	40,000	16,000	8,000	5,333
10%	5%	320	160,000	64,000	32,000	21,333
10%	2.5%	1,000	500,000	200,000	100,000	66,667

In the recreational fishery in Puget Sound and the Strait of Georgia, the 20% sampling goal set for coastwide fisheries may not be necessary to achieve a minimum of 10 recoveries if only annual estimates for a large fishery or fisheries aggregate are required. For example, in 1991, two Puget Sound coho salmon stocks (Nooksack and South Sound), had a contribution rate of 0.25% in the Area 5, 6, 9, 10 and 11 recreational fisheries. Given a contribution rate of 0.25% to 1%, and a 45,000 tag release, a 10% sampling rate will result in 11 to 45 expected total observed tag recoveries to these sport fisheries. Sampling and tagging programs must accommodate the observed recovery per stratum goals, as well as variations in marine survival and changes in fisheries regulations.

The relationship between observed recoveries, release size, sampling rate, and fishery contribution rate can be expressed as:

$$ObR = RS x SR x CR \qquad \textbf{(8-1)}$$

where,

ObR	=	Observed CWT recoveries;
RS	=	Release Size;
SR	=	Sampling Rate; and
CR	=	Contribution Rate.

Given any three of these values, the fourth can be easily estimated by algebraic manipulation. For example, given a target number of observed recoveries, the contribution rate for the desired fishery strata, and the sampling rate, the minimum required release size can be estimated by:

$$MRS = \frac{TOR}{SR \times CR} \qquad \textbf{(8-2)}$$

where,

MRS	=	Minimum required release size;
TOR	=	Target observed recoveries.

Similarly, the minimum sampling rate can be estimated by:

$$MSR=\frac{TOR}{RS\times CR} \tag{8-3}$$

where,

MSR = Minimum required sampling rate.

8.2.4 Escapement Sampling

Sampling of escapement for CWTs is crucial for estimating total survival and completing cohort analysis. Currently, counts (at weirs and fences) of adipose fin clipped fish represent a count of tagged fish. Heads are removed from all or a specified number of these tagged fish. After implementation of selective fisheries, estimation of total tag returns and recovery of CWTs will require that all fish (hatchery and natural) be electronically sampled.

8.3 Encounter Rate Sampling

Fisheries can be sampled to provide estimates of total encounter rates and incidental mortalities to help evaluate the effectiveness of selective fishery regulations and model predictions. However, information on stock-specific incidental mortalities can not be collected except in limited situations (e.g., single stock fishery, selective and non-selective fisheries occurring in the same time/area stratum).

8.4 Mark Rate Sampling

Existing sampling programs should be modified to collect information on the mark rate of the landed catch in each fishery. These data will allow the separation of total catch into marked and unmarked components.

8.5 Incremental Marking and Sampling Costs of Selective Fishery Programs in the Strait of Georgia and Puget Sound

Costs of implementing new selective fisheries will vary among agencies and will depend upon management objectives, species involved, numbers marked and areas of recovery. Table 8.2 provides an example of the incremental (above existing) marking and sampling costs associated with the implementation of a selective fishery for coho salmon in Puget Sound and the Strait of Georgia. These costs include modification of the CWT sampling programs for all fisheries in Puget Sound and the Washington ocean, all B.C. commercial fisheries and B.C. recreational fisheries in the straits of Georgia and Juan de Fuca and Barkley Sound. Sampling costs are based on existing sampling rates in commercial fisheries and a 10% direct sampling rate for recreational fisheries. Estimates are based on the use of the adipose fin as the selective mark, CWT recovery by electronic detection, and the use of double index tagging of indicator stocks. Costs for enforcement and public education, additional research, development of new management models and modification of existing models are not included.

In this example (Table 8.2), a total of 27.9 million coho salmon smolts would be adipose clipped by CDFO, WDFW, USFWS, and Tribes in the Strait of Georgia and Puget Sound. Capital costs for marking are $355,000 ($US) for CWT injector upgrades, facilities upgrades, and additional marking trailers. Annual marking costs for fin clipping and double index tagging are $586,000 and $76,000, respectively, for an overall annual cost of $662,000.

Sampling capital costs are $2,110,000 for purchase of 105 electronic tube detectors and 149 hand wand detectors. Annual sampling costs for fisheries and escapement are $1,040,000 and $35,000, respectively. Overall, total capital costs are $2,665,000, and total annual costs are $1,737,000.

8.6 Enforcement and Compliance Programs

Recent steelhead salmon angler compliance data collected by WDW enforcement shows greater than 95% compliance with unmarked wild fish release regulations (P. Hahn, WDFW, Pers. Comm.). This rate may not be entirely applicable to a specific selective fishery for coho salmon since many variables contribute to the actual compliance rate. Variables include regulation awareness, consistency with fisher expectations, enforcement intensity, perceived fairness, and program longevity. To foster compliance, public education programs and increased enforcement should be implemented.

Table 8.2. Estimated incremental capital and annual costs ($US) for marking and sampling associated with a selective fishery for hatchery coho salmon in Puget Sound and the Strait of Georgia. Estimates assume the adipose fin as the selective mark and CWT recovery by electronic detection.

	Agency			
	CDFO	WDFW	TRIBAL	USFWS
MARKING				
Marked smolt production	8 million	12 million	6.8 million	1.1 million
Capital Costs				
CWT machine upgrades	$130K	$0	$0	$0
Facilities upgrades	$110K	$0	$0	$0
Tagging trailers	$0	$240K	$75K	$0
Total marking capital	$240K	$240K	$75K	$0
Annual Costs				
Fin clipping	$180K	$204K	$175K	$27K
Double CWT index groups	$18K	$24K	$30K	$4K
Total marking annual	$198K	$228K	$205K	$31K
SAMPLING				
Capital Costs				
Fishery Sampling	$727K	$417K	$354K	$0
No. Tube detectors	33	18	21	0
No. Wand detectors	87	49	13	0
Rack and Escapement	$252K	$168K	$162K	$30K
No. Tube detectors	13	9	9	2
No. Wand detectors	19	11	9	0
Total sampling capital	$979K	$585K	$516K	$30K
Annual Costs				
Fishery Sampling	$660K	$340K	$40K	$0
Escapement	$35K	$0	$0	$0
Total sampling annual	$695K	$340K	$40K	$0
TOTALS				
Total capital expenditures	$1219K	$825K	$591K	$30K
Total annual expenditures	$893K	$568K	$245K	$31K

CHAPTER 9. EVALUATION OF SELECTIVE FISHERIES

Selective fisheries may address a variety of management objectives. If the success of the selective fishery is to be evaluated, these objectives will need to be carefully defined and measurable criteria will need to be identified. The objectives of selective fisheries may include reduced impacts on wild stocks, increased fishing opportunities, economic benefits to the fishing industry, and angler satisfaction.

The modelling exercises in Chapter 6 of this report present our predicted outcomes for various selective fishery scenarios. Although these predictions may be used as an initial indication of the potential for selective fisheries to meet objectives, considerable uncertainty exists around the predicted outcomes. This uncertainty exists due to our limited experience with selective fisheries and the inherent variability in the many factors and processes defining selective fisheries. Given the uncertainty of the predicted outcomes, assessment of the effectiveness of any selective fishery implemented will rely heavily on observation and measurement of actual outcomes.

9.1 Escapement

Changes in the level of wild stock escapements are one potential measure of the effectiveness of selective fishery regulations. However, escapement will be a meaningful evaluation criterion only if coupled with additional information, such as survival rates, stock distribution, and harvest rates in other fisheries.

Variation typical of wild escapements make it difficult to relate short-term changes in escapement to the effects of the selective fishery. Long-term trends are a more reliable indicator of true escapement changes. The ChTC has used escapement trends for assessing the effects of specific fishery regulations. Significant trends or differences however, are difficult to identify, even after data have been collected for more than one brood cycle (approximately five years for chinook).

Errors in measurement of wild escapement affect the precision of escapement estimates and cause such analyses of escapement trends to be insensitive to relatively minor changes in fishery effects. Precision of escapement estimates is affected by counting errors, effort expended to estimate escapement, and escapement survey design. Problems associated with estimation of spawning escapements are discussed in detail by Irvine and Nelson (1994), Irvine et al. (1992), and Tschaplinski and Hyatt (1991).

In summary, changes in spawning escapement may be one means of evaluating the long term effectiveness of selective fisheries. Escapement will be a relatively insensitive measure of fishery effects however, due to errors associated with the estimation procedures and changes in survival, stock distribution, and harvest rates in other fisheries. If selective fisheries effects are small (e.g., 10% of the total mortalities or less), escapement changes over a short period of evaluation (e.g., one to two brood cycles or three to six years for coho) are not likely to provide conclusive evidence of the effectiveness of selective fisheries.

9.2 Fishing Mortality

The ability to evaluate the effectiveness of selective fisheries is dependent on our ability to estimate landed and incidental mortalities. Incidental mortalities are comprised of release and dropoff mortalities. While nonselective fisheries also have nonlanded mortalities, selective fisheries will increase the relative contribution of incidental mortalities to the total fishery mortalities.

Direct measurement of incidental mortalities is not possible but useful estimates may be obtained assuming we know the rate of mortality for fish released, and the number of fish encountering the gear. Estimation of total encounters is possible with on-the-water sampling of the fisheries. Angler interviews or logbook programs may also provide information of value to the estimate but these data may be suspect without corroborating observations by trained, impartial personnel. Cost of on-the-water monitoring is high and for some fisheries, such as sport fisheries obtaining sufficient sample sizes could be difficult.

9.3 Exploitation Rate

The ChTC has used estimates of exploitation rates derived from recoveries of CWTs to evaluate the effectiveness of PST management actions. If exploitation rates on unmarked stocks could be estimated, they might provide a more reliable estimator of fishery impacts than catch or escapement since the exploitation rates would be independent of variations in survival or abundance. However, sampling error and the inability to accurately estimate escapements and incidental mortalities may reduce the precision of exploitation rate estimates, such that small changes in exploitation rates can not be detected.

On an annual basis, the smallest difference in exploitation rates between two groups (e.g., marked and unmarked) that we can expect to detect as statistically significant is 10 percentage points, assuming an optimistic CV of 5%. For most unmarked stock components in the Selective Fishery Model, a 10 percentage point reduction in the exploitation rate was not achieved until all hook and line fisheries were selective. Unfortunately, as the effectiveness of selective fisheries increases the precision of exploitation rate estimates declines (see Chapter 8). To use exploitation rates to measure the performance of selective fisheries may require increases in sampling, tagging, or both. At a minimum, double index tagging will be required to obtain an approximate estimate of exploitation rates of unmarked fish in the selective fisheries.

9.4 Fishery Opportunity

9.4.1 Recreational Opportunity

Selective fisheries are intended to provide fishing opportunity consistent with the need to protect wild fish. However, the provision of fishing opportunity by itself may not necessarily be a useful measure of the benefits of selective fisheries. If few fishers actually participate in the fishery, then little economic or social benefits are derived even if existing constraints on the opportunity to fish had been successfully removed. For example, there are currently several nonselective fisheries that provide ample fishing opportunity but do not stimulate much fisher participation (e.g., South Sound recreational). This may not necessarily be a problem if the provision of the opportunity is not expensive in terms of dollars or lost opportunity elsewhere. Clearly, however, selective fisheries will be expensive to implement, and some level of benefits must be obtained be justify the expense.

Since we have very little experience with selective fisheries for salmon, it is difficult to predict the likely level of angler participation. Measuring angler trips after implementation of the selective fisheries will be an essential component of the evaluation process. However, quantification of the additional fishing opportunities provided by the fishery will be difficult in the absence of an estimate of what the angler effort would have been in the absence of the selective fishery regulations. Changing rates of angler participation may be due to any number of factors, including changes in season length, varying numbers of anglers in the population, changes in catch success, fishery popularity, or the availability of alternative recreational opportunities.

9.4.2 Commercial Opportunity

Selective fishing may expand commercial fishing opportunity either by providing access to the marked stock or by providing access to species or stocks that are not marked but are caught coincidentally to the marked stock. Access to sockeye or chum salmon is often constrained by limitations placed on coho or chinook salmon by-catch. In some cases, very small reductions in impacts on weak stocks (marked stocks) can translate into significant increases in the total benefits derived from a fishery. Benefits in commercial fisheries are usually measured in total catch, biomass, or economic value.

9.5 Economic Benefit

Although we have identified some of the direct costs associated with implementing selective fisheries, we have not attempted to provide a complete description of the total monetary costs associated with selective fisheries. For example, there may be indirect costs such as staff time required to modify management models, public education and information, and additional enforcement. No attempt has been made to quantify economic benefits associated with selective fisheries. Clearly, any comprehensive evaluation of a specific selective fishery proposal must include a net economic benefit analysis.

9.6 Summary

The implementation of a selective fishery program represents a substantial departure from the management status quo. Actual outcomes are uncertain and implementation of the program entails large expenditures of resources. As such, it is critical to define success and evaluate actual outcomes against these expectations.

CHAPTER 10. CONCLUSIONS AND RECOMMENDATIONS

Conservation concerns for wild salmon have increased interest in exploring alternative management approaches that permit harvest while reducing impacts on stocks needing protection. One such approach is the implementation of selective fisheries which would allow retention of marked hatchery fish while requiring the release of unmarked fish. Although conceptually attractive, little is known about the potential impacts of selective fisheries on wild stocks or current management tools. Because of the importance of conservation and potential implications of selective fisheries for the coastwide coded-wire-tag (CWT) system, the Pacific Salmon Commission (PSC) established an ad-hoc committee to complete an assessment of selective fisheries. The assessment focused on two general questions:

> ***Can selective fishery regulations reduce harvest rates on unmarked salmon and can total exploitation rates be reduced and spawning escapements increase as a result?***
>
> ***Can the viability of the existing coastwide CWT program for stock assessment and management planning be maintained if selective fisheries are implemented?***

Although broadly applicable, the results of our assessment should not be considered to represent a comprehensive evaluation of any specific selective fishery proposal. Furthermore, our assessment did not evaluate the effectiveness of selective fisheries relative to alternative management options.

10.1 Applicability to Chinook

At this time, selective fisheries are only considered feasible for coho salmon. The logistics of marking are more problematic for chinook than for coho because of the large numbers of juveniles that would have to be marked, the smaller size of fish at release, the limited time for marking, and the necessity of handling the fish shortly before release. The complex life history of chinook, involving migration over multiple seasons and extensive geographic areas, greatly increases the difficulty of selective fishery assessment. Further, impacts of selective fisheries on chinook salmon would likely extend coastwide, increasing both costs and the difficulty of coordinating implementation. Because of these factors, our assessment focuses on evaluation of selective fisheries for coho salmon.

Recommendation:

1) ***Selective fisheries should not be considered for chinook salmon at this time.***

10.2 Selection of Mark Type

Under selective fisheries, fish that can be retained must be easily distinguished from fish that are to be released. The adipose fin clip and ventral fin clip were evaluated as the two most feasible mass marks for selective removal on the basis of four criteria: (1) ease and cost of application; (2) ease of recognition by an untrained observer; (3) mark induced mortality; and (4) stability over the life of the fish. The adipose fin is superior across all criteria.

A Selective Fishery Model (SFM), was developed and used to evaluate the effectiveness of various selective fishing scenarios involving stocks with different patterns of exploitation. Based on assumed lower mark induced mortality and marked recognition error rates, escapements of unmarked fish and catch levels were higher with adipose clips than with ventral clips.

Data generated by the SFM were used to evaluate the effect of mark induced mortality (mortality caused by mass marking) and marked recognition error (the inadvertent release of a marked fish) on CWT-based estimates derived through cohort analysis. Estimates of initial cohort size of marked and unmarked fish will be biased if these sources of errors cannot be accurately accounted for. Assuming that mark induced mortality and marked recognition error are lower and less variable for adipose fin clip compared to the ventral fin clip, then the adipose clip is the better choice.

Recommendations:

2) ***The adipose fin clip should be used as the mass mark for hatchery coho if selective fisheries are implemented.***

3) ***Research should be undertaken to provide improved estimates of mark induced mortality and marked recognition error rates for adipose-clipped fish.*** Definitive data are not yet available to enable reliable estimation of these critical factors.

10.3 Impacts of Selective Fisheries

Three primary questions relating to the impact of selective fisheries on coho salmon were addressed:

1. *Can a selective fishery reduce harvest rates on unmarked stocks?*

A fishery harvest rate is defined as the proportion of a total population available to a fishery that is killed by that fishery, whether as landed catch or incidental mortality. Harvest rates are assumed to be identical for all groups of fish available to the fishery.

Results from the SFM indicate that harvest rates on unmarked fish in selective fisheries can be substantially reduced. However, the magnitude of the reduction can be expected to be variable, depending upon release and dropoff mortality rates. The release mortality is the probability that a fish that is caught and released will die as a result. The dropoff mortality rate is the probability that an encounter with gear (e.g., hooking, entanglement) will kill a fish even if it is not landed.

Assuming that the adipose fin clip is used as the mass mark, selective fisheries reduced harvest rates on unmarked fish by as much as 70%-80% for gear types with low release and dropoff mortality rates to as little as 10%-50% for gear types with high release and dropoff mortality rates. These rates can be expected to vary, depending upon the manner in which the gear is operated and the time and location of the selective fishery. Recreational gear, traps, and beach seines are believed to have the lowest release mortality rates. Gillnets and purse seine fisheries in which a large number of fish are caught per set are believed to have the highest release mortality rates. Troll and purse seine fisheries in which a small number of fish are caught per set are believed to have intermediate release mortality rates.

Harvest rate reductions also depend to a lesser degree on the encounter rate of unmarked fish, marked recognition error, and the probability that a released fish will be recaptured in the fishery.

2. *Can reduced harvest rates on unmarked stocks in a selective fishery be translated into reductions in total stock exploitation rates and increases in escapement?*

A total stock exploitation rate is defined as the proportion of the initial cohort that is killed by fishing, whether through landed catch or incidental mortality. The effectiveness of selective fisheries in reducing total stock exploitation rates and increasing escapements of unmarked fish varies depending upon the exploitation pattern of individual stocks as well as the regulations, placement, and size of the selective fishery.

Compared to the current situation where no fisheries are selective, we estimate that total stock exploitation rates of most unmarked stocks can be expected to be reduced by less than 5% under scenarios involving only a single selective fishery. Under the most positive circumstances, a stock's exploitation rate was reduced by greater than 30%. If all fisheries were to operate under selective regulations, total stock exploitation rates of unmarked fish can be expected to be reduced from 20% to 60%.

For most unmarked stock components and scenarios, our assessment indicates that escapements should increase by 5% to 15%. These increases are small relative to the inherent variability of wild stock escapements. Under the most positive circumstances, spawning escapement increased by as much as 80%.

However, our evaluation also reveals that escapements of some wild stocks can actually decline under some scenarios. For example, if total abundance of marked fish is significantly reduced by mark induced mortality, then harvest rates may increase on both wild and marked fish in nonselective fisheries that are managed under quotas or bag limits, causing escapements to decline.

We conclude that the effectiveness of selective fisheries in increasing spawning escapements of unmarked fish depends upon these factors:

- The proportion of a stock that would be harvested by the fishery in the absence of selective regulations;

- the impact of nonselective fisheries that harvest unmarked fish released in selective fisheries;

- the degree to which reductions in total abundance caused by mark induced mortality increase harvest rates in nonselective fisheries that operate under catch quotas or bag limits; and

- the magnitude of harvest rate reductions resulting from the selective fishery.

3. *How would the catches and incidental mortality in selective fisheries be affected?*

No effort response was included in the SFM except for OutSp1 (bag limit effect), OutTr1 (ceiling effect), and InNet3 and OutNt2 (escapement goals). Landed catch declined significantly in all cases for selective fisheries, compared to nonselective regulation. Across the range of selective fisheries simulated, landed catches in the selective fisheries were reduced by between 30% and 70%. Declines in catch levels varied with the proportion marked, the degree of marked recognition error, reduced abundance of marked fish due to mark induced mortality, and the proportion of the harvested population that is marked.

The total catch in nonselective fisheries generally increased. Reduced harvest rates on unmarked fish and the marked recognition error in the selective fisheries increases abundance in subsequent fisheries. The degree to which catch was redistributed from selective to subsequent nonselective fisheries depends upon stock migration and fishing patterns. The largest increases in catch by nonselective fisheries were associated with the lowest marking mortalities under situations where nonselective fisheries follow selective fisheries.

The catch for all fisheries combined (selective and nonselective) was reduced by from 0% to 59% under the scenarios examined. Catch reductions in selective fisheries were offset in some cases by catch increases in other fisheries. This potential for redistribution of catch may present allocation problems or new opportunities for harvest, depending on specific circumstances.

Incidental mortalities increased significantly in all selective fishery scenarios. The relative increase in incidental mortalities ranged from 100% to 400%. In the scenarios examined, incidental mortalities amounted to as much as twice the level of retained catch.

10.4 Can the Viability of the CWT Program be Maintained?

Because the CWT is central to management of chinook and coho salmon, the viability of the CWT program is of vital concern. For this assessment, the viability of the CWT system is defined as:

1) The ability to use CWT data for assessment and management of wild stocks of coho and chinook salmon;

2) maintaining the program such that the uncertainty in our assessments and their applications does not unacceptably increase management risk; and

3) the ability to estimate stock-specific exploitation rates by fishery and age.

Based upon our analysis, it is apparent that the viability of the CWT program will be impaired if selective fisheries are implemented on a broad scale. Substantial changes to tagging and recovery programs will be needed to minimize the potential loss of management information. Interagency coordination in research and management methods must be increased to reduce the risk to the CWT system. Further, during transition periods when selective fisheries are either implemented or terminated, there is a higher risk that management capabilities would be degraded.

To minimize the loss of information if selective fisheries are implemented, the CWT program should be modified as follows:

Recommendations:

4) ***Do not use an external identifier for CWT fish. Electronic detection should be employed to randomly sample for CWTs in all fisheries and spawning escapements where CWTs are expected to be recovered. CWTs of 1-1/2 length should be used to increase the reliability of electronic detection.*** Given the adoption of Recommendation 2, the adipose fin clip could no longer be used as the external identifier of CWT fish. In addition, voluntary recovery of tags in recreational fisheries would no longer provide useful information so random sampling of recreational fisheries would be required.

5) ***Implement double index tagging of marked (ad-clip + CWT) and unmarked (CWT only) hatchery groups.*** Double index tagging involving the use of paired replicates will be required regardless of which mass mark type is finally chosen. This will approximately double the numbers of tags released for indicator stocks.

6) ***Maintain "adequate" levels of tagging and recovery sampling.*** Our ability to generate useful estimates from the CWT system depends upon the recovery of a sufficient number of CWTs. Specific levels of tagging and sampling will depend upon the objectives of the CWT program and selective fisheries.

7) ***Sample all fisheries for the proportion marked.*** Our ability to estimate catch compositions and interceptions will be compromised if all fisheries are not sampled for mark ratios.

8) ***Ensure extensive inter-agency cooperation and coordination of mass marking, CWT recovery programs, and selective fishing. Mass marking of hatchery fish by removing adipose fins should not be permitted until assurances are received from substantially affected jurisdictions that CWTs will be electronically sampled.*** Piecemeal implementation of selective fisheries is not possible. Once an agency decides to mass mark fish in anticipation of implementing a selective fishery, the viability of the CWT program cannot be maintained unless required changes to sampling programs in all affected agencies are made. If poorly implemented, selective fisheries could incur high costs while producing few benefits to fisheries.

9) ***Associate wild fish tagging programs with a representative hatchery marking program within the same production area for stocks that are significantly impacted by selective fisheries.*** Wild fish survivals and production cannot be evaluated without paired CWT experiments.

10) ***Management planning and stock assessment methods affected by selective fisheries must be modified prior to the implementation of these fisheries.***

Even with these efforts, however, some information and aspects of the present CWT program will be compromised or lost. The degree to which information is lost is directly related to the size of the selective fishery program.

- The independence of tag groups will be lost. Unmarked hatchery and wild tag groups must now be associated with marked and tagged hatchery groups. This association will be much more tenuous for unmarked wild tag groups.

- Uncertainty in our estimates obtained from cohort analysis will increase due to additional assumptions required to estimate incidental mortalities.

- We will not be able to estimate fishery-specific mortalities on unmarked stocks when multiple selective fisheries occur. Currently, fisheries are often regulated on the basis of limitations on stock-specific mortalities. The loss of information would impair management planning, allocation and stock assessment capabilities. This loss of information becomes increasingly critical as incidental mortalities increase.

- Under selective fisheries, incidental mortalities, which are not included in current estimates of interceptions, may become too large a component of interceptions to ignore.

On the other hand, many of the measures recommended for selective fisheries could improve the basis for fisheries management. For example, electronic detection of CWTs and direct random sampling of recreational catches could improve the precision of estimates of tag recoveries. In addition, the marking of all hatchery fish would increase the accuracy of accounting for this production in fisheries or escapement. However, we emphasize that these measures could be implemented independently of selective fisheries.

10.5 Evaluation of Selective Fisheries

Considerable uncertainty exists around the outcomes predicted by our assessment, due to our limited experience with selective fisheries and the inherent variability in the many factors and processes defining selective fisheries. Given the uncertainty of expected outcomes, our ability to assess the effectiveness of any selective fishery implemented will rely heavily on observation and measurement of actual outcomes. The utility of various types of measures is summarized below.

Recommendation:

11) ***Selective fishery programs should not be implemented without specific, measurable criteria to provide an objective basis for performance evaluation.***

10.5.1 Escapement

Changes in the level of wild stock escapements are one potential measure of the effectiveness of selective fishery regulations. However, escapement estimates have a relatively low sensitivity for evaluating fishery effects due to: (1) the errors associated with escapement estimates; and (2) non-fishery influences on spawner abundance, such as natural survival rates. If selective fisheries effects are small (e.g., 10% of the total mortalities or less), then over a short period (e.g., one to two brood cycles or three to six years for coho), escapement data alone are not likely to provide conclusive evidence of selective fishery impacts.

Through double index tagging, recoveries in escapements can be used to directly estimate the escapement rates (escapement divided by release) of paired, tagged releases of marked and unmarked fish in the same year. The differences in escapement rates could be used to make inferences regarding the potential effect of selective fisheries on wild stocks. An advantage of this approach is that hatchery escapements can be estimated with greater precision than wild escapements; further, impacts of survival and fishery differences and inter-annual variability are not factors for comparison within the same year. When coupled with estimates of wild stock escapements, total exploitation rates can be used to quantify the magnitude of change in spawning escapements due to selective fisheries.

10.5.2 Fishing Mortality

Landed catch would not be a useful criteria for evaluation of selective fishery impacts on unmarked fish. For unmarked fish, the impact will be in terms of incidental mortality. Sampling programs that provide estimates of total fish encounters can be combined with assumed release mortality rates to produce estimates for incidental mortalities associated with selective fishing. However, such programs would not provide information adequate to estimate incidental mortalities of individual unmarked stocks or evaluate the effectiveness of selective fisheries in reducing harvest rates on those stocks.

10.5.3 Exploitation Rate

Exploitation rates based on CWT recoveries provide a more reliable estimator of stock-specific fishery impacts than catch or escapement. Exploitation rates are independent of variations in survival or abundance. However, exploitation rates may not be useful for evaluating the effects of individual selective fisheries due to sampling error and the inability to accurately allocate incidental mortalities in individual selective fisheries when more than one selective fishery exists.

On an annual basis, total stock exploitation rates between two groups (e.g., marked and unmarked) must differ by at least 10 percentage points for us to detect that difference as being statistically significant. In our assessment, for most unmarked stock components, a 10 percentage point reduction in exploitation rates was not achieved until all hook and line fisheries were selective. To detect differences smaller than 10 percentage points, increases in tagging levels and/or sampling rates would be required.

If selective fisheries that account for a substantial portion of a stock's total fishing mortality are implemented, estimates of total stock exploitation rates will have reduced accuracy and precision. Estimates of incidental mortality in selective fisheries will depend upon assumptions used in the cohort analyses, including parameter values used for natural mortality and incidental mortality in nonselective fisheries.

The ability to estimate the effects of selective fisheries on exploitation rates of unmarked fish will depend upon the design of tagging and sampling programs. At a minimum, double index tagging and electronic tag detection capabilities will be required to obtain an approximate estimate of exploitation rates of unmarked fish in selective fisheries.

Through double index tagging of hatchery stocks, recoveries in escapements can be used to directly estimate the difference in total exploitation rates of marked and unmarked fish. Such estimates have the potential advantage of reducing uncertainty by avoiding errors associated with catch sampling.

Recommendation:

12) ***Differences in exploitation or escapement rates between paired replicate, double index tag groups should be the primary means of evaluating the impact of selective fishery regimes on individual stocks.*** It is important to note, however, that, when multiple selective fisheries exist, we will not be able to estimate differences in exploitation rates in individual selective fisheries.

10.5.4 Fishery Opportunity

Selective fisheries may reduce the need to impose additional constraints on fishing opportunity. Opportunity can be expressed in terms of season length or effort. Opportunity may also be defined in terms of access to species or stocks by either the selective fishery or other fisheries. For example, reductions in mortalities of unmarked fish from stocks of concern as the result of selective fisheries may improve access to other stocks or species, e.g., surplus hatchery production. In some cases, small reductions in impacts on critical stocks can significantly increase the total catch of other stocks or species. For instance, if a fishery is constrained by the need to achieve a minimum spawning escapement level of wild coho, the availability of more wild coho after a selective fishery could allow a higher harvest rate on large, commingled runs of sockeye or chum salmon.

Since we have very little experience with selective fisheries for salmon, it is difficult to predict the likely level of angler participation. Measuring angler trips after implementation of the selective fisheries will be an essential component of the evaluation process. However, quantification of the additional fishing opportunities provided by the fishery will be difficult in the absence of an estimate of what the angler effort would have been in the absence of the selective fishery regulations. Changing rates of angler participation may be due to any number of factors, including changes in season length, varying numbers of anglers in the population, changes in catch success, fishery popularity, or the availability of alternative recreational opportunities.

10.5.5 Economic Considerations

Our assessment indicates that selective fisheries have the potential to reduce exploitation rates and increase spawning escapements of unmarked stocks of coho salmon (to varying degrees), but they do not represent a panacea to stock conservation or fishery management problems. Their development will have wide-spread impacts on our ability to manage those same stocks. It is clear that the establishment of any selective fishery will require substantial changes in the CWT program if agencies wish to minimize information loss and the loss of production caused by mark induced mortality. The costs and the benefits of a selective fishery must therefore be examined on a case-by-case basis.

The monetary costs of selective fisheries are substantial. Table 10.1 summarizes some of the costs associated with implementing selective fisheries in the Strait of Georgia and Puget Sound. Cost estimates do not include expenses associated with evaluation, or implementation in other areas of the U.S. whose stocks or recovery programs may be affected, or revisions to analytical tools and management models.

Table 10.1. Predicted costs associated with implementing selective fisheries in the Strait of Georgia and Puget Sound.

Country	Capital Investment ($US)	Annual Operation (marking, tagging & sampling) ($US)
United States	1.446 million	0.844 million
Canada	1.219 million	0.893 million

The implementation costs for the first selective fishery would be high since major changes to the sampling programs and management would be required. The costs of additional selective fisheries would be lower since the major changes would be in place.

There are also costs associated with reduced catches, the loss of fish due to mark induced mortalities and increased incidental mortalities during selective fisheries. These costs could be large, depending on the selection of mass mark, the gear, the scale of the selective fisheries, and the ratio of marked to unmarked fish in the fishery.

10.6 Implementation

Ultimately, decisions about selective fisheries will rest upon value judgements contrasting wild stock conservation and fishing opportunities against the loss of information essential for management and the financial costs of implementation.

Selective fisheries can be employed to meet a variety of management objectives. The implementation of selective fisheries could increase the spawning escapements for some wild coho populations under certain conditions, but have different effects on harvest opportunity. If fishing opportunities are limited by the need to address wild stock conservation limits, then a selective fishery could provide for more efficient utilization of hatchery fish and may allow increased fishing opportunity. Conversion of an existing nonselective fishery to a selective fishery would reduce harvest and retention rates on unmarked fish while increasing management costs and uncertainties.

We have recommended the use of the adipose fin clip as a mass mark and electronic detection of CWTs if selective fisheries are to be implemented. If a decision is made to use a ventral fin clip as a mass mark, then direct monetary costs for implementation would be comparatively lower since electronic detection would not be required. However, because of the high and variable mortality of ventral fin clipping the ability to evaluate the effectiveness of selective fisheries could be lost, even with double index tagging. Catches, and our ability to evaluate stock-specific effects of selective fisheries would decline, while incidental mortalities and the uncertainty in key stock-specific parameters would increase.

Selective fisheries present both positive and negative changes for the coastwide CWT program. The net effect of selective fisheries, however, is highly dependent on how well the affected agencies coordinate their efforts and fund necessary changes in the CWT program. If the required changes are implemented correctly, improvements to the sampling programs may offset losses to some existing management capabilities. Without a coordinated approach, selective fisheries will jeopardize our abilities to manage wild coho and chinook.

To maintain the positive aspects of both selective fisheries and CWTs, a full and coordinated effort by all marking and affected sampling agencies will be required. Our assessment indicates that greater interdependencies among management jurisdictions will exist under selective fisheries. Decisions made by one agency to implement a selective fishery will unavoidably affect other agencies.

Recommendations:

13) ***Establish and adopt a format for selective fishery proposals to provide for effective review by all affected jurisdictions.*** A recommended general outline for such a format is presented in Appendix C; the detail required for the items indicated in the outline should be determined on a case-by-case basis.

14) ***Establish and adopt a process to review, approve and implement mass marking and selective fishery proposals. This process should involve all affected jurisdictions.***

10.7 Summary

The potential benefits of selective fisheries as a tool to address management concerns for wild coho and utilization of hatchery production are strong arguments for supporting the development of this management tool. However, this tool has numerous risks and will involve significant costs for implementation. These risks and costs affect almost every management agency and research program utilizing the existing CWT program. The viability of the CWT program - the only means available to perform stock-specific assessments of coho and chinook salmon - will be impaired by large scale selective fisheries.

A broad array of potential benefits and costs to fisheries, management capabilities, and the resource have been examined in our assessment. Where serious problems with implementation have been identified, we have tried to develop alternative procedures to overcome those problems, but we have not been completely successful. During a period of reduced budgets and increasing public concern for conservation of biological diversity, these potential benefits and risks must be carefully weighed. While selective fisheries may prove useful in achieving certain management objectives, less risky and costly alternatives exist that could accomplish many of these objectives.

Recommendations:

15) ***Management alternatives to selective fisheries should be fully considered and evaluated before selective fisheries are implemented.***

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APPENDIX A.

SUMMARY TABLES OF SELECTIVE FISHERY EFFECTS BY STOCK AND FISHERY

Appendix Table A-1. Summary of the effects of selective fisheries on wild stocks. The numbers represent a percent change from the base case. * signifies p < or = 0.05; ** signifies p < or = 0.025.

	Selective	OutStk1W		OutStk2W		InStk1W		InStk2W		InStk3W	
Scenario	Fishery	Escapement	Exp Rate	Escapement	Exp Rate	Escapement	Exp Rate	Escapement	Exp Rate	Escapement	Exp Rate
IA	OutSp1	[-2,0]	[0,2]	[7,15]**	[-4,-3]**	[0,1]	[-1,0]	[-1,1]	[0,0]	[2,9]	[-2,-1]**
IC	OutSp1	[-2,0]	[0,2]	[10,16]**	[-6,-3]**	[-2,1]	[-1,1]	[0,2]	[-1,0]	[5,11]**	[-2,-1]**
ID	OutSp1	[-8,-3]*	[2,6]	[8,15]**	[-5,-3]**	[-2,0]	[0,1]	[-1,1]	[0,0]	[5,10]**	[-2,-1]**
2A	OutTr2	[-2,1]	[-1,2]	[4,11]**	[-3,-2]**	[-2,1]	[0,1]	[-1,1]	[0.0]	[5,9]**	[-2,-1]**
2C	OutTr2	[-3,0]	[0,3]	[4,13]**	[-4,-2]**	[-1,1]	[-1,1]	[-1,1]	[0,1]	[1,7]	[-2,0]
2D	OutTr2	[-9,-6]**	[5,7]**	[2,7]	[-2,0]	[-3,-1]**	[0,2]**	[0,2]	[-1,0]	[1,6]	[-1,0]
3A	InSp2	[-2,0]	[0,2]	[-7,-1]	[1,2]	[-1,3]	[-1,0]	[-1,3]	[-1,0]	[8,16]**	[-3,-2]**
3C	InSp2	[-3,0]	[0,2]	[-1,1]	[-1,0]	[0,3]	[-1,0]	[1,4]*	[-2,0]**	[10,16]**	[-3,-2]**
3D	InSp2	[-10,-6]**	[4,8]**	[-9,-3]	[1,3]*	[-3,0]	[0,1]	[1,4]	[-1,0]**	[3,13]**	[-3,-1]**
4A	InSp1	[0,0]	[0,1]	[-4,1]	[0,1]	[76,80]**	[-33,-32]**	[2,5]**	[-2,-1]**	[1,6]	[-1,0]
4C	InSp1	[-1,1]	[-1,1]	[-3,4]	[-1,1]	[76,80]**	[-33,-32]**	[1,4]	[-2,0]**	[-3,4]	[-1,1]
4D	InSp1	[-2,-1]	[1,2]	[-2,1]	[0,1]	[76,80]**	[-32,-32]**	[1,5]**	[-2,-1]**	[-5,0]	[0,1]
5A	OutNt1	[-1,0]	[-1,1]	[30,38]**	[-14,-11]**	[-1,1]	[0,1]	[0,2]	[-1,0]	[2,9]	[-2,0]
5B	OutNt1	[-1,1]	[-1,1]	[8,18]**	[-6,-3]**	[-1,1]	[0,1]	[0,2]*	[-1,0]**	[2,9]	[-2,0]
5C	OutNt1	[-1,1]	[-1,1]	[32,43]**	[-15,-13]**	[-1,1]	[0,1]	[0,2]	[-1,0]	[-1,8]	[-1,0]
5D	OutNt1	[-1,1]	[-1,1]	[11,18]**	[-6,-4]**	[-2,0]	[0,1]	[0,3]	[-1,0]	[-3,3]	[1,1]
6A	All Rec	[-4,-1]	[1,3]	[9,13]**	[-5,-3]**	[77,82]**	[-34,-33]**	[1,4]	[-2,0]**	[15,23]**	[-5,-4]**
6C	All Rec	[-4,-1]	[1,3]	[9,14]**	[-5,-3]**	[75,79]**	[-34,-32]**	[-1,2]	[-1,0]	[12,30]**	[-6,-3]**
6D	All Rec	[-11,-7]**	[6,9]**	[0,8]**	[-3,0]**	[73,78]**	[-33,-32]**	[2,5]**	[-2,-1]**	[13,22]**	[-5,-3]**
7A	H&L	[74,88]**	[-51,-47]**	[65,79]**	[-26,-23]**	[143,150]**	[-61,-60]**	[2,7]	[-3,-1]	[53,63]**	[-14,-12]**
7C	H&L	[75,88]**	[-51,-47]**	[69,83]**	[-27,-25]**	[140,149]**	[-60,-60]**	[3,7]**	[-3,-1]**	[45,58]**	[-12,-11]**
7D	H&L	[77,91]**	[-52,-48]**	[62,76]**	[-25,-22]**	[144,150]**	[-61,-60]**	[1,7]	[-3,0]**	[53,65]**	[-13,-12]**
8A	All	[69,102]**	[-52,-48]**	[106,135]**	[-46,-43]**	[133,149]**	[-61,-60]**	[39,62]**	[-21,-16]**	[128,169]**	[-35,-34]**
8B	All	[75,89]**	[-51,-48]**	[83,101]**	[-33,-31]**	[143,149]**	[-61,-60]**	[3,8]**	[-3,-1]**	[88,94]**	[-20,-19]**
8C	All	[68,100]**	[-52,-47]**	[107,151]**	[-45,-43]**	[134,154]**	[-61,-60]**	[46,66]**	[-20,-15]**	[135,173]**	[-35,-34]**
8D	All	[76,93]**	[-53,-49]**	[84,98]**	[-34,-31]**	[144,150]**	[-61,-60]**	[4,7]**	[-3,-2]**	[87,101]**	[-21,-20]**

Appendix Table A-2. Summary of the effects of selective fisheries on hatchery stocks. The numbers represent a percent change from the base case. * signifies p < or = 0.05; ** signifies p < or = 0.025.

Scenario	Selective Fishery	OutStk1H		OutStk2H		OutStk3H		InStk1H		InStk2H		InStk3H	
		Escapement	Exp Rate	Escapement	Exp Rate	Escapement	Exp Rate	Escapement	Exp Rate	Escapement	Exp Rate	Escapement	Exp Rate
1A	OutSp1	[-2,0]	[0,2]	[-9,-4]**	[0,2]	[-3,2]	[-3,-1]*	[-1,1]	[-1,0]	[-9,-7]**	[1,2]**	[-8,0]*	[-1,1]
1C	OutSp1	[-2,0]	[0,2]	[-7,-1]**	[-1,1]	[-3,1]	[-3,-1]*	[-2,1]	[0,1]	[-8,-7]**	[1,2]**	[-6,0]**	[-1,0]
1D	OutSp1	[-7,-3]**	[3,6]**	[-22,-17]**	[-1,1]	[-2,2]	[-12,-8]**	[-3,-1]	[0,1]	[-23,-22]**	[1,2]**	[-20,-17]**	[-1,0]
2A	OutTr2	[-2,1]	[-1,2]	[-9,-2]**	[-1,2]	[-6,0]**	[-1,1]	[-2,0]	[0,1]	[-7,-6]**	[1,2]**	[-2,1]	[-1,0]
2C	OutTr2	[-3,0]	[0,3]	[-8,-4]**	[0,1]	[-4,1]	[-3,0]	[-1,1]	[-1,1]	[-9,-6]**	[1,1]**	[-8,-3]**	[-1,1]
2D	OutTr2	[-9,-5]**	[4,7]**	[-24,-20]**	[0,1]	[-4,-1]	[-12,-8]**	[-3,-1]**	[0,1]**	[-22,-20]**	[0,1]	[-22,-16]**	[-1,0]
3A	InSp2	[-2,0]	[0,1]	[-6,-1]	[0,2]	[-5,1]	[0,3]	[-6,-2]**	[-1,1]	[-14,-11]**	[3,4]**	[-6,2]	[-1,0]
3C	InSp2	[-3,0]	[0,2]	[-1,3]	[-1,0]	[-1,2]	[-1,1]	[-6,-3]**	[-1,1]	[-13,-10]**	[2,3]**	[-5,1]	[-2,0]
3D	InSp2	[-10,-6]**	[4,8]**	[-9,-3]	[1,3]	[-4,3]	[-1,1]	[-23,-21]**	[1,2]**	[-25,-23]**	[1,3]**	[-22,-15]**	[-1,1]
4A	InSp1	[-1,0]	[-1,1]	[-5,1]	[-1,1]	[-5,1]	[-1,3]	[-3,-1]	[-1,-1]**	[2,5]**	[-2,-1]**	[2,6]	[-1,0]
4C	InSp1	[-2,0]	[0,1]	[-2,5]	[-1,1]	[-4,3]	[-1,2]	[-2,0]	[-2,-2]**	[1,4]*	[-1,0]**	[-2,4]	[-1,0]
4D	InSp1	[-3,-1]	[1,2]	[-4,1]	[0,1]	[-1,4]	[-2,0]	[-6,-5]**	[-8,-7]**	[1,4]**	[-2,-1]**	[-5,1]	[0,1]
5A	OutNt1	[-1,1]	[-1,1]	[-7,1]	[-2,1]	[-1,3]	[-1,1]	[-1,1]	[0,1]	[0,2]	[-1,0]*	[2,9]	[-2,0]
5B	OutNt1	[-1,1]	[-1,1]	[-8,0]	[-1,1]	[-1,4]	[-1,1]	[-1,1]	[0,1]	[0,2]	[-1,0]**	[2,9]	[-2,0]
5C	OutNt1	[-1,1]	[-1,1]	[-2,5]	[-3,-1]**	[-3,0]	[0,1]	[-1,1]	[0,1]	[0,2]	[-1,0]	[-1,7]	[-1,0]
5D	OutNt1	[-2,1]	[-1,1]	[-18,-15]**	[-2,0]**	[-2,1]	[-1,1]	[-2,1]	[0,1]	[0,3]	[-1,0]	[-3,3]	[-1,0]
6A	All Rec	[-9,-5]**	[1,3]	[-7,-4]**	[0,1]	[-5,0]	[-2,1]	[-2,1]	[-2,-1]**	[-22,-19]**	[6,7]**	[-6,0]**	[-1,1]
6C	All Rec	[-11,-7]**	[2,4]**	[-9,-5]**	[0,1]	[-5,-2]	[-2,0]	[-2,0]	[-2,-1]**	[-23,-22]**	[6,8]**	[-9,5]*	[-2,1]
6D	All Rec	[-30,-26]**	[6,8]**	[-27,-21]**	[1,3]**	[-6,-1]	[-11,-9]**	[-8,-6]**	[-7,-6]**	[-31,-28]**	[4,5]**	[-21,-14]**	[-2,0]
7A	H&L	[-22,-12]**	[5,11]**	[-10,-1]**	[0,2]**	[-5,-1]	[-1,1]	[-4,-1]**	[-1,0]	[-40,-37]**	[12,15]**	[-8,-1]**	[-1,1]
7C	H&L	[-21,-11]**	[2,9]**	[-13,-4]**	[-1,2]	[-6,-2]**	[-2,0]	[-3,1]	[-2,-1]**	[-39,-36]**	[11,14]**	[-11,-1]**	[0,1]
7D	H&L	[-17,-9]**	[-8,-2]	[-15,-10]**	[-4,-2]**	[-6,-1]**	[-10,-8]**	[2,5]*	[-12,-11]**	[-44,-40]**	[8,10]**	[-14,-8]**	[-3,-2]**
8A	All	[-24,-12]**	[6,12]**	[-17,-2]	[1,4]**	[-5,2]	[-5,0]	[-8,2]	[-2,1]	[-94,-90]**	[27,35]**	[-9,5]	[-2,0]
8B	All	[-22,-11]**	[5,11]**	[-15,-8]**	[1,4]**	[-4,1]	[-3,0]	[-5,0]*	[-2,1]	[-67,-60]**	[21,23]**	[-6,-1]*	[-1,1]
8C	All	[-25,-8]*	[2,8]**	[-18,-4]	[0,3]	[-5,2]	[-5,0]	[-9,2]	[-3,-1]**	[-93,-90]**	[27,34]**	[-8,5]	[-2,-1]**
8D	All	[-16,-8]**	[-9,-4]	[-14,-8]**	[-5,-3]**	[-4,0]**	[-11,-8]**	[3,5]*	[-12,-11]**	[-61,-58]**	[16,18]**	[-6,1]**	[-5,-4]**

Appendix Table A-3. Summary of the effects of selective fisheries on catch on incidental mortalities. * signifies p < or = 0.05; ** signifies p < or = 0.025.

		SELECTIVE FISHERIES								NONSELECTIVE FISHERIES	ALL FISHERIES
		% Change From Base									
Scenario	Selective Fishery	Harvest Rate Unmarked	Harvest Rate Marked	Catch	Incidental Mortalities	IM/Catch	% Marked	First Retained	IM/Catch	% Change Catch	% Change Catch
1A	OutSp1	[-79,-78]**	[3, 7]**	-32%	167%	393%	62%	0.60	0.12	2%	0%
1C	OutSp1	[-78,-77]**	[1,4]	-36%	179%	436%	62%	0.60	0.13	1%	-1%
1D	OutSp1	[-78,-77]**	[-16,-9]**	-55%	224%	720%	59%	0.70	0.22	-6%	-9%
2A	OutTr2	[-68,-63]**	[-7,3]	-40%	175%	458%	63%	0.60	0.28	0%	-2%
2C	OutTr2	[-67,-64]**	[-10,-3]	-44%	189%	516%	63%	0.60	0.31	0%	-1%
2D	OutTr2	[-68,-61]**	[-25,-12]**	-61%	222%	826%	58%	0.70	0.50	-4%	-6%
3A	InSp2	[-80,-80]**	[-3,2]	-46%	175%	509%	54%	0.80	0.15	1%	-1%
3C	InSp2	[-81,-80]**	[-8,-3]**	-48%	177%	533%	53%	0.90	0.16	1%	-1%
3D	InSp2	[-80,-80]**	[-21,-20]**	-63%	200%	811%	49%	1.00	0.24	-5%	-8%
4A	InSp1	[-74,-73]**	[-5,-4]**	-63%	371%	1273%	23%	3.30	0.38	5%	-5%
4C	InSp1	[-74,-73]**	[-8,-6]**	-64%	372%	1311%	24%	3.20	0.39	4%	-6%
4D	InSp1	[-74,-73]**	[-20,-18]**	-73%	386%	1800%	22%	3.50	0.54	4%	-8%
5A	OutNt1	[-49,-46]**	[-3,4]	-55%	96%	436%	45%	1.27	0.87	0%	-1%
5B	OutNt1	[-20,-14]**	[-2,5]	-56%	198%	677%	45%	1.22	1.35	0%	-1%
5C	OutNt1	[-50,-48]**	[-6,-2]*	-55%	92%	427%	43%	1.33	0.85	0%	-1%
5D	OutNt1	[-22,-18]**	[-9,-4]**	-70%	214%	1047%	41%	1.44	2.09	0%	-2%
6A	All Rec	NA	NA	-51%	264%	743%	41%	1.40	0.22	8%	-9%
6C	All Rec	NA	NA	-53%	276%	800%	41%	1.40	0.24	6%	-10%
6D	All Rec	NA	NA	-66%	296%	1165%	38%	1.60	0.35	0%	-18%
7A	H&L	NA	NA	-53%	333%	921%	38%	1.60	0.45	32%	-31%
7C	H&L	NA	NA	-53%	350%	957%	38%	1.60	0.47	31%	-31%
7D	H&L	NA	NA	-67%	372%	1430%	36%	1.80	0.70	25%	-43%
8A	All	NA	NA	-42%	217%	547%	41%	1.40	0.50	0%	-42%
8B	All	NA	NA	-44%	280%	679%	41%	1.40	0.62	0%	-44%
8C	All	NA	NA	-43%	231%	581%	41%	1.40	0.53	0%	-43%
8D	All	NA	NA	-58%	317%	993%	39%	1.60	0.90	0%	-58%

APPENDIX B.

REDISTRIBUTION OF STOCK MORTALITIES DUE TO SELECTIVE FISHERIES

Appendix Table B-1. **Distribution of percent of total mortality of each stock for the base case and Case 1A. Shaded area indicates selective fishery.**

Case 1A. OutSp1 Selective, Adipose Clip Mass Mark

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	39	61	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	38	7	9	0	0	0	0	0	0	19
	Not Marked	30	38	8	2	0	0	0	0	0	0	22
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	3	13	20	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	22	0	0	9	38	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	26	27	2	3	2	7	7	0	4	2	19
	Not Marked	25	27	3	1	2	7	7	0	4	2	22
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	25	3	4	0	0	6	2	4	2	34
	Not Marked	20	25	3	1	0	0	6	2	4	3	35

Appendix Table B-2. **Distribution of percent of total mortality of each stock for the base case and Case 1C. Shaded area indicates selective fishery.**

Case 1C. OutSp1 Selective, Ventral Clip Mass Mark (Best Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	39	61	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	38	7	9	0	0	0	0	0	0	19
	Not Marked	30	38	8	2	0	0	0	0	0	0	21
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	4	13	19	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	22	0	0	9	38	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	26	28	2	3	2	7	7	0	4	2	19
	Not Marked	25	28	3	1	2	7	7	0	4	2	22
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	26	3	4	0	0	6	2	4	3	34
	Not Marked	20	26	3	1	0	0	6	2	4	3	35

Appendix Table B-3. **Distribution of percent of total mortality of each stock for the base case and Case 1D. Shaded area indicates selective fishery.**

Case 1D. OutSp1 Selective, Ventral Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	37	62	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	39	7	8	0	0	0	0	0	0	19
	Not Marked	29	39	8	2	0	0	0	0	0	0	21
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	31	4	13	17	0	0	0	0	0	0	35
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	23	0	0	9	37	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	25	28	2	3	2	7	7	0	4	2	20
	Not Marked	25	28	3	1	2	7	7	0	4	2	22
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	26	3	4	0	0	6	2	4	3	34
	Not Marked	20	26	3	1	0	0	6	2	4	3	35

Appendix Table B-4. **Distribution of percent of total mortality of each stock for the base case and Case 2A. Shaded area indicates selective fishery.**

Case 2A. OutTr2 Selective, Adipose Clip Mass Mark

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	39	60	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	38	7	9	0	0	0	0	0	0	19
	Not Marked	29	38	3	9	0	0	0	0	0	0	21
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	25	3	13	19	0	0	0	0	0	0	39
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	22	0	0	9	38	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	26	27	2	3	2	7	7	0	4	2	20
	Not Marked	25	27	1	3	2	7	7	0	4	2	21
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	25	3	4	0	0	6	2	4	3	34
	Not Marked	20	25	1	4	0	0	6	2	4	3	35

Appendix Table B-5. **Distribution of percent of total mortality of each stock for the base case and Case 2C. Shaded area indicates selective fishery.**

Case 2C. OutTr2 Selective, Ventral Clip Mass Mark (Best Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	39	60	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	38	7	9	0	0	0	0	0	0	18
	Not Marked	29	38	3	10	0	0	0	0	0	0	20
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	3	13	20	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	22	0	0	9	38	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	25	27	2	3	2	7	7	0	4	2	19
	Not Marked	25	27	1	3	2	7	7	0	4	2	21
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	25	3	4	0	0	6	2	4	3	34
	Not Marked	19	25	1	4	0	0	6	2	4	3	35

Appendix Table B-6. **Distribution of percent of total mortality of each stock for the base case and Case 2D. Shaded area indicates selective fishery.**

Case 2D. OutTr2 Selective, Ventral Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	37	63	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	39	6	9	0	0	0	0	0	0	19
	Not Marked	27	39	3	10	0	0	0	0	0	0	20
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	31	4	11	20	0	0	0	0	0	0	34
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	29	23	0	0	9	38	0	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	26	28	2	3	2	7	7	0	5	2	19
	Not Marked	25	28	1	4	2	7	7	0	5	2	20
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	26	2	4	0	0	6	2	4	2	34
	Not Marked	19	26	1	4	0	0	6	2	4	3	34

Appendix Table B-7. **Distribution of percent of total mortality of each stock for the base case and Case 3A. Shaded area indicates selective fishery.**

Case 3A. InSp2 Selective, Adipose Clip Mass Mark, High Mark Rate

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	39	60	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked											
	Not Marked	26	38	7	9	0	0	0	0	0	0	19
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	24	3	14	19	0	0	0	0	0	0	38
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	30	22	0	0	9	37	0	0	0	0	0
	Not Marked	30	22	0	0	9	38	0	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	24	27	2	3	2	7	7	0	4	2	21
	Not Marked	25	27	2	3	2	7	1	0	5	2	25
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	25	3	4	0	0	6	2	4	3	34
	Not Marked	21	25	3	4	0	0	1	2	4	3	36

Appendix Table B-8. Distribution of percent of total mortality of each stock for the base case and Case 3C. Shaded area indicates selective fishery.

Case 3C. InSp2 Selective, Ventral Clip Mass Mark (Best Case), High Mark Rate

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	40	59	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked											
	Not Marked	27	37	8	9	0	0	0	0	0	0	19
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	25	3	14	20	0	0	0	0	0	0	38
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	30	22	0	0	9	38	0	0	0	0	0
	Not Marked	30	22	0	0	9	38	0	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	25	27	2	3	2	7	6	0	5	2	21
	Not Marked	25	27	2	3	2	7	1	0	5	2	24
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	25	3	4	0	0	5	2	4	3	34
	Not Marked	21	25	3	4	0	0	1	2	4	3	36

Appendix Table B-9. Distribution of percent of total mortality of each stock for the base case and Case 3D. Shaded area indicates selective fishery.

Case 3D. InSp2 Selective, Ventral Clip Mass Mark (Worst Case), High Mark Rate

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	37	62	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked											
	Not Marked	26	39	7	9	0	0	0	0	0	0	18
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	25	4	13	20	0	0	0	0	0	0	38
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	29	23	0	0	9	38	0	0	0	0	0
	Not Marked	30	23	0	0	9	38	0	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	25	28	2	3	2	7	5	0	4	2	21
	Not Marked	25	28	2	3	2	7	1	0	5	2	24
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	26	3	4	0	0	4	2	4	3	34
	Not Marked	20	26	3	4	0	0	1	2	4	3	36

Appendix Table B-10. **Distribution of percent of total mortality of each stock for the base case and Case 4A. Shaded area indicates selective fishery.**

Case 4A. InSp1 Selective, Adipose Clip Mass Mark

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	40	60	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked											
	Not Marked	27	38	7	9	0	0	0	0	0	0	19
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	25	3	14	19	0	0	0	0	0	0	39
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	31	22	0	0	9	37	1	0	0	0	0
	Not Marked	53	22	0	0	14	10	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked											
	Not Marked	27	27	2	3	3	2	7	0	5	2	22
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked											
	Not Marked	19	25	3	4	0	0	6	2	4	3	34

Case 4C. InSp1 Selective, Ventral Clip Mass Mark (Best Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	39	60	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked											
	Not Marked	27	38	8	9	0	0	0	0	0	0	19
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	25	3	14	19	0	0	0	0	0	0	39
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	31	22	0	0	10	36	1	0	0	0	0
	Not Marked	53	22	0	0	15	10	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked											
	Not Marked	26	27	2	3	3	2	7	0	4	3	23
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked											
	Not Marked	19	25	3	4	0	0	6	2	4	3	34

Case 5B. OutNt1 Selective, Adipose Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	40	59	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	27	37	7	9	0	0	0	0	0	0	19
	Not Marked	31	37	7	9	0	0	0	0	0	0	15
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	26	3	13	19	0	0	0	0	0	0	37
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	22	0	0	9	38	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked											
	Not Marked	26	27	2	3	2	7	7	0	4	2	20
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked											
	Not Marked	20	25	3	4	0	0	6	2	3	3	34

Appendix Table B-15. **Distribution of percent of total mortality of each stock for the base case and Case 5C. Shaded area indicates selective fishery.**

Case 5C. OutNt1 Selective, Ventral Clip Mass Mark (Best Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	40	59	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	28	37	7	9	0	0	0	0	0	0	18
	Not Marked	37	37	7	9	0	0	0	0	0	0	9
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	25	3	13	20	0	0	0	0	0	0	38
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	22	0	0	9	38	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked											
	Not Marked	26	27	2	3	2	7	7	0	4	2	20
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked											
	Not Marked	19	25	3	4	0	0	6	2	3	3	34

Appendix Table B-16. Distribution of percent of total mortality of each stock for the base case and Case 5D. Shaded area indicates selective fishery.

Case 5D. OutNt1 Selective, Ventral Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked											
	Not Marked	40	60	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	28	38	7	9	0	0	0	0	0	0	17
	Not Marked	31	37	7	9	0	0	0	0	0	0	15
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked											
	Not Marked	25	3	13	19	0	0	0	0	0	0	39
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked											
	Not Marked	30	22	0	0	9	38	1	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked											
	Not Marked	26	27	2	3	2	7	7	0	5	2	20
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked											
	Not Marked	19	25	3	4	0	0	6	2	4	3	34

Appendix Table B-17. **Distribution of percent of total mortality of each stock for the base case and Case 6A. Shaded area indicates selective fishery.**

Case 6A. All Recreational Fisheries Selective, Adipose Clip Mass Mark

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	39	60	0	0	0	0	0	0	0	0	0
	Not Marked	39	60	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	38	8	9	0	0	0	0	0	0	18
	Not Marked	30	38	9	2	0	0	0	0	0	0	21
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	3	14	20	0	0	0	0	0	0	36
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	31	22	0	0	10	36	0	0	0	0	0
	Not Marked	53	22	0	0	14	10	0	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	22	27	3	3	2	7	6	0	4	2	24
	Not Marked	25	27	3	1	3	2	1	0	5	3	31
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	25	3	4	0	0	6	2	4	3	35
	Not Marked	22	25	4	1	0	0	1	0	4	3	39

Appendix Table B-18. **Distribution of percent of total mortality of each stock for the base case and Case 6C. Shaded area indicates selective fishery.**

Case 6C. All Recreational Fisheries Selective, Ventral Clip Mass Mark (Best Base)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	38	62	0	0	0	0	0	0	0	0	0
	Not Marked	38	61	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	39	7	9	0	0	0	0	0	0	18
	Not Marked	30	39	9	2	0	0	0	0	0	0	21
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	4	13	20	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	31	22	0	0	10	36	0	0	0	0	0
	Not Marked	53	22	0	0	14	10	0	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	22	28	2	3	2	7	6	0	4	2	24
	Not Marked	25	28	3	1	3	2	1	0	5	3	30
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	26	3	4	0	0	6	2	4	3	34
	Not Marked	23	26	3	1	0	0	1	0	4	3	39

Appendix Table B-19. Distribution of percent of total mortality of each stock for the base case and Case 6D. Shaded area indicates selective fishery.

Case 6D. All Recreational Fisheries Selective, Ventral Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	36	63	0	0	0	0	0	0	0	0	0
	Not Marked	36	63	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	25	40	7	8	0	0	0	0	0	0	19
	Not Marked	29	40	8	2	0	0	0	0	0	0	21
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	31	4	14	17	0	0	0	0	0	0	34
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	34	23	0	0	11	31	0	0	0	0	0
	Not Marked	52	23	0	0	14	10	0	0	0	0	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	24	28	2	3	2	6	5	0	5.	2	23
	Not Marked	26	28	3	1	3	2	1	0	5	3	29
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	20	26	3	4	0	0	5	2	4	3	35
	Not Marked	22	26	3	1	0	0	1	0	4	3	38

Appendix Table B-20. **Distribution of percent of total mortality of each stock for the base case and Case 7A. Shaded area indicates selective fishery.**

Case 7A. All Hook and Line Fisheries Selective, Adipose Clip Mass Mark

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	35	65	0	0	0	0	0	0	0	0	0
	Not Marked	70	30	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	24	41	7	9	0	0	0	0	0	0	17
	Not Marked	45	19	3	2	0	0	0	0	0	0	30
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	4	13	20	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	30	23	0	0	9	36	0	0	0	0	0
	Not Marked	72	10	0	0	5	11	0	0	1	1	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	17	29	2	3	2	7	6	0	5	2	27
	Not Marked	25	12	1	1	1	2	2	0	6	4	46
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	18	26	3	4	0	0	6	2	4	3	34
	Not Marked	29	11	1	1	0	0	1	0	5	4	46

Appendix Table B-21. Distribution of percent of total mortality of each stock for the base case and Case 7C. Shaded area indicates selective fishery.

Case 7C. All Hook and Line Fisheries Selective, Ventral Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	34	65	0	0	0	0	0	0	0	0	0
	Not Marked	69	31	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	25	41	7	9	0	0	0	0	0	0	17
	Not Marked	45	20	3	2	0	0	0	0	0	0	29
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	4	12	20	0	0	0	0	0	0	38
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	30	24	0	0	9	36	0	0	0	0	0
	Not Marked	72	11	0	0	5	11	0	0	1	1	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	18	29	2	3	2	7	6	0	5	2	27
	Not Marked	26	13	1	1	1	2	2	0	6	4	45
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	18	26	3	4	0	0	5	2	4	2	34
	Not Marked	28	12	1	1	0	0	1	0	5	4	46

Appendix Table B-22. Distribution of percent of total mortality of each stock for the base case and Case 7D. Shaded area indicates selective fishery.

Case 7D. All Hook and Line Fisheries Selective, Ventral Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	42	57	0	0	0	0	0	0	0	0	0
	Not Marked	69	30	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	28	37	6	8	0	0	0	0	0	0	20
	Not Marked	44	19	3	2	0	0	0	0	0	0	30
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	31	3	11	18	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	38	21	0	0	9	32	0	0	0	0	0
	Not Marked	72	10	0	0	5	11	0	0	0	1	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	19	25	2	3	2	6	5	0	4	2	31
	Not Marked	25	13	1	1	1	2	2	0	5	4	47
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	21	23	2	4	0	0	5	2	4	3	37
	Not Marked	29	12	1	1	0	0	1	0	5	4	47

Appendix Table B-23. **Distribution of percent of total mortality of each stock for the base case and Case 8A. Shaded area indicates selective fishery.**

Case 8A. All Fisheries Selective, Adipose Clip Mass Mark (Best Case)

Stock	Mark Status	Escpmnt	Fishery								
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	34	65	0	0	0	0	0	0	0	0	0
	Not Marked	69	31	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	25	42	7	9	0	0	0	0	0	0	17
	Not Marked	59	20	3	2	0	0	0	0	0	0	15
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	4	13	20	0	0	0	0	0	0	36
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	30	24	0	0	9	36	0	0	0	0	0
	Not Marked	72	10	0	0	5	11	0	0	1	1	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	5	29	2	3	2	7	6	0	5	2	39
	Not Marked	41	13	1	1	1	2	2	0	6	4	31
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	26	3	4	0	0	6	2	4	2	33
	Not Marked	47	11	1	1	0	0	1	3	5	4	26

Appendix Table B-24. **Distribution of percent of total mortality of each stock for the base case and Case 8B. Shaded area indicates selective fishery.**

Case 8B. All Fisheries Selective, Adipose Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	34	65	0	0	0	0	0	0	0	0	0
	Not Marked	69	31	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	25	41	7	9	0	0	0	0	0	0	17
	Not Marked	50	20	3	2	0	0	0	0	0	0	25
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	4	13	20	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	30	24	0	0	9	36	0	0	0	0	0
	Not Marked	72	10	0	0	5	11	0	0	1	1	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	10	29	2	3	2	7	6	0	5	2	34
	Not Marked	27	12	1	1	1	2	2	0	6	4	44
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	19	26	3	4	0	0	6	2	4	3	33
	Not Marked	35	11	1	1	0	0	2	2	5	4	38

Appendix Table B-25. **Distribution of percent of total mortality of each stock for the base case and Case 8C. Shaded area indicates selective fishery.**

Case 8C. All Fisheries Selective, Ventral Clip Mass Mark (Best Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	35	64	0	0	0	0	0	0	0	0	0
	Not Marked	69	30	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	26	41	7	9	0	0	0	0	0	0	17
	Not Marked	59	19	3	2	0	0	0	0	0	0	16
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	26	4	12	20	0	0	0	0	0	0	38
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	31	23	0	0	9	36	0	0	0	0	0
	Not Marked	72	11	0	0	5	11	0	0	0	1	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	5	28	2	3	2	7	6	0	4	2	40
	Not Marked	40	13	1	1	1	2	2	0	6	4	32
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	20	26	3	4	0	0	6	2	4	3	33
	Not Marked	47	12	1	1	0	0	1	3	5	4	26

Appendix Table B-26. **Distribution of percent of total mortality of each stock for the base case and Case 8D. Shaded area indicates selective fishery.**

Case 8D. All Fisheries Selective, Ventral Clip Mass Mark (Worst Case)

Stock	Mark Status	Escpmnt	Fishery									
			OutTr1	OutTr2	OutSp1	InTr1	InSp1	InSp2	InSp3	InNt1	InNt2	Term.Net
OutStk1	Base	39	60	0	0	0	0	0	0	0	0	0
	Mass Marked	41	58	0	0	0	0	0	0	0	0	0
	Not Marked	70	30	0	0	0	0	0	0	0	0	0
OutStk2	Base	27	37	7	9	0	0	0	0	0	0	19
	Mass Marked	30	37	7	8	0	0	0	0	0	0	19
	Not Marked	50	19	3	2	0	0	0	0	0	0	25
OutStk3	Base	26	3	13	20	0	0	0	0	0	0	38
	Mass Marked	30	3	12	17	0	0	0	0	0	0	37
	Not Marked											
InStk1	Base	30	22	0	0	9	38	1	0	0	0	0
	Mass Marked	38	21	0	0	8	32	0	0	0	0	0
	Not Marked	72	10	0	0	5	11	0	0	1	1	0
InStk2	Base	25	27	2	3	2	7	7	0	5	2	20
	Mass Marked	14	25	2	3	2	6	5	0	5	2	36
	Not Marked	27	12	1	1	1	2	2	0	6	4	45
InStk3	Base	19	25	3	4	0	0	6	2	4	3	34
	Mass Marked	22	23	3	4	0	0	5	2	4	3	34
	Not Marked	35	11	1	1	0	0	2	2	5	4	38

APPENDIX C.

EXAMPLE FORMAT FOR SELECTIVE FISHERY PROPOSALS

C.1 Elements of Proposed Selective Fisheries Programs

The Committee is aware that specific proposals for marking hatchery produced coho and chinook, and for implementing selective fisheries are being prepared for consideration. Although these proposals are likely to be generated by individual management entities, the effects of selective fishery programs are likely to extend beyond the local or regional level. Recognizing the interjurisdictional nature of selective fisheries and the importance of coordination and cooperation in realizing management success, the Committee recommends that initiating organizations include the following key elements in their proposals. These key elements will facilitate effective review by all affected jurisdictions.

C.1.1 Problem Statement

Since selective fisheries require major changes to current management practices, conditions should exist that compel managers to undertake these changes. A description of the current condition, including a statement that defines the need for change, will provide the context for the proposal. The statement may address a changing resource condition, an inability to affect necessary protection using existing management actions, and/or fishery outcomes that are considered unacceptable.

C.1.2 Objective

The objective of a selective fishery program should be to remedy the existing problems defined above. Continuation of the program should depend upon the ability to measure a specific outcome. If the problem is related to a resource condition, the objective will reflect desired changes in resource status. Current status of the species, stock or population, preferably in quantitative terms, would clarify the concern. For example, the objective may be to increase escapement of wild fish by reducing the rate of exploitation relative to levels measured in recent years. If the objective is to increase spawning escapement, then the statistic to be used in evaluating success must be specified (e.g., average percent increase over a base period).

The objective may address fishery objectives such as stable opportunity, in terms of season length or the number of anglers participating in the fishery. Again, the desired outcome must be specified in measurable terms. For example, if the objective is to increase harvest, then specification must include the magnitude of the effect in direct terms (e.g., average 200,000 angler trips over a three year period) or relative terms (e.g., a 10% increase over a base period average).

C.2 Description of the Proposal

The scope of the selective fishery program is defined by programs for marking, tagging, sampling, assessment and management, as well as a description of the selective fisheries involved.

C.2.1 Marking Program

The marking program that enables selective fishing is defined by: (1) the stocks to be marked; (2) the portion of the production to be marked; and (3) the type of mark to be employed. Logistical considerations such as schedules and costs are delineated in another section of the proposal description.

C.2.2 CWT Tagging Program

The CWT tagging program should be described with respect to estimating stock specific fishery effects of interest to the evaluation of the selective fisheries program and to the generation of information required for stock assessment and fishery management. A description of the existing program will provide a perspective for understanding the degree of change necessitated by implementation of the selective fishery program. A description of the tagging design should include the total release size and the proportion to be CWT.

C.2.3 The Sampling Program

The sampling program description should identify changes to existing programs necessitated by the selective fishery program. This program is obviously tied to the design of the tagging program. Recognizing the interjurisdictional nature of coho and chinook management, a description of sampling program changes is incomplete if it does not include implications for fishery sampling by jurisdictions beyond the region in which the selective fishery proposal originates.

Important elements of the sampling program description include plans for collection of information within the selective fisheries such as CWT's, encounters of marked/unmarked fish, catches and effort. Sampling of non-selective fisheries should be included as well as the description of selective fishery activities.

Escapement sampling program design is likely to change with implementation of a hatchery marking program and design modifications should be included.

C.2.4 The Assessment Program

The assessment program should describe the quantitative management tools used to predict the expected outcomes of the program as well as those used to estimate the actual outcomes. The description of the stock impact assessment methods should include: (1) fishery simulation models used in management planning; (2) post-season stock contribution methods and models (e.g., stock composition models); and (3) in-season fishery management procedures (e.g., terminal area runsize estimators). Changes anticipated in definition of quantitative fishery management controls, such as harvest quotas (due to change in stock composition and impact of landed catch) should be included.

C.2.5 General Management Activities

General management activities requiring description include enforcement and public education. These are essential components of a successful selective fishery, since selective fishing represents a substantial change in angler behavior.

A description of the *fisheries to be selective* must include definitions of gear type (e.g., recreational, hook-and-line), time (e.g., seasons) and areas for which the selective regulations apply. Regulations defining the selection process can vary and must be specified. For example, limited retention of unmarked fish may be allowed as an alternative to a complete selective fishery. For recreational fisheries, selectivity is regulated by the daily bag limit. For commercial fisheries, selectivity could be regulated by landing limits.

C.2.6 Implementation

In order to provide affected management entities and fishery participants an opportunity to respond to a selective fishery proposal, *activity schedules* and *decision processes* of the program must be defined.

A specific time-line for activities is important since marking and tagging projects will be initiated approximately two years in advance of the actual selective fishery. For the purpose of program evaluation, the proposal should specify the period of time required to effectively assess actual outcomes.

If the proposal affects existing management agreements, compacts, laws, policies or plans between the initiator of a proposal and affected parties, then the process required for modification of those management structures must be described. For example, it is likely that selective fisheries will result in modification of harvest sharing or hatchery production levels and will require changes to programs for collection of information vital to the management of wild salmon (e.g., the CWT program). If these issues are important elements of existing management agreements or plans, then the process for modification of those agreements needs to be specified.

C.2.7 Costs

To appreciate the net benefit of a selective fishery program, some detail of the cost must be included with a proposal. Direct costs to be detailed include capital outlays (equipment) and annual expenditures for the marking, tagging and sampling programs. New expenses associated with the selective fishery program, such as for enforcement or public education, should be included. Given that the effects of selective fisheries extend beyond the initiating management jurisdiction, estimates for likely costs incurred by other management entities should be included (although it is recognized that these estimates would most appropriately be provided by the affected management entities themselves).

C.2.8 Analysis and Estimation of Effects

Benefits of a selective fishery proposal are described by the expected changes in fishery impacts and a comparison of those changes with the objectives of the program. The Selective Fisheries Evaluation Committee has developed a simulation model to estimate the expected changes resulting from selective fisheries. The SFM is available for application to specific selective fishery proposals. However, the predicted effects are sensitive to the input data. Parameters describing the specific stock and fishery characteristics, and assumptions related to processes such as release mortality, migration, effort changes in the fishery and mortality caused by marking would need to be defined for each proposal.

C.2.9 Alternatives to the Selective Fishery Proposal

Management actions to address a problem, such as the need to reduce impacts on wild fish, are obviously not limited to selective fisheries. The problem may also be addressed by regulating fisheries by seasonal closures, area restrictions, daily bag limits or other catch limitations. In order to judge the effectiveness of selective fisheries, a proposal should include comparisons to alternative management actions.

C.2.10 Evaluation

Uncertainty about outcomes from a selective fishery program makes it important to plan for direct measurement of actual effects. If the problem statement addresses the status of wild fish, then what wild fish characteristics must be measured to evaluate the program's success? How will outcomes be analyzed and for how many years must data be collected to effectively conclude that a change is attributable to the selective fishery? If fishery outcomes are important to the definition of success, then what statistic will be used to gauge improvement in the current condition? Are angler surveys planned to address popular appreciation for the dramatic change in fishing practices expected with selective fisheries? All expected outcomes have actual counterparts that must be measured and analyzed in order to provide accountability of management actions. In addition, actual expenses for the program should be compared to the predicted expenses.