Agenda Item F.1
Situation Summary
November 2010

PRESEASON SALMON MANAGEMENT SCHEDULE FOR 2011

To plan, announce, and meet *Federal Register* deadlines for public hearing sites and the entire preseason salmon management process, staff needs to confirm details of the process prior to the end of November. The proposed 2011 process and schedule are contained in Agenda Item F.1.a, Attachment 1.

For 2011, Council staff recommends one salmon management option hearing per coastal state, the same schedule as in 2010. The hearings would be:

March 28, 2011 Westport, Washington and Coos Bay, Oregon
March 29, 2011 Eureka, California

In 2011, the March Council meeting will occur in Vancouver, Washington and the April Council meeting in San Mateo, California. Therefore, the public comment period on Monday of the April meeting in San Mateo also serves as a public comment opportunity. If the states desire to have additional hearings, we suggest they organize and staff them as was done in past years. The table below provides the public attendance at the hearing sites since 1997 for Council reference.

Hearing Site Location[1/]	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Westport	22	4	18	24	30	11	16	16	25	26	34	20	27	21
Astoria	16		14											
Tillamook		28		13	16 [2/]	18 [2/]								
Coos Bay	27	15	31	36	18	40	26	26	105	146	43	60	108	60
Eureka	27	16	18	37	12	25	46	-				167	65	34
Ft. Bragg								27	38					
Sacramento		13												
Santa Rosa				4						500	35			
Moss Landing[2/]		100	51	50	33	14								

1/ Sites in bold are proposed for Council staffing in 2011.
2/ Hearing staffed by state personnel.

Council Action:

1. **Confirm Council-staffed hearing sites and state intentions for additional hearings.**
2. **Approve staff's overall proposed schedule and process for developing 2011 ocean salmon management measures.**

Reference Materials:

1. Agenda Item F.1.a, Attachment 1: Pacific Fishery Management Council Schedule and Process for Developing 2011 Ocean Salmon Fishery Management Measures.

Agenda Order:

a. Agenda Item Overview **Chuck Tracy**
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Adopt a 2011 Preseason Management Schedule

PFMC
10/4/10

PACIFIC FISHERY MANAGEMENT COUNCIL SCHEDULE AND PROCESS FOR DEVELOPING 2011 OCEAN SALMON FISHERY MANAGEMENT MEASURES

Nov 3-9, 2010	The Council and advisory entities meet at the Hilton Orange County, Costa Mesa, California, to consider any changes to methodologies used in the development of abundance projections or regulatory options.
Jan. 18-21, 2011	The Salmon Technical Team (STT) and National Marine Fisheries Service (NMFS) economist meet in Portland, Oregon to draft *Review of 2010 Ocean Salmon Fisheries*. This report summarizes seasons, quotas, harvest, escapement, socioeconomic statistics, achievement of management goals, and impacts on species listed under the Endangered Species Act. (February 8 print date, available on-line February 11.)
Feb. 8-11	STT meets in Portland, Oregon to complete *Preseason Report I Stock Abundance Analysis for 2011 Ocean Salmon Fisheries*. This report provides key salmon stock abundance estimates and level of precision, harvest and escapement estimates when recent regulatory regimes are projected on 2011 abundance, and other pertinent information to aid development of management options (February 17 print date, February 18 mailed to the Council and available on-line).
Feb. 12 through Mar. 4	State and tribal agencies hold constituent meetings to review preseason abundance projections and range of probable fishery options.
Feb. 18	Council reports summarizing the 2010 salmon season and salmon stock abundance projections for 2011 are available to the public from the Council office.
Mar. 5-10	Council and advisory entities meet at the Hilton Vancouver Washington to adopt 2011 regulatory options for public review. The Council addresses inseason action for fisheries opening prior to May 1 and adopts preliminary options on March 7, adopts tentative options for STT analysis on March 8, and final options for public review on March 10.
Mar. 14-18	The STT completes *Preseason Report II: Analysis of Proposed Regulatory Options for 2011 Ocean Salmon Fisheries* (March 21 print date, March 22 available to the public).
Mar. 15 though Apr. 7	Management agencies, tribes, and public develop their final recommendations for the regulatory options. North of Cape Falcon Forum meetings are scheduled for March 15 in Olympia, Washington, March 16 in Lacey, Washington and April 5-6 in Lynwood, Washington.
Mar. 22	Council staff distributes *Preseason Report II: Analysis of Proposed Regulatory Options for 2011 Ocean Salmon Fisheries* to the public. The report includes the public hearing schedule, comment instructions, option highlights, and tables summarizing the biological and economic impacts of the proposed management options.

Mar. 28-29	Sites and dates of public hearings to review the Council's proposed regulatory options are: Westport, Washington (March 28); Coos Bay, Oregon (March 28); and Eureka, California (March 29). Comments on the options will also be taken during the Council meeting on April 11 in San Mateo, California.
Apr. 9-14	Council and advisory entities meet to adopt final regulatory measures at the San Mateo Marriott, San Mateo, California. *Preseason Report II: Analysis of Proposed Regulatory Options for 2011 Ocean Salmon Fisheries* and information developed at the Council meeting is considered during the course of the week. The Council will tentatively adopt final regulatory measures for analysis by the STT on April 12. Final adoption of recommendations to NMFS are tentatively scheduled to be completed on April 14.
Apr. 15-20	The STT and Council staff completes *Preseason Report III: Analysis of Council-Adopted Regulatory Measures for 2011 Ocean Salmon Fisheries* (April 21 print date, mailed to the Council and available to the public April 22). Council and NMFS staff completes required National Environmental Policy Act documents for submission.
Apr. 22	Council staff distributes adopted ocean salmon fishing management recommendations, and *Preseason Report III* is made available to the public.
May 1	NMFS implements Federal ocean salmon fishing regulations.

PFMC
10/13/10

Agenda Item F.1.b
Supplemental STT Report
November 2010

SALMON TECHNICAL TEAM REPORT ON PRESEASON SALMON MANAGEMENT SCHEDULE FOR 2011

The Salmon Technical Team (STT) is concerned that the February 8-11 schedule for completion of Preseason I Stock Abundance Analysis for 2011 Ocean Salmon Fisheries is too early to provide enough time for development of all the preseason forecasts. The following week (February 14-18) four members of the STT will be attending the Pacific Salmon Commission meeting and will not be available to work on the report. The STT would like the Council to consider delaying the work session to the next week with completion of the report and availability on the Council website on February 25. The STT acknowledges that this date precludes inclusion of the report in the briefing package for the March meeting.

PFMC
11/05/10

FISHERY MANAGEMENT PLAN AMENDMENT 16, ANNUAL CATCH LIMITS AND ACCOUNTABILITY MEASURES

At its September 2010 meeting the Council adopted alternatives, including preliminary preferred alternatives, to release for public review prior to taking final action on Amendment 16 to the Salmon Fishery Management Plan (FMP). The alternatives addressed the following topics: stock classification, status determination criteria (SDC), overfishing limit (OFL)/acceptable biological catch (ABC)/annual catch limit (ACL) reference point framework, accountability measures (AMs), and *de minimis* fishery provisions (Agenda Item F.2.a, Attachment 1). Since September, the ad hoc Salmon Amendment Committee (SAC) has reviewed the alternatives and requests Council clarification and guidance on several issues (Agenda Item F.2.b, SAC Report) so the SAC can complete a draft Environmental Assessment (EA) to inform the remainder of the decision-making process.

It has become necessary to delay taking final Council action on Amendment 16 until after the November 2010 meeting. The Council should consider workload and administrative timelines for taking final action on Amendment 16, completing the EA, and implementing a final rule.

In March 2010, the Council recommended state and tribal co-managers provide input on Salmon Technical Team (STT) proposals for trigger points used to identify potential overfishing concerns for Puget Sound coho. With the subsequent development of Amendment 16 SDC alternatives, it became apparent the co-manager input would also be instrumental in developing new SDC alternatives for both Puget Sound and Washington Coastal coho. Therefore, Council staff requested the co-managers respond to the alternative SDC reference points developed by the STT for use in Amendment 16 (Agenda Item F.2.a, Attachment 2). This will allow the SAC to complete an EA using appropriate assumptions for SDC reference points.

Council Task:

1. **Provide guidance on development and analysis of alternatives.**
2. **Provide guidance on timelines for final action and implementation of Amendment 16.**

Reference Materials:

1. Agenda Item F.2.a, Attachment 1: Salmon FMP Amendment 16: Tentative Range of Alternatives for Public Review.
2. Agenda Item F.2.a, Attachment 2: Letter to co-managers regarding status determination criteria for Washington Coastal and Puget Sound coho stocks.
3. Agenda Item F.2.b, SAC Report: Salmon Amendment Committee Issue Paper Regarding Alternative for Amendment 16 to the Salmon Fishery Management Plan.
4. Agenda Item F.2.c, Public Comment.

Agenda Order:

a. Agenda Item Overview **Chuck Tracy**
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action:** Review the Adopted Alternatives and Provide Further Guidance for the Public Review Draft

PFMC
10/18/10

Salmon FMP Amendment 16: Tentative range of alternatives for public review. Based on Council staff interpretation of motion 3 and amendments at the September 2010 Council meeting.

Classifying Stocks in the FMP

Alternative 1

Status Quo
All stocks currently in FMP remain in the fishery.

Alternative 2

Minor reorganization + 3 Complexes
Smith River Chinook separated from CA coastal Chinook (ESA listed); Rogue coho out of OCN, into SONCC; CVF, SONC, FNMSS Chinook complexes

Alternative 3

Ecosystem Components + 2 Complexes
Smith River Chinook, Rogue coho same as Alt. 2; Non-ESA FNM Chinook and pink are EC; CVF, SONC Chinook complexes

Prelimimary Preferred Alternative

All stocks currently in FMP remain in the fisheryMinor reorganization + 2 Complexes and no Ecosystem Components

Smith River Chinook separated from CA coastal Chinook (ESA listed); Rogue coho out of OCN, into SONCC; CVF, SONC Chinook complexes

International Exceptions

Alternative 1

Status Quo
None Specified

Alternative 2

Non-ESA PST stocks
URB, CR Summers, OR/WA Coastal fall, Canadian Chinook;
WA Coastal, Puget Sound, Canadian coho;
Puget Sound and Canadian pink salmon

Alternative 3

Non-EC PST stocks
CR Summers, Canadian Chinook;
WA Coastal, Puget Sound, Canadian coho

Prelimimary Preferred Alternative

Non-ESA PST stocks - 14 Chinook, 11 coho and 2 pink
URB, CR Summers, OR/WA Coastal fall, Canadian Chinook;
WA Coastal, Puget Sound, Canadian coho;
Puget Sound, Canadian pink

Status Determination Criteria for Overfishing and Overfished

Alternative 1

Status Quo - SDC Not explicit in FMP

Overfishing: STT Assessment

Overfished: STT Assessment, Overfishing Concern triggered (3 consecutive years < conservation objective

Approaching Overfished: 2-years below conservation objective and Conservation Alert triggered

Rebuilt: Spawning escapement > conservation objective (single year) or rebuilding plan

Alternatives 2 & 4

Single-year; MSST = 0.5*Smsy (Alt 2) & 0.75*Smsy (Alt 4)

Overfishing: Exploitation rate >Fmsy

Overfished: Spawning Escapement < MSST

Approaching Overfished: Projected spawning escapement < MSST

Rebuilt: Spawning Escapement > Smsy

Alternatives 3 & 5 & 8

3-year Geo Mean; MSST = 0.5*Smsy (Alt 3) & 0.75*Smsy (Alt 5) & 0.86*Smsy (Alt 8)

Overfishing: Exploitation rate >Fmsy (single-year)

Overfished: 3-year GeoMean Spawning Escapement < MSST

Approaching Overfished: Recent 2-year and projected GeoMean spawning escapement < MSST

Rebuilt: 3-year GeoMean spawning Escapement > Smsy

NEW Alternatives 6 & 7

3-year Arithmetic Mean; MSST = 0.5*Smsy (Alt 6) & 0.75*Smsy (Alt 7)

Overfishing: Exploitation rate >Fmsy (single-year)

Overfished: 3-year arithmetic mean Spawning Escapement < MSST

Approaching Overfished: Recent 2-year and projected arithmetic mean spawning escapement < MSST

Rebuilt: 3-year arithmetic mean spawning Escapement > Smsy

Preliminary Preferred Alternative

Blend of 3-year Arithmetic Mean and single year; MSST = 0.5*Smsy

Overfishing: Exploitation rate >Fmsy (single-year)

Overfished: 3-year Arithmetic Mean Spawning Escapement < MSST

Approaching Overfished: Recent 2-year and projected Arithmetic Mean spawning escapement < MSST

Rebuilt: Spawning Escapement > Smsy (single-year)

OFL, ABC, and ACL Specification

Alternative 1

Status Quo - Not Defined in FMP

None Specified

Alternative 2

Catch-Based (C-Based)

OFL: Fmsy*N

ABC: Fabc*N: Fabc=Fmsy*0.95 (Tier 1 stocks; KRFC) or Fabc=Fmsy*0.90 (Tier 2 stocks; SRFC, Hoh or FNM SpSu)

ACL: Fabc*N

Alternative 3 - Preliminary Preferred

Spawning escapement-Based (S-Based)

OFL: (1-Fmsy)*N

ABC: (1-Fabc)*N: Fabc=Fmsy*0.95 (Tier 1 stocks; KRFC) or Fabc=Fmsy*0.90 (Tier 2 stocks; SRFC, Hoh or FNM SpSu)

ACL: (1-Fabc)*N

Accountability Measures

Alternative 1

Status Quo

Target conservation objective except at low abundance

No current FMP measures specified as AM.

Alternative 2 - Preliminary Preferred

Modify Overfishing Criteria

Target Conservation Objective except at high (ACL) or low (de minimis) abundance

Rename Overfishing Concern to Abundance Alert

Increase flexibility to implement *de minimis* fisheries under Conservation Alert (delete fishery closure requirement)

Retain notification measures, other current FMP measures

Reevaluate ACL if exceeded more than 1 in 4 years: Uncertainty tiers, ACT, S/R update, etc.

Alternative 3

Replace Overfishing Criteria

Target Conservation Objective except at high (ACL) or low (de minimis) abundance

Eliminate Conservation Alert, Overfishing Concern and associated actions

AM for SDC wouild be developed

AM for ACL would include other current FMP measures

Reevaluate ACL if exceeded more than 1 in 4 years: Uncertainty tiers, ACT, S/R update, etc.

De minimis **Fishing Provisions**

Stock specific abundance levels identified represent approximate examples under the assumption that MSST=0.5*Smsy unless otherwise noted.

Alternative 1

Status Quo

SRFC: 0% SRR below 122K

KRFC: A-15; ~25% SRR between 47K and 30K, less below 30K

US v Wash, Hoh v Baldrige: No Change

Alternative 2

No fishing below midpoint of Smsy-MSST

SRFC: 25% SRR between 162.7K and 122K, 0% at 91.5K

KRFC: 25% SRR between 54.3K and 40.7K, 0% at 30.5K

US v Wash, Hoh v Baldrige: No Change

Alternative 2b

No fishing below midpoint of Smsy-MSST; KRFC conservation objective = 35K

SRFC: 25% SRR between 162.7K and 122K, 0% at 91.5K

KRFC: 25% SRR between 46.7K and 40.7K, 0% at 30.5K

US v Wash, Hoh v Baldrige: No Change

Alternative 3

No fishing below MSST

SRFC: 25% SRR between 162.7K and 81.3K, 0% at 61K

KRFC: 25% SRR between 54.3K and 27.1K, 0% at 20.35K

US v Wash, Hoh v Baldrige: No Change

Alternative 3b

No fishing below MSST: KRFC conservation objective = 35K

SRFC: 25% SRR between 162.7K and 81.3K, 0% at 61K

KRFC: 25% SRR between 46.7K and 27.1K, 0% at 20.35K

US v Wash, Hoh v Baldrige: No Change

Alternative 4

No fishing below 1/2 of MSST

SRFC: 25% SRR between 162.7K and 40.7K, 0% at 30.5K

KRFC: 25% SRR between 54.3K and 13.6K, 0% below 10.2K

US v Wash, Hoh v Baldrige: No Change

Preliminary Preferred Alternative

No defined structure for reducing F below 25% when below midpoint of Smsy and MSST; KRFC conservation objective = 35K

SRFC: 25% SRR between 162.7K and 91.5K, F < 25% below 91.5K

KRFC: 25% SRR between 46.7K and 30.5K, F < 25% below 30.5K

US v Wash, Hoh v Baldrige: No Change

For the purpose of implementing de minimis fishing provisions Cape Falcon will be the northern limit for impacts counted toward SRFC and KRFC allowable F.

Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101, Portland, OR 97220-1384
Phone 503-820-2280 | Toll free 866-806-7204 | Fax 503-820-2299 | www.pcouncil.org
Mark Cedergreen, Chairman Donald O. McIsaac, Executive Director

September 24, 2010

Washington State and Tribal Co-Managers

Dear Co-manager:

The Pacific Fishery Management Council (Council) is currently developing a fishery management plan (FMP) amendment (Amendment 16) to implement changes required by the Magnuson-Stevens Reauthorization Act (Act). To ensure consistency with the Council's evaluation of "overfished" stocks and "overfishing," the Act requires specification of annual catch limits (ACL) and, to be consistent with the National Standard 1 Guidelines, the specification of quantifiable status determination criteria (SDC). The Act allows an exception to the ACL requirement for stocks managed under an international agreement, such as the Pacific Salmon Treaty. Alternatives currently under consideration by the Council invoke this exception for coho stocks from Puget Sound and Washington coast, but these stocks would still require SDC. The SDC must include a minimum stock size threshold (MSST) defined in terms of spawner abundance, and the National Standard 1 Guidelines recommend that the MSST be greater than or equal to one half of maximum sustainable yield spawning escapement (S_{MSY}). The SDC also must include specification of a maximum fishing mortality threshold (MFMT) that is less than the maximum sustainable yield exploitation rate (F_{MSY}).

The National Marine Fisheries Service is required to report stock status in its annual Report to Congress on the Status of Fisheries. For this purpose the Council would conclude that overfishing had occurred if the fishing mortality rate exceeded the MFMT (in a single year), and the Council would classify a stock as "overfished" if spawner abundance fell below the MSST (either in a single year or as a mean of three years; both alternatives are being considered). If a stock is classified as "overfished," the Council would presumably initiate an assessment of factors contributing to that status and would consider adopting a rebuilding plan, analogous to the current process when an overfishing concern is triggered (e.g., Queets coho in 2009).

The Council's Salmon Technical Team (STT) has developed alternative methods for defining SDC for Washington coast coho stocks. The STT originally proposed to use the midpoint of the escapement goal range as an S_{MSY} proxy, and one half of that as the MSST. The midpoint was proposed because the Pacific Salmon Commission uses that reference point to determine categorical status for evaluating compliance with the Pacific Salmon Treaty's Southern Coho Management Plan (Annex IV, Chapter 5, December, 2008). Estimates of F_{MSY} have not been defined for coastal coho stocks by the tribal and state co-managers. The STT developed direct estimates of both F_{MSY} and S_{MSY} from spawner-recruit analysis using escapement data for coastal coho stocks and ocean recruits derived from backward Fishery Regulation Assessment Model runs (see attached appendix from the Amendment 16 Draft Environmental Assessment). The same method was used for the Queets and western Strait of Juan de Fuca coho overfishing reviews last year. The STT is considering recommending the F_{MSY} estimates as the basis for defining MFMTs, and recommending use of the S_{MSY} estimates to calculate the MSSTs for coastal coho stocks.

For Puget Sound coho stocks, the STT recommended using the "normal" fishing mortality ceilings as estimates of F_{MSY} to develop MFMTs. Options for MSSTs include the escapement associated with the "low/critical" abundance breakpoint and the "low" harvest rate ceiling, or half of the escapement associated with the "normal/low" breakpoint and the "normal" harvest rate ceiling.

It is important that the Council hear from the co-managers regarding these STT proposals. The Council adopted alternatives for Amendment 16 to release for public review last week, which include some of the reference points described above, which in turn will affect the analysis of impacts from the alternatives. It is important for the analysis to reflect appropriate assumptions so that the Council can make informed decisions, and constituents can contribute relevant comments. If the co-managers have preferences or other recommendations for SDC, the Council would greatly appreciate receiving those recommendations as soon as possible.

The Council will consider clarification of adopted alternatives and additional guidance to developing analysis of Amendment 16 at its November meeting. The briefing book deadline for the November Council meeting is October 15, and comments received by the briefing book deadline will be distributed to all Council members prior to the November meeting.

Thank you for your attention to these issues, and the Council looks forward to hearing from the co-managers. If you have questions or need any assistance with these issues, please call on Council staff officer Chuck Tracy.

Sincerely,

D. O. McIsaac, Ph.D.
Executive Director

CAT:kam

Attachment: Appendix E from the Draft Environmental Assessment for Amendment 16.

c: Council Members
SAC
Mr. Craig Bowhay
Mr. Andy Rankis
Ms. Sandy Zeiner

APPENDIX E: DEVELOPMENT OF REFERENCE POINTS FOR WASHINGTON COASTAL COHO STOCKS

Estimates of biological reference points (F_{MSY} and S_{MSY}) are lacking for Washington coastal coho stocks. These reference points are needed to develop needed to develop required status determination criteria (SDC) for Amendment 16 to the Salmon Fishery Management Plan. Required SDC include a maximum fishing mortality threshold (MFMT) and a minimum stock size threshold (MSST). One solution to this problem is to use a proxy value for F_{MSY} derived from other stocks to develop MFMTs and to develop MSSTs from the current conservation objectives for Washington coastal coho. However, data are available to derive stock specific estimates of the necessary reference points for Washington coastal stocks, eliminating the need for a proxy.

Methods

Spawning escapement estimates and reconstructed ocean abundance for natural coho stocks were extracted from outputs of backward coho FRAM runs for each individual year from 1986-2008. The initial ocean abundances were scaled by a factor of 0.812, which is the product of natural survival (1-natural mortality) over the 5 time periods used in the coho FRAM, and represents the probability of a fish at the beginning of the first time period surviving to spawn in the absence of fishing. This scales the initial ocean abundance to adult-equivalent (AEQ) recruits, with the result that exploitation rates are also in terms of AEQ.

Beverton-Holt (equation 1) and Ricker (equation 2) SRRs were fitted to the data for each stock. In the analyses done in support of current FMP reference points for Puget Sound stocks, Beverton-Holt SRRs were used. There is some evidence to support this form of relationship, but this SRR always produced higher intrinsic productivity than a Ricker SRR fitted to the same data, with a consequently higher estimate of F_{MSY}, and in some cases the best fit of a Beverton-Holt SRR was spawner independent (i.e., F_{MSY} = 1.0 and S_{MSY} = 0). For this reason, and the fact that Ricker SRRs were used in developing F_{MSY} values for Chinook, both forms were examined for coho.

$$R = \frac{aS}{(b+S)} \qquad (1)$$

$$R = Se^{(\alpha-\beta S)} \qquad (2)$$

Beverton-Holt SRRs were fitted by non-linear least-squares regression of recruits on spawning escapement. For the Beverton-Holt SRR S_{MSY} was calculated using equation (3).

$$S_{MSY} = \sqrt{ab} - b \qquad (3)$$

F_{MSY} was calculated as $(R_{MSY}-S_{MSY})/R_{MSY}$, and R_{MSY} was calculated by substituting S_{MSY} from equation (3) into equation (1).

Ricker SRR were fitted using the procedures described in STT (2005), including correction for process error.

Results and Discussion

Fits of Beverton-Holt SRRs (Table E-1) do not appear to provide meaningful results. With the exception of the Skagit management unit, all estimates of S_{MSY} are below current goals (Tables E-2 and E-3) and all estimates of F_{MSY} are greater than 0.8. For the Snohomish, Big Beef Creek, and Quillayute fall stocks, the best fits are independent of spawning escapement and expected yield is maximized by harvesting 100% of

F-fishing mortality rate; MFMT-maximum fishery mortality threshold; MSST-minimum stock size threshold; MSY-maximum sustainable yield; NS1Gs-National Standard 1 Guidelines; OFL-overfishing limit; S-spawning escapement; SDC-status determination criteria

the abundance. For these reasons, results from fitting Beverton-Holt SRRs are excluded from further consideration.

The Ricker SRRs appear to be much more reasonable fits of the data than those of the Beverton-Holt (Figure E-1). For Quillayute fall, Queets, and Hoh stocks, all estimates of S_{MSY} (Table E-4) are within the range of estimates used to develop current management objectives (Table E-3) (Lestelle, et al. 1984). Estimates of F_{MSY} range from 0.59 for Quillayute fall coho to 0.69 for the Hoh and Grays Harbor.

Recommendations

In light of these results, we recommend that reference points in Table E-4 be used as SDC for Washington Coastal stocks with MFMT = F_{MSY} and MSST = 0.5*S_{MSY}.

F-fishing mortality rate; MFMT-maximum fishery mortality threshold; MSST-minimum stock size threshold; MSY-maximum sustainable yield; NS1Gs-National Standard 1 Guidelines; OFL-overfishing limit; S-spawning escapement; SDC-status determination criteria

Table E-1. Parameters and associated reference points from fitting Beverton-Holt SRRs to Puget Sound and Washington coast coho stocks, and MSST calculated as 0.5*S_{MSY}. Big Beef Creek, Dungeness, and Chehalis do not encompass the entire management unit, so the S_{MSY} and MSST are not applicable to the FMP stock.

Stock	a	b	F_{MSY}	S_{MSY}	MSST
Skagit	146286	41734.4	0.47	36,401	18,201
Stillaguamish	39568	700.5	0.87	4,564	2,282
Snohomish	185475	0.0	1.00	0	0
Big Beef Creek (Hood Canal)	34523	0.0	1.00	0	0
Dungeness (Strait of Juan de Fuca)	3291	87.2	0.84	448	224
Quillayute Fall	14592	0.0	1.00	0	0
Hoh	7421	107.6	0.88	786	393
Queets	14647	254.8	0.87	1,677	839
Chehalis (Grays Harbor)	67623	1792.4	0.84	9,217	4,609

Table E-2. Current proposed FMP reference points for Puget Sound Management units.

Management Unit	MFMT	S_{MSY}	MSST
Skagit	0.60	25,000	14,857
Stillaguamish	0.50	10,000	6,100
Snohomish	0.60	50,000	31,000
Hood Canal	0.65	14,362	10,217
Strait of Juan de Fuca	0.60	11,000	7,007

Table E-3. Current proposed reference points for Washington coastal coho stocks.

Management Unit	MFMT	Escapement goal	S_{MSY}
Quillayute fall	F_{MSY} proxy	6,300-15,800	4,700-9,600
Hoh	F_{MSY} proxy	2,000-5,000	1,500-3,100
Queets	F_{MSY} proxy	5,800-14,500	4,200-9,400
Grays Harbor	F_{MSY} proxy	35,400	-

F-fishing mortality rate; MFMT-maximum fishery mortality threshold; MSST-minimum stock size threshold; MSY-maximum sustainable yield; NS1Gs-National Standard 1 Guidelines; OFL-overfishing limit; S-spawning escapement; SDC-status determination criteria

Table E-4. Parameters and associated reference points from fitting Ricker SRRs to Washington Coast coho stocks. Chehalis does not encompass the entire management unit, so the S_{MSY} and MSST are not applicable to the FMP stock.

Stock	α'	β	F_{MSY}	S_{MSY}	MSST
Quillayute Fall	4.36	0.0000987	0.59	5,873	2,937
Hoh	6.34	0.0002729	0.69	2,520	1,260
Queets	6.10	0.0001232	0.68	5,500	2,750
Chehalis (Grays Harbor)	6.43	0.0000303	0.69	22,802	11,401

F-fishing mortality rate; MFMT-maximum fishery mortality threshold; MSST-minimum stock size threshold; MSY-maximum sustainable yield; NS1Gs-National Standard 1 Guidelines; OFL-overfishing limit; S-spawning escapement; SDC-status determination criteria

SALMON AMENDMENT COMMITTEE ISSUE PAPER REGARDING ALTERNATIVES FOR AMENDMENT 16 TO THE SALMON FISHERY MANAGEMENT PLAN

After initial consideration of the alternatives adopted for public review at the September 2010 Council meeting, including preliminary preferred alternatives (PPA), the Salmon Amendment Committee (SAC) has the following comments and requests for further guidance from the Council.

Classification/Annual Catch Limits

Under the PPA for stock classification, all stocks currently in the salmon fishery management plan (FMP) remain in the fishery, therefore, all stocks that are not Endangered Species Act (ESA), hatchery, or internationally managed stocks must have annual catch limits (ACL). The far north migrating spring summer (FNMSS) Chinook stocks (mid-Columbia, Grays Harbor, Queets, Hoh, and Quillayute spring/summer Chinook) meet those conditions so ACLs must be specified. The PPA does not include these stocks as a complex with an indicator stock, so each individual stock would require an ACL. Information necessary to establish and evaluate ACLs include:

- Preseason: an adult equivalent (AEQ) abundance forecast and the ACL exploitation rate (F_{ACL}).
- Postseason: actual preseason AEQ abundance and a postseason estimate of exploitation rate (F_t).

Based on the level of information available, it appears that specifying ACLs for Mid-Columbia and some Washington Coast spring stocks may not be possible. The SAC has identified several potential solutions:

- Identify Classification Alternative 2 as PPA (including FNMSS Stock Complex with Hoh spring Chinook as an indicator stock).
- Eliminate FNMSS stocks from fishery – not in need of Council conservation and management measures, including essential fish habitat (EFH). These stocks have base period exploitation rates in Council area fisheries of less than 5 percent, and probably less than 1 percent, which would be similar to species like chum and sockeye.
- Designate FNMSS stocks as ecosystem component (EC) – similar to elimination from the fishery, but would allow continued monitoring and reconsideration, if appropriate.

Status Determination Criteria

Puget Sound Pink Salmon

Puget Sound Pink salmon is an aggregate stock managed under the Pacific Salmon Treaty (PST), which is not exempt from status determination criteria (SDC) requirements. Therefore an F_{MSY} estimate (or proxy) and an annual postseason estimate of realized F_t will be required to evaluate overfishing. The FMP specifies a conservation objective of 900,000 natural spawners (or management consistent with the PST); 900,000 could serve as a maximum sustainable yield spawning level (S_{MSY}) proxy for specifying the minimum stock size threshold (MSST) and assessing overfished, approaching overfished and rebuilt status. However, estimating F_t for this stock aggregate would be difficult. Several options exist for specifying SDC for pink salmon:

- Eliminate the stock from the FMP and defer management to state/tribal co-managers, subject to jurisdictional limitations (possibly limited to Washington registered vessels). This would allow co-managers to set retention limits for commercial and recreational fisheries, but would eliminate designation of EFH for pink salmon. However, EFH protection would remain as a result of EFH designations for Puget Sound Chinook and coho.
- Determine if it is possible to calculate an aggregate F_t to evaluate overfishing.
- Divide the aggregate stock into component stocks and set individual stock status benchmarks.

Preliminary Preferred Alternative Ambiguity in Overfished and Rebuilt Status

For the Council's PPA, a stock would be overfished when the three year arithmetic mean of S is below the MSST (MSST = $0.5*S_{MSY}$), and rebuilt when a single year S exceeds S_{MSY}. The structure of the PPA could result in a stock being simultaneously overfished and rebuilt, which is not operationally feasible. Metrics used to determine overfished, approaching an overfished condition, and rebuilt status should be symmetrical (i.e., all based on either 1 or 3 year metrics) to avoid ambiguous status determinations and provide consistent measures of stock status.

Appropriateness of Geometric or Arithmetic Mean

Given the inherent variability of salmon population abundance and the semelparous nature of their reproduction, the SAC has determined that population status is best described using a three-year metric. The most appropriate metric for this purpose is the one best suited for lognormally distributed abundance data. The geometric mean, not the arithmetic mean, is the most appropriate measure of central tendency for lognormally distributed data. Furthermore, the SSC has concluded that "…SDC be based on 3-year geometric means as they will be less subject to random error (noise) in the estimation and evaluation process" (SSC supplemental statement, September 2010). The geometric mean is currently used in other aspects of salmon assessment and management, including the ongoing status reviews of all ESA listed species being conducted by NMFS.

Washington Coastal and Puget Sound Coho: S_{MSY} and F_{MSY} Assumptions

In developing the draft Environmental Assessment (EA) for Amendment 16, the SAC initially used the midpoint of the escapement goal range of Washington Coastal coho stocks as an S_{MSY} proxy, and one half of that as the MSST. The midpoint was proposed because the Pacific Salmon Commission uses that reference point to determine categorical status for evaluating compliance with the PST's Southern Coho Management Plan (Annex IV, Chapter 5, December, 2008). Estimates of F_{MSY} have not been defined for coastal coho stocks by the tribal and state co-managers. As part of the Amendment 16 process, direct estimates of both F_{MSY} and S_{MSY} were developed from spawner-recruit analyses using escapement data for coastal coho stocks and ocean recruits derived from backward Fishery Regulation Assessment Model (FRAM) runs. The same method was used for the Queets and western Strait of Juan de Fuca coho overfishing reviews last year. The SAC requests guidance from the co-managers and Council on use of the F_{MSY} estimates as the basis for defining maximum fishing mortality thresholds (MFMTs), and use of the S_{MSY} estimates to calculate the MSSTs for coastal coho stocks.

For Puget Sound coho stocks, the SAC used the "normal" fishing mortality ceilings as estimates of F_{MSY} to develop MFMTs for Amendment 16 Draft EA. The SAC requests guidance on the following two options for MSST:

- The escapement associated with the "low/critical" abundance breakpoint and the "low" harvest rate ceiling,
- Half of the escapement associated with the "normal/low" breakpoint and the "normal" harvest rate ceiling.

Actions When SDC are Triggered

The MSA requires implementation of an FMP, plan amendment, or proposed regulations within two years of a stock becoming overfished. The adoption of rebuilt SDC and *de minimis* fishing provisions provide a default rebuilding plan for salmon stocks; however, other actions may be necessary, or at least worth considering in the event a stock is determined to be overfished. The current FMP includes specific actions for when an overfishing concern is triggered, some of which could be carried over for implementation when a stock is determined to be overfished according to the new overfished SDC. The Council may want to preserve the flexibility to implement actions through either process - amendment or proposed regulations - depending on the specific circumstances; however the Council should indicate the actions to be taken if the various SDC are triggered. For **example**:

When a stock is determined to be overfished the Council shall require an assessment of:

- The role of fishing, scientific and management uncertainty,
- The ability to achieve rebuilding within ten years under the current control rule and rebuilt SDC,
- Management actions necessary to ensure rebuilding is achieved in the required time frame.

Pending the findings of the assessment, the Council also may:

- Consider if MSST and MFMT should be updated,
- Consider development of a rebuilding plan that includes measures or criteria other than what is included in the default rebuilding plan,
- Consider assessing the role of freshwater and marine survival in triggering the SDC.

When overfishing on a stock has occurred, the Council shall:

- Identify and, if possible, correct the cause of overfishing and ensure that current or future overfishing ends and is prevented. The STT will report in the SAFE document any instances of overfishing and identify the source(s) of mortality, and compare postseason exploitation rates with preseason expectations. The Council will then notify relevant management agencies so that they can respond to the overfishing appropriately.
- Implement AM(s) for when the ACL is exceeded, for those stocks/complexes that have ACLs specified. If overfishing occurs on these stocks, then the ACL will have also been exceeded. Therefore, AM(s) associated with exceeding the ACL will also be implemented if overfishing occurs on stocks with ACLs.

The SAC requests the Council consider the above **examples** and provide guidance on what actions should be included so the SAC can develop appropriate draft FMP language to be included in the next draft EA.

Annual Catch Limits

There were comments at the September meeting requesting consideration of using the tier limits in another way for stock complexes. Complexes by definition have components without directly estimated F_{MSY}, therefore it may be appropriate to consider using the lower of Tier 1 F_{ABC} ($0.95*F_{MSY}$) or Tier 2 F_{ABC} ($0.90*F_{MSY}$) for the indicator stock when accounting for scientific uncertainty. This would not change any of the proposed F_{ABC} levels in the three stock complexes identified in the alternatives because two (Central Valley Fall [CVF] and FNMSS) have Tier 2 indicator stocks, and the Klamath River fall Chinook (KRFC; indicator for the Southern Oregon/Northern California [SONC] Chinook complex) Tier 1 F_{ABC} (0.68) is lower than the proposed Tier 2 F_{ABC} (0.70). However, these circumstances could change as new information becomes available for KRFC or other potential indicator stocks (e.g., South Oregon Coast Chinook), or if the tier buffers are modified.

***De minimis* fishing provisions**

The Council's motion for a PPA specified that the exploitation rate was "unspecified" below the midpoint of the conservation objective and MSST. The SAC has characterized the Council's intent as an unspecified reduction from the *de minimis* fishing mortality rate below that midpoint. For SRFC and KRFC the midpoints are 91,500 and 26,250, respectfully. The SAC asks that the Council confirm or clarify their intent for the *de minimis* fishing PPA.

Schedule for Final Council Action

The Council has delayed taking final action on Amendment 16 until after the November 2010 meeting, and should consider a revised schedule. Final action in November was delayed because the draft EA would not be sufficiently complete in time for the November briefing book; specifically, the affected environment (Chapter 3) and analysis of alternatives (Chapter 4) were incomplete, and FMP language for the PPA could not be completed in time. Given the workload associated with the preseason planning process and other commitments, it would be difficult to complete these tasks before the June 2011 meeting. However, the SAC believes that final Council action in June 2011 would allow sufficient time to complete the draft EA, accomplish all of the internal review and comment processes, and have the final proposed rule published by March 1, 2012, in time for the 2012 preseason planning process.

PFMC
10/18/10

Agenda Item F.2.b
Supplemental SAC PowerPoint
November 2010

Salmon Amendment Committee Report

Amendment 16 to the Pacific Coast Salmon Fishery Management Plan

FNMSS Chinook

- ACL Specification Problematic for PPA
  - Insufficient information to manage individually
- Could form stock complex
  - Classification Alternative 2

FNMSS Chinook Complex

Table 2-5. Alternatives for identifying Chinook stock complexes and indicator stocks. Stock classification alternatives that the complex would be associated with are also identified (see Table 2-3).

Stock Complex	Component Stocks	Indicator Stocks	Stock Classification Alternative
Far-North-Migrating Spring/Summer Chinook (FNMSS)	Spring stocks from Oregon tributaries north of the Elk River (except Umpqua) Mid-Columbia River spring (Klickitat, Deschutes, John Day, Yakima) Grays Harbor spring Queets Spring/summer Hoh spring Quillayute summer	Hoh Spring	Alternative 2

FNMSS Chinook

- Evidence of similarity between WA coast spring and fall stocks
  - Ocean impacts similar
  - Springs are escapement indicator stock in PSC (monitored)
  - Springs not actively managed under PST (AABM, ISBM)
- SAC recommends forming third complex with all FNMSS Chinook initially (Alt 2)
  - Could modify composition after additional analysis

PPA SDC Overfished & Rebuilt

- OF'd: 3yr mean < MSST = ½ S_{MSY}
- Rebuilt: 1yr > S_{MSY}
- Defn. problem: simultaneous status
  - 10K, 10K, 40.7K $\bar{x}$=20.2K MSST=20.35K

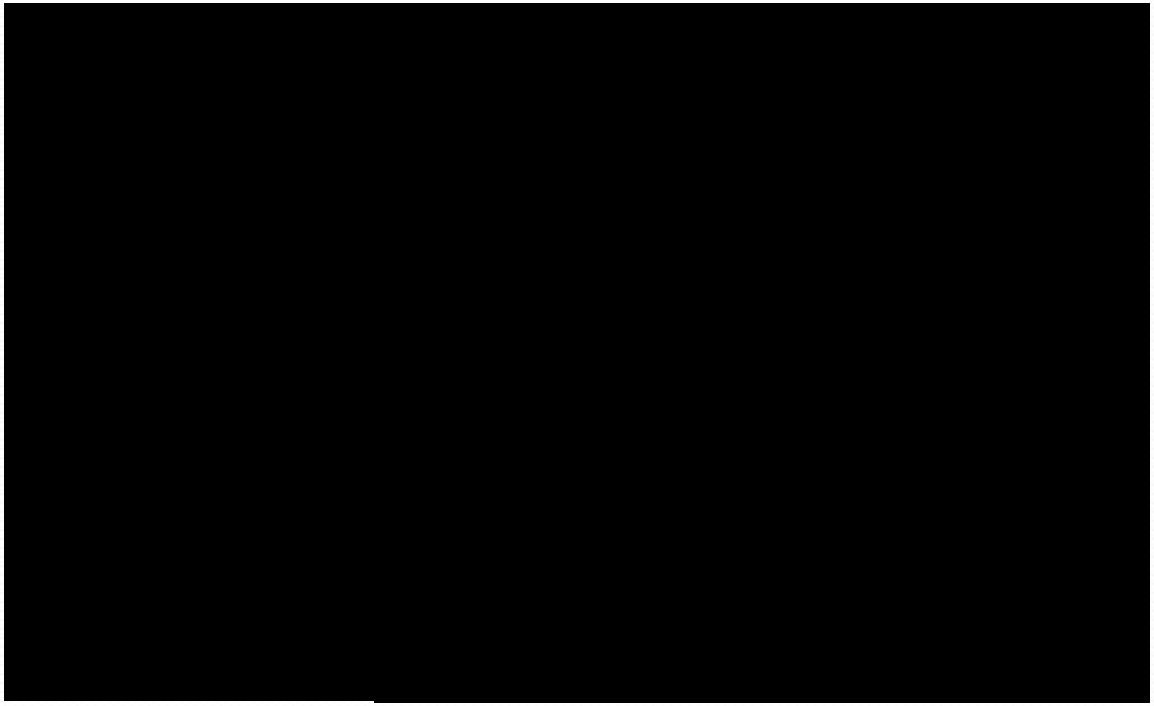
SDC Considerations

- SAC, SSC recommended 3 yr SDC
- OF'd PPA bar lower at ½ S_{MSY} than under current FMP
- 1 year rebuilt inadequate for coho life history

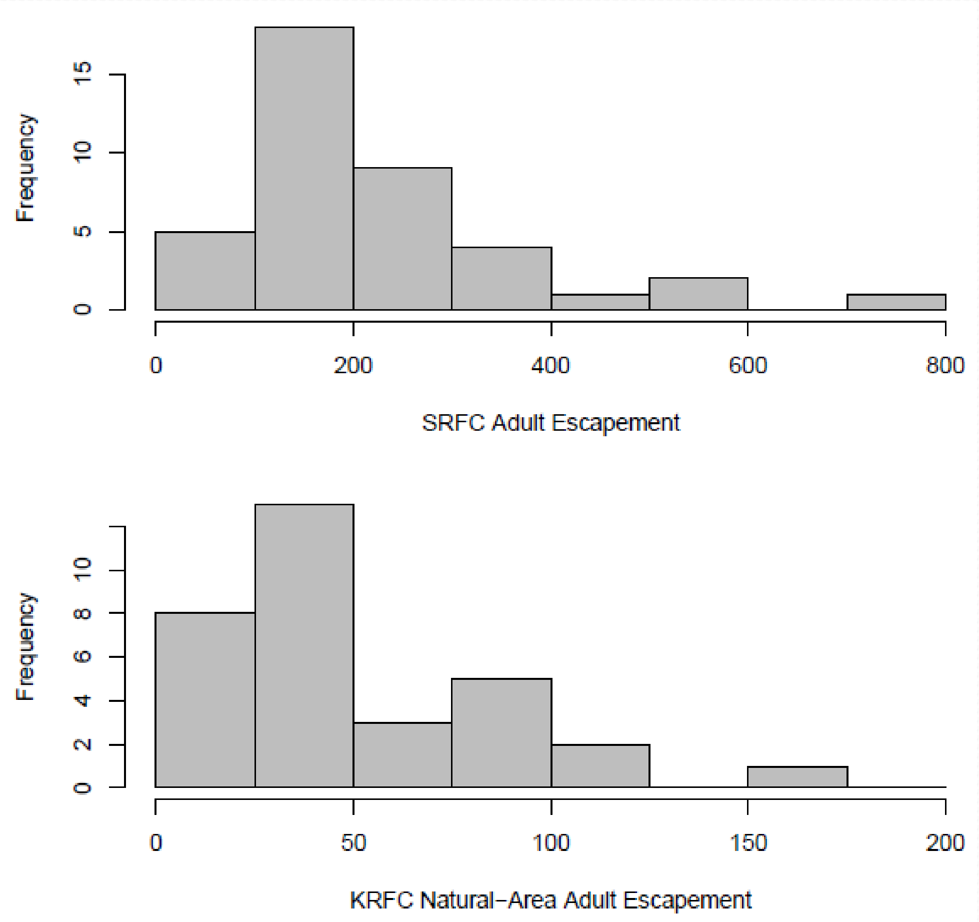
[redacted]

[redacted]

Mean Stuff



More Mean Stuff



Actions When SDC Are Triggered

- Need to include responses to SDC triggers in FMP similar to current Overfishing Concern and Conservation Alert responses
- SAC will include draft FMP language in Draft EA
- Council guidance now would be helpful

OF’d Response Examples

- When a stock is determined to be overfished the Council could require an assessment of:
  - The role of fishing, scientific and management uncertainty,
  - The ability to achieve rebuilding within ten years under the current control rule and rebuilt SDC,
  - Management actions necessary to ensure rebuilding is achieved in the required time frame.

Assessment Response Examples

- Pending the findings of the assessment, the Council also may:
  - Consider if MSST and MFMT should be updated,
  - Consider development of a rebuilding plan that includes measures or criteria other than what is included in the default rebuilding plan,
  - Consider assessing the role of freshwater and marine survival in triggering the SDC.

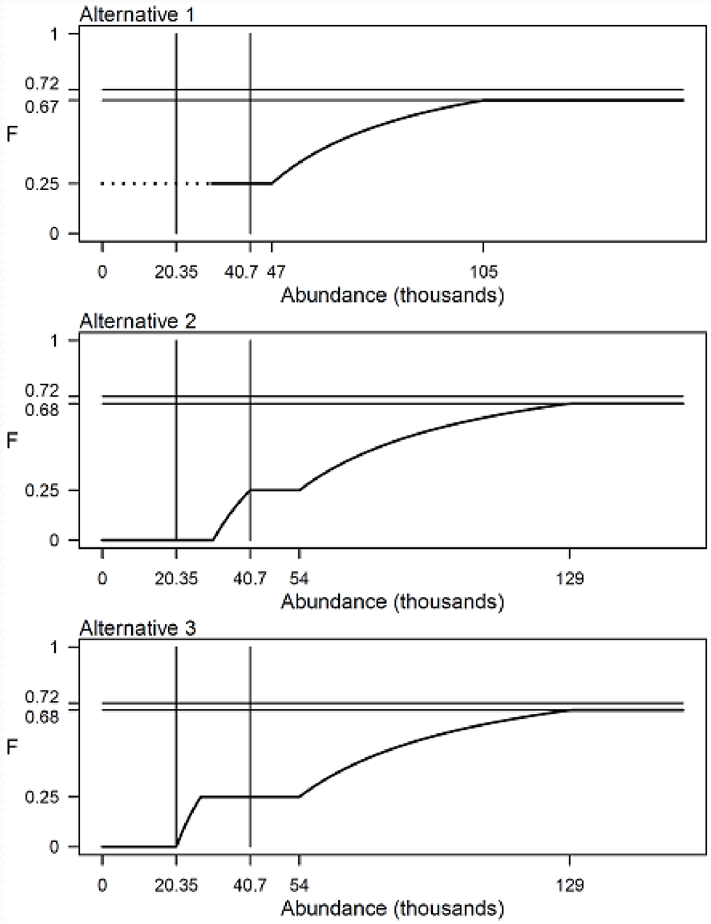
OF'ing Response Examples

- When overfishing on a stock has occurred, the Council could:
  - Identify and, if possible, correct the cause of overfishing and ensure that current or future overfishing ends and is prevented.
  - Require the STT to report in the SAFE document any instances of overfishing and identify the source(s) of mortality, and compare postseason exploitation rates with preseason expectations.
  - Notify relevant management agencies so that they can respond to the overfishing appropriately.
  - Implement AM(s) for when the ACL is exceeded, for those stocks/complexes that have ACLs specified.

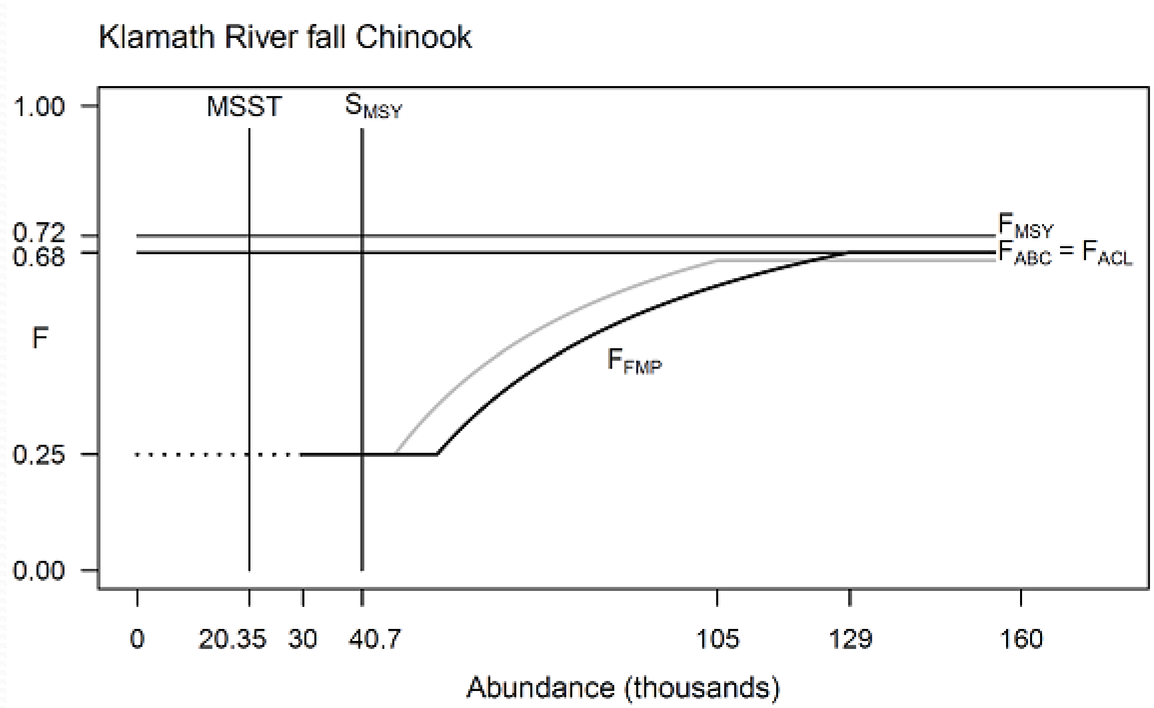
De Minimis Fishing Provisions

- The Council's motion for a PPA specified that the exploitation rate was "unspecified" below the midpoint of ~~the conservation objective~~ S_{MSY} and MSST. The SAC has characterized the Council's intent as an unspecified ***reduction*** from the *de minimis* fishing mortality rate below that midpoint. For SRFC and KRFC the midpoints are 91,500 and ~~26,250~~ 30,500, respectively (assuming MSST is ½ of S_{MSY}).
- The SAC asks that the Council confirm or clarify their intent for the *de minimis* fishing PPA.

SAC De Minimis Alternatives



PPA De Minimis Alternative



Amendment 15 Language

- 50 CFR 660.410 West Coast Salmon Fisheries: Conservation Objectives

- (d) Within the Cape Falcon to Point Sur area, the Council may allow
- de minimis fisheries which: permit an ocean impact rate of no more than
- 10 percent on age-4 Klamath River fall Chinook, if the projected natural
- spawning escapement associated with a 10 percent age-4 ocean impact
- rate, including river recreational and tribal impacts, is between the
- conservation objective (35,000) and 22,000. If the projected natural
- escapement associated with a 10 percent age-4 ocean impact rate is
- less than 22,000, the Council shall further reduce the allowable age-4 ocean
- impact rate to reflect the status of the stock. \1\
- --

- \1\ NMFS interprets that, consistent with the de minimis provisions
- of the FMP, the maximum allowable 10 percent age-4 ocean impact rate may
- be implemented only when the anticipated escapement is near the 35,000
- natural spawner floor. As escapement falls below approximately 30,000,
- the impact rate will need to decline automatically.

SALMON ADVISORY SUBPANEL REPORT ON FISHERY MANGEMENT PLAN AMENDMENT 16, ANNUAL CATCH LIMITS AND ACCOUNTABILITY MEASURES

The Salmon Advisory Subpanel (SAS) reiterates its September recommendation that whatever classification alternative selected for pink salmon should allow regulation of pink salmon retention in Council area fisheries, either directly through the Council process or through state management processes.

The SAS recommends that far north migrating spring/summer (FNMSS) Chinook stocks from the Oregon coast be included in a stock complex to facilitate annual catch limit (ACL) specification. Washington coastal FNMSS stocks should be considered for an exception to ACL specification because of management under an international exception.

The SAS would like to see an analysis of fisheries operated under the current Salmon Fishery Management Plan compared to fisheries operated under the Amendment 16 preliminary preferred alternatives to assess season length, expected catch, and economic effects. It is important to have this analysis available as soon as possible to allow the SAS to make informed recommendations for Council final action. We would prefer to have the analysis available at the March 2011 meeting.

PFMC
11/05/10

SCIENTIFIC AND STATISTICAL REPORT ON FISHERY MANAGEMENT PLAN AMENDMENT 16, ANNUAL CATCH LIMITS AND ACCOUNTABILITY MEASURES

Mr. Chuck Tracy briefed the Scientific and Statistical Committee (SSC) on outstanding issues related to Amendment 16. The SSC discussed two related issues: time spans for computing overfishing and rebuilding, and the use of arithmetic versus geometric mean abundances when applying Status Determination Criteria (SDC).

In our September 2010 review of Amendment 16, the SSC recommended "…the SDC be based on three-year geometric means as they will be less subject to random error (noise) in the estimation and evaluation process." This statement was based on the original one- and three-year options. The arithmetic mean was not suggested at that time.

Salmon abundance often varies widely from year to year. Chinook salmon year-classes are spread over three to five years, while coho salmon have three largely independent brood cycles. Averaging abundance over a three-year period captures abundance patterns on a scale that is biologically appropriate. As the SSC previously stated, it also reduces annual "flip-flops" in status that could result from high interannual variability. The Salmon Amendment Committee (SAC) provided retrospective analysis of several options for SDCs in their August 2010 draft document. The SSC recommends adding these one- and three-year options to the retrospective analysis.

Salmon abundance over time follows a log-normal distribution. The geometric mean is appropriate for describing the most likely value of such distributions. It is most sensitive to low values. For salmon abundance distributions the arithmetic mean will generally be higher than the geometric mean, and more than half the observations will be below the arithmetic mean. High values have most influence on the arithmetic mean.

Choice of which mean to use will affect how often stocks are defined as overfished, and levels needed to be declared recovered, with the geometric mean being more precautionary. A retrospective analysis would aid in understanding the implications of the two means, especially in combination with one- and three-year time frames.

PFMC
11/05/10

Yurok Tribal Comments regarding Amendment 16, November 4, 2010

My name is Dave Hillemeier, Fisheries Program Manager for the Yurok Tribe. The Yurok Reservation is located along the lower 44 miles of the Klamath River. The Yurok Tribe relies on the fisheries of the Klamath River; therefore my brief comments pertain to Klamath River fisheries, especially Klamath fall Chinook.

I realize the intent of this agenda item today is for the Salmon Amendment Committee to seek clarification and guidance regarding the alternatives that will be analyzed for the Environmental Assessment. I would like to take this opportunity to clarify for the Council concerns the Tribe has with a couple of the draft preliminary preferred alternatives that were identified at the September Council meeting. In particular, we are concerned that some of the prelimary preferred alternatives identified at the September meeting are not based upon the use of the best available science (such as advice and or findings from STT and SSC). Furthermore, we are concerned that some of the identified preferred preliminary alternatives are focused more on short-term fishing opportunity rather than maximizing harvest over the long-term.

Overfished/Rebuilt/Geometric and Arithmetic Means

As noted in the "Issues Paper" of the SAC, there was somewhat of a contradiction in the preliminary preferred alternatives from the September meeting, given that a three year period was recommended for determining when a stock is "overfished" yet only a one year period was recommended for determining when a stock is "rebuilt"; therefore, under these criteria, it possible for a stock to be simultaneously classified as overfished and rebuilt. To remedy this situation, and for these stock classifications to be more reflective of stock status, we recommend that a three-year period be used to determine whether a stock is "overfished" and whether a stock is "rebuilt". Given the inherent variability in fall Chinook abundance, and the fact that a three-year period encompasses more cohorts than a single year, we believe the three year period is more reflective of the stock's status than just a single year and therefore a better indicator of whether a stock is "overfished" or "rebuilt".

In regard to the use of the geometric vs. the arithmetic mean over this three-year period, I recommend that you use the geometric mean as recommended by the STT and SSC. Their recommendation is technically sound; therefore the geometric mean is typically used in other areas of salmon management.

MSY/Control Rule and de minimis fishing

The control rule that will be adopted for managing Klamath fall Chinook is extremely important for the future of this stock. Therefore this rule should be based upon the best available science; i.e. MSY. The Salmon Fisheries Management Plan speaks to the importance of managing for Optimum Yield, and the fact that Optimum Yield is prescribed on the basis of the Maximum Sustainable Yield of the fishery. The FMP goes on to say that MSY is usually approached in terms of annually achieving the number of adult spawners associated with this goal. After many years of managing Klamath fall chinook under harvest rate management regime (with a minimum floor of 35,000 natural adult spawners), we now have well over 20 years of completed cohort data from which to conduct a Stock/Recruit (S/R) analysis so that MSY can be estimated. This S/R analysis was conducted by the STT in 2005; they estimated the value of MSY to be 40,700 adults. This analysis was supported by the SSC's determination that the STT's analysis represents the best available science regarding the MSY value. While a control rule that goes to a lower value, such as the 35,000 that is in the preliminary preferred alternative, may allow slightly higher harvest rates in the short-term, this value is not based on science, nor will this higher harvest rate achieve optimum yield for the fishery over the long-term. We recommend that the PFMC adopt the STT's estimate of 40,700 adult Chinook as being the appropriate MSY for Klamath fall Chinook, and that this value serves as the basis for the control rule for Klamath fall Chinook.

De minimus Fisheries

We are concerned that the preliminary preferred alternative basically punts in regard to how the stock will be managed during times of extremely low abundance; i.e. the status quo with no control rule explicitly defined below stock sizes of 30,000. Rather than wait to make such decisions when going through the somewhat rushed, as well as politically/socially charged pre-season management process, we think the control rule adopted through Amendment 16 should extend throughout the range of stock sizes that are associated with de minimis fisheries. We would expect this rule to reflect expected fishing levels that NMFS stated could be expected in letters to the PFMC and the Yurok Tribal Council following adoption of Amendment 15 (i.e. they expected the 25% rate to decline as stock size dropped below 30,000 and that they expected to see a substantially greater decline in harvest rates at stock sizes near 22,000). We also would like to see an alternative that begins reducing the spawner reduction rate below 25% at the 0.75 MSY value (i.e. 30,525) – we thought this had made it in the alternatives at the September meeting, but cannot find it listed.

Miscellaneous

Regarding the timeline for adoption of Amendment 16, we hope that enough time is given for the SAC to give the thorough analysis necessary for this complex amendment, as well ample time for public review of the final Environmental Analysis. We would have no problem with this Amendment not being adopted until June of next year.

KLAMATH MANAGEMENT ZONE FISHERIES COALITION
P.O. Box 1521 · Gold Beach, OR · 97444

October 7, 2010

Mr. Mark Cedargreen, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 111
Portland, OR 97220-1384

Dear Mr. Cedargreen:

I am writing on behalf of ocean sport and commercial salmon fishermen, mostly in the Klamath Management Zone but also from Point Sur to Cape Lookout, whose fishing opportunity is driven by the allowable ocean catch of Klamath Fall Chinook salmon. As you know, that opportunity has been progressively curtailed for the past thirty years to, the point that now we are lucky in some years to have any open fishing days at all.

We understand that, under Amendment 16 to the Salmon framework Management Plan, the Pacific Fishery Management Council (PFMC) is contemplating increasing the minimum sustainable yield (MSY) number of 40,700 in order to comply with the most recent version of the Sustainable Fisheries Act. We strongly urge the Council to not adopt this change. Three technical reviews of the current methodology have all supported use of the 35,000 natural spawner floor. We believe the current harvest rate management plan is sound and ask that you retain it.

We note that, under harvest rate management, Klamath fall natural escapement has bracketed MSY, falling below 13 times and above 14 times. Average escapement has been well above MSY.

First, raising the target by 5000 natural spawners means reducing the allowable Klamath catch by that much plus the additional 3000 to 5000 hatchery fish associated with those natural spawners. Second, in ocean fisheries we use our relatively scarce number of available Klamath fish to access the (normally) far more abundant Sacramento fall Chinook stocks, so that each Klamath fish "saved" for spawning means a reduction in total ocean catch of from ten to 50 fish. At best, a reduction of eight to 10,000 available Klamath fish translates to about a 100,000 reduction in ocean landings; in lean years it will mean the difference between worthwhile fisheries and none at all.

We understand and support the need to manage fisheries to ensure the robust survival of future generations. We believe the current method does that (to the extent that constraining fisheries to deal with habitat-generated issues can do it). But we do not understand and cannot support constraints to fisheries which have no demonstrable benefit to the health of the resource. We believe the proposed change to a target of 40,700 would seriously damage the remaining ocean salmon fisheries while offering only paper benefits.

We look forward to our work together and thank you in advance for considering our comments.

Sincerely,

Lucie LaBonte, chair of KMZFC

Jimmy Smith, KMZFC Board Member, 1st District Supervisor, County of Humbolt

Georgia Yee Nowlin, KMZFC Board Member, Curry County Commissioner

Curry County
Board of Commissioners

Bill Waddle, *Chair*
Georgia Yee Nowlin, *Vice Chair*
George Rhodes, *Commissioner*

94235 Moore Street/P.O. Box 746
Gold Beach, OR 97444
541-247-3296, 541-247-2718 Fax
800-243-1996 *www.co.curry.or.us*

October 13, 2010

RECEIVED
OCT 18 2010
PFMC

Mr. Mark Cedargreen, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 111
Portland, OR 97220-1384

Dear Mr. Cedargreen:

We, the Curry County Board of Commissioners, are writing on behalf of the ocean sport and commercial salmon fishermen in Curry County. As part of the Klamath Management Zone, fishing opportunity is driven by the allowable ocean catch of Klamath Fall Chinook salmon. That opportunity has been progressively curtailed for the past thirty years so that in some years we are fortunate to have any open fishing days at all.

Now, we understand that the Pacific Fishery Management Council (PFMC) is contemplating increasing the minimum sustainable yield (MSY) number to 40,700 in order to comply with the most recent version of the Sustainable Fisheries Act.

We strongly urge the Council to not adopt this change. Three technical reviews of the current methodology have all supported use of the 35,000 natural spawner floor. We believe the current harvest rate management plan is sound and ask that you retain it.

We note that, under harvest rate management, Klamath Fall natural escapement has bracketed MSY, falling below 13 times and above 14 times. Average escapement has been well above MSY.

We understand and support the need to manage fisheries to ensure the robust survival of future generations. We believe the current method does that (to the extent that constraining fisheries to deal with habitat-generated issues can do it.) But we do not understand and cannot support constraints to fisheries which have no demonstrable benefit to the health of the resource. We believe the proposed change to a target of 40,700 would seriously damage the remaining ocean salmon fisheries while offering only paper benefits.

Thank you for considering our comments.

Sincerely,

Absent

Bill Waddle
Chair

Georgia Yee Nowlin
Vice Chair

George Rhodes
Commissioner

HUMBOLDT AREA SALTWATER ANGLERS, INC.

October 13,2010

RECEIVED
[illegible] 2010
PFMC

Mr. David Ortmann, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, Oregon 97220-1384

Dear Sir:

The members of the Humboldt Area Saltwater Anglers (HASA) are aware that the Pacific Fisheries management Council will be considering a new fishery management plan (FMP) for salmon at the Council's November 2010 meeting in Costa Mesa. As we understand it, this new FMP is intended to align the salmon annual catch limits (ACL) with the requirements of the Magnuson Stevens Act (MSA).

We understand the Salmon Technical Team (STT) has recommended that escapement for Klamath River should be set at the maximum sustained yield (MSY) for that river of 40,700 natural Chinook spawners (KRFC). While we concur that the use of MSY is appropriate when managing the Klamath Fall Chinook during periods when the river is considered "Over Fished", we firmly believe that the escapement in other periods should remain at the conservation objective of 35,000 KRFC. An escapement of 35,000 KRFC is sufficient to satisfy the needs of the hatcheries on both the Klamath and Trinity rivers. This level also allows a reasonable number of fish for the ocean salmon, river recreational salmon and tribal salmon fisheries. Raising the escapement to the 40,700 on a permanent basis would deal a serve economic blow to the region. Many businesses rely upon the income derived from all three fisheries during the summer and fall fishing seasons. Additionally, establishing a minimum level at 40,700 will potentially overpopulate the available natural spawning capability of both rivers. It would also cause the PFMC to consider raising the escapement floor to an unattainable number should the river be considered "Over Fished" with an annual escapement floor of 40,700.

HASA is requesting that the PFMC continue to use the escapement for of 35,000 (the conservation objective) as opposed to the MSY of 40,700 for the management of KRFC.

Sincerely,

Tim Klassen
President

P.O. BOX 6191
EUREKA, CA. 95502

E-MAIL hasa6191@gmail.com

WEB SITE www.humboldttuna.com

David Bitts
President
Larry Collins
Vice-President
Duncan MacLean
Secretary
Mike Stiller
Treasurer

PACIFIC COAST FEDERATION of FISHERMEN'S ASSOCIATIONS

W.F. "Zeke" Grader, Jr.
Executive Director
Glen H. Spain
Northwest Regional Director
Vivian Helliwell
Watershed Conservation Director
In Memoriam:
Nathaniel S. Bingham
Harold C. Christensen

STEWARDS OF THE FISHERIES

Please Respond to:

☐ **California Office**
P.O. Box 29370
San Francisco, CA 94129-0370
Tel: (415) 561-5080
Fax: (415) 561-5464

www.pcffa.org

☐ **Northwest Office**
P.O. Box 11170
Eugene, OR 97440-3370
Tel: (541) 689-2000
Fax: (541) 689-2500

25 October 2010

Dr. Donald McIsaac, Executive Director
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, Oregon 97220-1384

RE: Amendment 16 to the PFMC Salmon Fishery Management Plan
November Agenda Item F.2a

Dear Doctor McIsaac and Members of the Pacific Council:

The Pacific Coast Federation of Fishermen's Associations (PCFFA), representing working men and women in the West Coast commercial fishing fleet, including many organized salmon trollers, has reviewed the proposed Amendment 16 to your salmon fishery management plan (FMP) as it relates to an Annual Catch Limit (ACL).

The document, in its current form is horribly confused, and PCFFA respectfully asks that all efforts be made to create a clear and easy to follow document that plainly states each option under consideration, what it entails and what the expected affects will be on fish conservation and fishing. This is important to ensure you understand and the public understands the choices before the Council in selecting an ACL for the salmon fishery. PCFFA is not opposing a change from the status quo in establishing a salmon ACL, but it is extremely nervous about changes that would allow more fishing than status quo at low stock levels and equally nervous about changes that might restrict fishing from current levels at higher stock sizes. Our preference, in other words, would be to err on the side of conservation at predicted low stock levels, while favoring much higher fishing opportunity when stock levels are large.

If you have any questions, please do not hesitate to contact us. PCFFA's representatives look forward to working with the Council and its staff on the development of an acceptable ACL for the salmon fishery.

Sincerely,

W.F. "Zeke" Grader

W.F. "Zeke" Grader, Jr.
Executive Director

KLAMATH MANAGEMENT ZONE FISHERIES COALITION
P.O. Box 1521 · Gold Beach, OR · 97444

October 7, 2010

RECEIVED
OCT 2 1 2010
PFMC

Mr. Mark Cedargreen, Chair
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 111
Portland, OR 97220-1384

Dear Mr. Cedargreen:

I am writing on behalf of ocean sport and commercial salmon fishermen, mostly in the Klamath Management Zone but also from Point Sur to Cape Lookout, whose fishing opportunity is driven by the allowable ocean catch of Klamath Fall Chinook salmon. As you know, that opportunity has been progressively curtailed for the past thirty years to, the point that now we are lucky in some years to have any open fishing days at all.

We understand that, under Amendment 16 to the Salmon framework Management Plan, the Pacific Fishery Management Council (PFMC) is contemplating increasing the minimum sustainable yield (MSY) number of 40,700 in order to comply with the most recent version of the Sustainable Fisheries Act. We strongly urge the Council to not adopt this change. Three technical reviews of the current methodology have all supported use of the 35,000 natural spawner floor. We believe the current harvest rate management plan is sound and ask that you retain it.

We note that, under harvest rate management, Klamath fall natural escapement has bracketed MSY, falling below 13 times and above 14 times. Average escapement has been well above MSY.

First, raising the target by 5000 natural spawners means reducing the allowable Klamath catch by that much plus the additional 3000 to 5000 hatchery fish associated with those natural spawners. Second, in ocean fisheries we use our relatively scarce number of available Klamath fish to access the (normally) far more abundant Sacramento fall Chinook stocks, so that each Klamath fish "saved" for spawning means a reduction in total ocean catch of from ten to 50 fish. At best, a reduction of eight to 10,000 available Klamath fish translates to about a 100,000 reduction in ocean landings; in lean years it will mean the difference between worthwhile fisheries and none at all.

We understand and support the need to manage fisheries to ensure the robust survival of future generations. We believe the current method does that (to the extent that constraining fisheries to deal with habitat-generated issues can do it). But we do not understand and cannot support constraints to fisheries which have no demonstrable benefit to the health of the resource. We believe the proposed change to a target of 40,700 would seriously damage the remaining ocean salmon fisheries while offering only paper benefits.

We look forward to our work together and thank you in advance for considering our comments.

Sincerely,

Lucie LaBonte, chair of KMZFC

Jimmy Smith, KMZFC Board Member, 1st District Supervisor, County of Humbolt

Georgia Yee Nowlin, KMZFC Board Member, Curry County Commissioner

PROGRESS REPORT ON SACRAMENTO RIVER FALL CHINOOK OVERFISHING ASSESSMENT

At its March 2010 meeting, the Council reviewed the most recent information and determined that Sacramento River fall Chinook had triggered an Overfishing Concern (not meeting the conservation goal for the three most recent years). The Council directed the Salmon Technical Team (STT) and Habitat Committee (HC) to work with relevant co-managers to conduct an assessment of the factors causing the Overfishing Concern. The STT and HC were directed to use the March 18, 2009 Southwest Fishery Science Center draft report concerning the cause of the Sacramento River fall Chinook stock collapse as framework for the assessment, and to include relevant new and updated information and analysis.

A joint subcommittee made up of members of the STT and HC has met twice since that time and will provide a progress report on their efforts. The final report is due at the March 2011 Council meeting.

Council Action:

1. **Provide guidance on completion of the Sacramento River Fall Chinook Overfishing Assessment.**

Reference Materials:

1. Agenda Item F.3.b, Supplemental Progress Report: Joint Subcommittee of the Salmon Technical Team and Habitat Committee Progress Report on the Sacramento River Fall Chinook Overfishing Assessment.

Agenda Order:

a. Agenda Item Overview **Chuck Tracy**
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. Council Discussion and Guidance

PFMC
10/18/10

SALMON ADVISORY SUBPANEL REPORT ON PROGRESS REPORT ON SACRAMENTO RIVER FALL CHINOOK OVERFISHING ASSESSMENT

The Salmon Advisory Subpanel (SAS) feels that some of the solutions for improving the status of the Sacramento River Fall Chinook are:

1. Reducing pollution from the discharge of harmful substances into the Sacramento River drainage.

    a. Agricultural runoff
    b. Sewage outfall
    c. Lack of water to flush the river system

2. Increased flow in the river system for temperature control and to give the spawners passage to their natal streams and for the smolt passage to the ocean.

3. Keep improving hatchery operations.

4. Bureau of Reclamation needs to work with the hatcheries so the smolt have safe passage pass all pumping stations and spawners are able to return to their natal streams.

5. Develop comprehensive water plan for Central Valley agriculture.

PFMC
11/04/10

SALMON TECHNICAL TEAM REPORT ONPROGRESS REPORT FOR SACRAMENTO RIVER FALL CHINOOK OVERFISHING ASSESSMENT

The subcommittee comprised of Salmon Technical Team and Habitat Committee members has met twice to work on the Sacramento River fall Chinook (SRFC) overfishing assessment. In accordance with Council guidance, subcommittee members have been working on assignments associated with updating data and analyses, when feasible, from the SRFC collapse report by Lindley et al. (2009).

It is the intention of the subcommittee to use status determination criteria, and rebuilding benchmarks, defined by the Fishery Management Plan as amended through Amendment 16. However, final action is not scheduled be taken on Amendment 16 in time for the completion of the SRFC overfishing assessment. Therefore the subcommittee proposes to evaluate the status of the stock relative to the alternative criteria under consideration by the Council.

PFMC
11/05/10

MITCHELL ACT HATCHERY DRAFT ENVIRONMENTAL IMPACT STATEMENT

The Draft Environmental Impact Statement to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs (MA DEIS) was released on August 6 for public review and comment (online at http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Hatcheries/MA-EIS.cfm.).

The Council received a presentation on the MA DEIS at its September meeting and developed a process for developing and finalizing its comments by the December 3, 2010 comment deadline. The process included the development of a list of questions (Attachment 1) to be answered by the agencies, tribes, or Council advisory bodies, and the formation of the ad hoc Mitchell Act Committee to review the answers and develop draft comments for the Council to consider at the November Council meeting. The comments received in time to include in the initial briefing book mailing are contained in Agenda Item F.4.b, Management Entity Comments, and include comments by the US Fish and Wildlife Service, Oregon Department of Fish and Wildlife, and the Salmon Technical Team. Additional comments will be included in supplemental attachments and various advisory body reports.

Council staff will work with the Mitchell Act Committee on November 3 to review the response to questions and draft comments for Council review

Council Action:

1. **Consider draft comments developed by the ad hoc Mitchell Act Committee and others.**
2. **Provide guidance for finalizing Council comments and approve final comments to meet the December 3, 2010 comment deadline.**

Reference Materials:

1. Mitchell Act DEIS available on line at: http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Hatcheries/MA-EIS.cfm.
2. Agenda Item F.4.a, Attachment 1: List of Questions for Consideration in Preparing Comments on Mitchell Act Hatchery Draft Environmental Impact Statement.
3. Agenda Item F.4.b: Management Entity Response to Council Questions Concerning Preparation of Comments on the MA DEIS.
4. Agenda Item F.4.c: Public Comment.

Agenda Order:

a. Agenda Item Overview **John Coon**
b. Reports and Comments of Management Entities and Advisory Bodies
c. Public Comment
d. **Council Action:** Finalize Comments on the DEIS

PFMC
10/19/10

LIST OF QUESTIONS FOR CONSIDERATION IN PREPARING COMMENTS ON MITCHELL ACT HATCHERY DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS)

Council Staff has developed a draft list of potential questions, the answers to which may be useful to the Ad Hoc Mitchell Act Committee in developing recommendations for Council consideration at the November Council meeting. Recognizing that many agencies represented at the Council may be conducting concurrent reviews of the DEIS, candidates to answer questions are shown with the goal of not assigning questions to Council advisory bodies or Council staff that might be duplicative of activity already planned by other entities. The Council confirmed the thrust of the questions and tasked Council staff with communicating the process and questions to the parties as soon as possible.

1. Have the population and fishery impacts methodologies used in the analysis been peer reviewed, and is there agreement with the States and Tribes that it represents the best available science? (**WA, OR, ID, Tribes, AK, NMFS**)

2. Are the mitigation requirements and responsibilities under the Mitchell Act adequately described in the DEIS? (**WA, OR, ID, Tribes, AK**)

3. What are the other alternatives that meet the purpose and need of the proposed action that were not included in the DEIS? (**USFWS, NMFS**)

4. Can hatchery reform concepts other than percent of hatchery origin spawners (pHOS) and percent of natural origin broodstock (pNOB), such as natural rearing strategies, be used to develop alternatives that meet the purpose and need of the DEIS but maintain more production than Alternatives 3-5? (**Tribes, AK, OR, WA, ID**)

5. What fisheries are assumed in the analysis to be mark-selective, and at what point in time? (**OR, WA, ID, Tribes, AK, NMFS**)

6. Were Native American tribes engaged in government to government consultations in development of the DEIS, including but not limited to the four Washington coastal treaty tribes and the four Columbia River treaty tribes? (**Tribes**)

7. Are the impacts to all ocean fisheries in areas under management authority of the Pacific Council, the Pacific Salmon Commission, and the State of Alaska included in the analysis of each alternative in DEIS (harvest impacts to individual fishery strata, socioeconomic impacts, and the environmental justice analyses)? (**STT**)
    - If not, what is the list of fisheries not included and what is the relationship of Mitchell Act hatchery production to the stock composition of those fisheries? (**STT**)

8. Are impacts in all Columbia River basin fisheries included in the DEIS, including tributary ceremonial and subsistence and recreational fisheries? (**Tribes, OR, WA, ID**)

9. Is production from all Columbia Basin hatcheries included in the analysis? (**USFWS, OR, WA, ID, Tribes**)

10. Is the methodology describing economic impacts complete and proper, including the use of consistent metrics? (**SSC Economic and Salmon Subcommittees**)

11. Were expected benefits to fisheries from increased wild production included in the economic analyses? (**WA, OR, ID, Tribes, AK**)

12. Were current fishery and hatchery management agreements used to estimate impacts (e.g., *US v Oregon*, Pacific Salmon Treaty Chinook Annex, *US v Washington, Hoh v Baldrige,* etc.)? (**WA, OR, ID, Tribes, AK**)

13. Were impacts to commitments and expectations in the PST, *US v Oregon*, *US v Washington, Hoh v Baldrige* properly described in the DEIS? (**WA, OR, ID, Tribes, AK**)

14. Are there relevant sources of information omitted from socioeconomic analysis? (**SSC Economic and Salmon Subcommittees**)

15. Is the temporal scale of the impact assessment adequate? (**WA, OR, Tribes, ID, AK**)

16. Are the natural salmon populations targeted for restoration, particularly those that become limiting factors in hatchery production, appropriately identified? (**WA, OR, ID, Tribes, Council Staff**)

17. Recognizing recent changes in the hatchery practices that have already occurred, what is the period used to decide the status quo alternative? (**OR, USFWS, NMFS**)

18. Are the DEIS alternatives consistent with adopted state recovery plans? (**OR, WA, ID**)

PFMC
10/19/10

Management Entity Response to Council Questions Concerning Preparation of Comments on the Mitchell Act Hatchery DEIS

FWS Responses to PFMC Mitchell Act DEIS Questions

Disclaimer

These responses to the Pacific Fishery Management Council's (Council) questions on the Mitchell Act Draft Environmental Impact Statement are technical comments and are not the position of the U.S. Fish and Wildlife Service. The U.S. Fish and Wildlife Service is currently developing policy and technical comments on the Mitchell Act DEIS, and will provide an official response at a later date.

PFMC Question #3

What are the other alternatives that meet the purpose and need of the proposed action that were not included in the DEIS?

The DEIS defines the Purpose and Need of NMFS' proposed action as follows:

"The combination of funding pressures under the Mitchell Act, the 13 ESA listings for salmon and steelhead in the Columbia River basin, and the value of a comprehensive review of hatchery programs to inform decision makers have resulted in the need for the proposed action. NMFS' purpose for the action is to develop a policy direction related to Columbia River basin hatchery production that will 1) guide its decisions about distribution of funds for hatchery production under the Mitchell Act; and 2) inform its future review of the individual Columbia River hatchery programs under the ESA." (emphasis added)

In its review of the DEIS, the Council noted that the DEIS does not provide a discussion of how the mitigation commitments that were the very purpose for implementing most of the Columbia River hatchery programs described in the DEIS, including the Mitchell Act program, could or would be met through alternate means if the hatchery programs were in fact terminated or substantially reduced under any of the current DEIS alternatives, let alone the cost and social-economic effects of those other alternatives relative to the hatchery programs. Other alternatives that might address how the mitigation debt could be accommodated might include but not be limited to habitat restoration, dam removal, technological/physical infrastructure measures to increase fish passage survival, water management measures targeted to benefit fish life history survival, etc.

Mitigation is a legal and stewardship responsibility and commitment to the American public just as are ESA recovery, treaty trust responsibilities to the Tribes, and other legally binding agreements and legislative directives. Some mitigation commitments and responsibilities for Columbia River hatchery programs were more clearly defined than others during the history of the development of the hatchery programs with the Lower Snake River Compensation Plan (LSRCP) program established in 1976, probably providing one of the most explicit mitigation commitment descriptions in terms of adult returns back to the project area (mouth of the Snake River) after accounting for prior intervening fisheries. The LSRCP program provides mitigation/compensation for the four lower Snake River dams (Ice Harbor, Lower Monumental, Little Goose, and Lower Granite dams).

Unfortunately, other earlier hatchery mitigation programs such as the Mitchell Act program (authorized in 1938) and Grand Coulee Dam program (authorized in 1941) had little or no explicit definition of what the mitigation responsibility was in terms of numbers of smolts to be produced let alone the numbers of adult fish those hatchery programs were supposed to replace for the habitat that was lost to hydrosystem and other related Columbia River basin development. However, even with a lack of specificity of what the mitigation obligation for the Mitchell Act program was to be, it is clear from the historical record and magnitude of the Columbia River Fishery Development Program, which the Mitchell Act annually funded, that Congressional intent for the scope of the Mitchell Act program was indeed very large. Over the history of the Mitchell Act program more than 20 individual salmon and steelhead facilities were built, many with multiple salmon and steelhead programs. The DEIS indicates that the current program distributes Mitchell Act appropriations to the operators of 62 hatchery programs that release more than 71 million juvenile fish and that this is already a substantial reduction (45 percent) from the level of about 128.6 million juveniles that were produced by these Mitchell Act facilities in the mid-1990's that occurred primarily because of funding shortfalls to continue that level of Mitchell Act production.

As the Region struggles with the complex issues of how to move forward with ESA recovery, including determining appropriate and scientifically defensible levels of hatchery production that allow continued fishery opportunities and address mitigation commitments to the American public, the Council believes that a broader discussion of the current management agreements and responsibilities, including ongoing mitigation commitments, is appropriate and necessary to inform final decisions in this DEIS especially if the second purpose (developing policy direction to "inform" its future review of the individual Columbia River hatchery programs under the ESA remains as a part of the DEIS. In that regard, the Council believes that there needs to be a focused discussion in the DEIS on how other non-hatchery mitigation alternatives might achieve the fishery benefits that hatcheries were called upon to generate as development, especially hydrosystem development, occurred within the Columbia River basin and habitat for native stocks was lost.

Another option, and perhaps preferred option at this point, might be to separate the two purposes in the DEIS and refocus the DEIS back to its original need and purpose (to develop policy direction to guide future distribution of funds for hatchery production under the Mitchell Act). Subsequent NEPA processes could then be more appropriately developed as needed during the actual ESA consultation process as more specific ESA requirements for individual programs become more clearly defined. At that point, non-hatchery mitigation actions would need to be considered if in fact hatchery program reductions/terminations were the necessary outcome of ESA compliance determinations.

While the Region cannot turn back the clock on Columbia River basin development, the Region can and should make informed policy and funding decisions that implement a suite of management actions that enable ESA recovery while meeting treaty Indian fishing rights and tribal trust responsibilities and commitments and that uphold its promise and commitment to the general American public to maintain the mitigation fishery opportunities and benefits lost due to basin development. That suite of management actions likely would involve a blend of all four H's (i.e., hydro, hatchery, harvest, and habitat actions). Affected stakeholders and the general American public deserve an explanation of how the mitigation debt for their fishery interests will be addressed, if hatchery production is significantly reduced as a part of this or any future EIS process before a final Record of Decision is developed.

PFMC Question #9

Is production from all Columbia Basin hatcheries included in the analysis?

Relative to hatchery production for USFWS National Fish Hatchery (NFH) programs it appears that the DEIS incorporates correct production releases for all NFH programs except for the following omissions or corrections, albeit at the 2007 production level for status quo (Alternative 1) versus the more appropriate 2010 production level: (See also response to question #17.)

1. Entiat NFH 200,000 summer Chinook program is not included.

2. Leavenworth NFH spring Chinook program listed as 1,650,200 should be corrected to 1,200,000.

3. Umatilla River spring Chinook program listed as 925,300 via Little White Salmon NFH is now being conducted at Umatilla SH with no tie to Little White Salmon NFH.

4. Ringold SH spring Chinook program listed at 487,100 via Little White Salmon NFH should be deleted since Little White Salmon no longer provides broodstock eggs for this program.

5. Upper Yakima-Naches coho program listed as 452,100 via Little White Salmon NFH should be corrected as via Eagle Creek NFH.

6. Spring Creek NFH tule fall Chinook program listed as 15,044,900 should be corrected to 10,500,000.

7. Little White Salmon NFH should include an acclimated release of 1,700,000 tule fall Chinook via spring Creek NFH and an acclimated release of 2,500,000 upriver bright fall Chinook via Bonneville SH in addition to the currently listed production.

8. Bonneville SH should include a tule fall Chinook release of 2,800,000 via broodstock eggs from Spring Creek NFH and a reduction of 2,500,000 upriver bright fall Chinook (transferred to Little White Salmon NFH) in its on-station release of this stock.

Adjustments for 6-8 above are the result of the Spring Creek NFH Reprogramming Agreement that currently extends through 2011.

PFMC Question #17

Recognizing recent changes in the hatchery practices that have already occurred, what is the period used to decide the status quo alternative?

A number of DEIS tables reference 2007 as the "base year" to define the status quo alternative. Given recent hatchery program changes that have occurred in the last several years, including some that specifically implemented Hatchery Scientific Review Group recommendations, it seems appropriate that 2010 hatchery production programs should be designated as the "base year" programs for the status quo alternative with appropriate adjustments made to the document to reflect this update to the status quo production program.

Oregon
Theodore R. Kulongoski, Governor

Department of Fish and Wildlife
Fish Division
3406 Cherry Avenue NE
Salem, OR 97303
503-947-6200
Fax: 503-947-6202
TTY: 503-947-6339
www.dfw.state.or.us

October 7, 2010

Dr. John Coon
Deputy Director
Pacific Fishery Management Council
7700 NE Ambassador Place, Suite 101
Portland, OR 97220-1384

Dear Dr. Coon:

Enclosed are Oregon's responses to questions posed in the list attached to the September 23, 2010 memorandum concerning Council comments on the Mitchell Act DEIS. Our understanding is that Council staff will compile responses from the entities identified for each question and will distribute the compilation to Council members and advisors in the November Council briefing book. The responses will serve as reference material for the Mitchell Act Committee when it meets on November 3 to draft an initial set of recommended comments for review and approval by the Council at its November meeting.

Please contact me at 971-673-6082 (tony.nigro@state.or.us) or Kathryn Kostow at 971-673-6025 (kathryn.e.kostow@state.or.us) with any questions.

Sincerely,

Signature on original

Tony Nigro, Manager
Ocean Salmon and Columbia River Program

Cc. Stephen Williams
Kathryn Kostow

Oregon Responses to PFMC Questions Regarding the Mitchell Act Hatchery Draft Environmental Impact Statement (DEIS)

1. *Have the population and fishery impacts methodologies used in the analysis been peer reviewed, and is there agreement with the States and Tribes that it represents the best available science? (WA, OR, ID, Tribes, AK, NMFS)*

The DEIS analysis is multi-disciplined and Oregon will only comment on the harvest and hatchery science.

The harvest model that was used in the DEIS has not been peer-reviewed; however our own review of it indicates that it is a reasonable model. We found that some of the harvest input data and harvest assumptions contain errors or are out-dated (for example, the harvest rates used and the assumed harvest structure such as application of mark-selective fisheries or abundance-based harvest rates). These problems can be corrected by using updated harvest data, management agreements and harvest biological opinions.

The hatchery risk assessment in the DEIS is poorly explained and documented, and could be substantiated and improved by a sound literature review. The peer-reviewed hatchery risk science is extensive. A short list of recent review papers is appended[1], and additional reference information is available from the Hatchery Scientific Review Group, available on line at: http://www.hatcheryreform.us/hrp/reports/system/welcome_show.action (accessed October 6, 2010); and the US Fish and Wildlife Federal Hatchery Review, available on line at: http://www.fws.gov/Pacific/fisheries/hatcheryreview/reports.html (accessed October 6, 2010).

2. *Are the mitigation requirements and responsibilities under the Mitchell Act adequately described in the DEIS? (WA, OR, ID, Tribes, AK)*

The DEIS incorporates the text of the Mitchell Act (Box 1-2, page 1-4), which "*provide(s) for the conservation of the fishery resources of the Columbia River.*"

We recognize that the Act lacks specificity in its language. The Mitchell Act funding has been used by the States to provide mitigation for a wide variety of human-related development and natural resource use in the Columbia Basin. The EIS does not recognize the use of this funding for mitigation, nor identify alternative mitigation in lieu of hatchery programs. We interpret the current funding scenario as a minimum responsibility to meet what we believe to be the mitigation responsibilities under the Act.

---

[1] Araki, H. et al. 2009. Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild. Biol. Lett. DOI:10.1098/rsbl.2009.0315

Araki, H. et al. 2008. Fitness of hatchery-reared salmonids in the wild Evolutionary Applications DOI:10.1111/j.1752-4571.2008.00026.x

Ford, M. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. Conserv. Biol. 16:815-925.

Fraser, D.J. 2008 How well can captive breeding programs conserve biodiversity? A review of salmonids Evolutionary Applications DOI:10.1111/j.1752-4571.2008.00036.x

Kostow, K. 2009 Factors that contribute to the ecological risks of salmon and steelhead hatchery programs and some mitigating strategies. Rev. Fish. Biol. Fisheries 19:9-31.

Morbrand, L.E. et al. 2005. Hatchery reform in Washington State: Principles and emerging issues. Fisheries 30:11-23.

Naish, K.A. et al. 2008. An Evaluation of the Effects of Conservation and Fishery Enhancement Hatcheries on Wild Populations of Salmon. Advances in Marine Biology, Volume 53 DOI: 10.1016/S0065-2881(07)53002-6

3. *What are the other alternatives that meet the purpose and need of the proposed action that were not included in the DEIS? (USFWS, NMFS)*

This DEIS combines two Actions, with the majority of the text devoted to the second action:

- **The specific action of funding Mitchell Act hatchery programs;**
- **A broad, programmatic action of providing policy guidance for reviewing HGMPs.**

We recommend the current DEIS focus on the first action, funding for Mitchell Act hatchery programs, and develop appropriate alternatives that recognize the current program and incorporates hatchery reform measures.

Should NOAA pursue a programmatic EIS in the future, we recommend that clear alternative policies be identified. The language of the current alternatives lacks policy substance and it is not evident how the alternatives would differ from each other if stripped of their implementation scenarios.

4. *Can hatchery reform concepts other than percent of hatchery origin spawners (pHOS) and percent of natural origin broodstock (pNOB), such as natural rearing strategies, be used to develop alternatives that meet the purpose and need of the DEIS but maintain more production than Alternatives 3-5? (Tribes, AK, OR, WA, ID)*

The DEIS needs to include a broad recognition of hatchery reform actions. These may include various standards and best management practices that have been developed by the HSRG, the Technical Recovery Teams, Recovery Plans, other state and federal policies and regulations, and the scientific literature. Consideration of hatchery reform actions should not be exclusive of new, developing or future strategies as they become available. Hatchery reform actions need to be integrated with harvest management to promote more efficient strategies that increase the number of fish harvested per number of hatchery fish released.

5. *What fisheries are assumed in the analysis to be mark-selective, and at what point in time? (OR, WA, ID, Tribes, AK, NMFS)*

Mark-selective fisheries can be modeled in the AHA and harvest models that were used in the DEIS. However, at this time it is difficult to determine how such fisheries were incorporated into the Implementation Scenarios because the DEIS is not explicit. Many of the harvest assumptions appear to be out-dated and the revised EIS needs to incorporate updated harvest data, management agreements and harvest biological opinions.

6. *Were Native American tribes engaged in government to government consultations in development of the DEIS, including but not limited to the four Washington coastal treaty tribes and the four Columbia River treaty tribes? (Tribes)*

No comment from ODFW.

7. *Are the impacts to all ocean fisheries in areas under management authority of the Pacific Council, the Pacific Salmon Commission, and the State of Alaska included in the analysis of each alternative in DEIS (harvest impacts to individual fishery strata, socioeconomic impacts, and the environmental justice analyses)? (STT)*

- *If not, what is the list of fisheries not included and what is the relationship of Mitchell Act hatchery production to the stock composition of those fisheries? (STT)*

We are confident that the STT will address this question. However the revised EIS needs to incorporate updated harvest data, management agreements and harvest biological opinions.

8. *Are impacts in all Columbia River basin fisheries included in the DEIS, including tributary ceremonial and subsistence and recreational fisheries? (Tribes, OR, WA, ID)*

It appears that all Columbia River fisheries were considered. However the revised EIS needs to incorporate updated harvest data, management agreements and harvest biological opinions.

9. *Is production from all Columbia Basin hatcheries included in the analysis? (USFWS, OR, WA, ID, Tribes)*

All Columbia River fish production is considered. We recommend that the scope of the current EIS be narrowed to address only Mitchell Act-funded hatchery programs.

If NOAA pursues a programmatic EIS in the future, it will need to incorporate updated fish propagation information and recognize the production agreements in the US v OR 2008-2017 agreement.

10. *Is the methodology describing economic impacts complete and proper, including the use of consistent metrics? (SSC)*

No comment from ODFW.

11. *Were expected benefits to fisheries from increased wild production included in the economic analyses? (WA, OR, ID, Tribes, AK)*

The DEIS is not explicit on this point, but based on supplemental material that has been provided by NOAA, it appears that some increased wild production and associated fisheries benefits were anticipated. However, fisheries decline under all alternatives compared to Alternative 1, Status Quo.

12. *Were current fishery and hatchery management agreements used to estimate impacts (e.g., US v Oregon, Pacific Salmon Treaty Chinook Annex, US v Washington, Hoh v Baldrige, etc.)? (WA, OR, ID, Tribes, AK)*

The DEIS states that the alternatives do not account for these agreements. A revised EIS would need to incorporate updated harvest data, management agreements and harvest biological opinions, and recognize the production agreements in the US v OR 2008-2017 agreement.

13. *Were impacts to commitments and expectations in the PST, US v Oregon, US v Washington, Hoh v Baldrige properly described in the DEIS? (WA, OR, ID, Tribes, AK)*

The anticipated decreases in hatchery production and harvest described in Alternatives 2-5 are not consistent with the anticipated harvest and hatchery production tables in the 2008-2017 US v OR

management agreement. The DEIS states that the alternatives do not account for these commitments, but also that they are not intended to supersede the commitments.

14. *Are there relevant sources of information omitted from socioeconomic analysis? (SSC)*

No comment from ODFW.

15. *Is the temporal scale of the impact assessment adequate? (WA, OR, Tribes, ID, AK)*

The temporal scale of the DEIS is 10 years, which reflects the duration of the 2008-2017 US v OR management agreement. We may not see the biological benefits of some of the hatchery reform actions in a 10-year time period.

16. *Are the natural salmon populations targeted for restoration, particularly those that become limiting factors in hatchery production, appropriately identified? (WA, OR, ID, Tribes, Council Staff)*

The natural salmon and steelhead populations addressed in the DEIS appear to be the same primary and contributing populations that are identified in the HSRG and recovery planning forums, and are therefore appropriate. Similar to the approach taken by the HSRG, stabilizing populations were not considered.

17. *Recognizing recent changes in the hatchery practices that have already occurred, what is the period used to decide the status quo alternative? (OR, USFWS, NMFS)*

According to NOAA staff, the Status Quo alternative is based largely on the period 2004 – 2007. The Status Quo alternative in a final EIS will need to recognize hatchery reform actions that have been implemented by the states, tribes, and federal government since that period.

18. *Are the DEIS alternatives consistent with adopted state recovery plans? (OR, WA, ID)*

The DEIS alternatives did not consider adopted state recovery plans. As a result the alternatives and the Implementation Scenarios are frequently not consistent with these plans. The final EIS will need to take these into consideration.

Subject: STT question for Mitchell Act DEIS comments
From: Robert Kope <Robert.Kope@noaa.gov>
Date: Tue, 28 Sep 2010 13:41:00 -0700
To: Larrie LaVoy <Larrie.LaVoy@noaa.gov>
CC: "Milward, Douglas A (DFW)" <Douglas.Milward@dfw.wa.gov>, Chuck Tracy <Chuck.Tracy@noaa.gov>, Sandy Zeiner <szeiner@nwifc.org>, Keith Lutz <lutz@nwifc.org>, Mike O'Farrell <Michael.OFarrell@noaa.gov>, Craig Foster <Craig.A.Foster@state.or.us>, Henry Yuen <henry_yuen@fws.gov>, Eric Schindler <Eric.D.Schindler@state.or.us>, Melodie Palmer-Zwahlen <mpalmer@dfg.ca.gov>, "Beeghley, Wendy L (DFW)" <Wendy.Beeghley@dfw.wa.gov>, Jennifer Simon <jsimon@dfg.ca.gov>, "Haymes, Jeffrey (DFW)" <Jeffrey.Haymes@dfw.wa.gov>

The consideration of fishery impacts in the Mitchell Act DEIS is described in Appendix K (pages 1063-1124 of the DEIS). This analysis was performed by Gary Morishima and Larry Lestelle. They apparently relied heavily on the PSC Chinook and coho (FRAM) models and baseline data to configure and parameterize simplified spreadsheet models for the purpose of analyzing impacts of alternative scenarios on fisheries.

For the coho model, FRAM fisheries were used. These included troll fisheries from the southern extent of fishing in California to Northwest Alaska, sport fisheries from the southern extent of fishing through northern British Columbia, and net fisheries from the Columbia River through Alaska. This represents complete coverage of all fisheries under the jurisdiction of the Pacific Fishery Management Council, the Pacific Salmon Commission, and the State of Alaska where Columbia River coho are likely to be encountered. So I do not think we need to address question about the contribution of Mitchell Act hatcheries to coho fisheries.

For the Chinook model, the Northern extend of fisheries included was Southeast Alaska, and the southernmost fisheries were WA/OR troll, WA ocean sport, and Columbia River net. These are fisheries from the PSC Chinook model, which has a focus on stocks and fisheries that are subject to the Pacific Salmon Treaty. It appears that for convenience, the WA/OR troll fishery was assumed to be confined to the area north of Cape Falcon, thus all fishery impacts were considered to occur north of Cape Falcon. This is similar to the assumption in Council processes that ocean fishery impacts on Sacramento Fall Chinook are negligible north of Cape Falcon. However, the contribution of Columbia River hatcheries to Chinook fisheries south of Cape Falcon appears to be something greater than "negligible". So we should address the question of the contribution of Mitchell Act hatcheries to Chinook troll and sport fisheries south of Cape Falcon. I think that Larrie and I can probably do that.

A couple of observations that mitigate the omission of these fisheries from the DEIS:

1) During the time period considered for the analysis (early 2000's) the abundance of California Chinook was high and they would have diluted the contribution of Columbia River fish to fisheries off the Oregon coast. Recent years for which we have GSI data SRFC have been scarce, so naturally the Columbia River Chinook make a larger contribution.
2) The intent of the socioeconomic and environmental justice analyses is to compare and contrast the different alternatives, so the comparisons are viewed in relativistic terms. Omission of a couple of fisheries from this comparison is unlikely to have much of an impact on the relative impacts of the different alternatives.

--Robert

Supplemental

Management Entity Response to Council Questions Concerning Preparation of Comments on the Mitchell Act Hatchery DEIS

PFMC
11/3/10

ALASKA DEPARTMENT OF FISH AND GAME RESPONSE TO PFMC QUESTIONS ON MITCHELL ACT HATCHERY DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS)

A September 23, 2010 memorandum from Executive Director Don McIsaac posed a number of questions to salmon management agencies and entities with regard to the NMFS *"Draft Environmental Impact Statement to Inform Columbia River Hatchery Operations and the Funding of Mitchell Act Hatchery Programs."* The following are Alaska Department of Fish and Game responses to questions suggested for input from Alaska. Additional input will be provided through Alaska's participation in the November Council meeting process:

1. *Have the population and fishery impacts methodologies used in the analysis been peer reviewed, and is there agreement with the States and Tribes that it represents the best available science?* **(WA, OR, ID, Tribes, AK, NMFS)**

Alaska does not have detailed knowledge regarding the level of peer review that the EIS fishery modeling detailed in Appendix K has undergone by other agencies. However, the modeling exercise is based upon standard and accepted algorithms that are components of the PSC Chinook Model and the PFMC FRAM Model, albeit in simplified form. Chinook stock groupings were manipulated; many stocks were aggregated to estimate the ocean fishery impacts using the PSC Chinook Model stock structure. These groupings were then disaggregated before estimating the fishery impacts within the Columbia River. Assuming that the stock group aggregations and disaggregations were done in a manner that was representative and consistent with the stock group representation in the PSC Chinook Model, this portion of the modeling of the fishery impacts seems appropriate.

Although the method employed could provide plausible estimates of the fishery impacts to the Columbia River stocks under different NEPA alternatives, there are several issues that are not adequately addressed in the analysis. First, the analysis is overly simplistic by assuming production from non-Columbia River stocks in the ocean is constant and totally independent from the Columbia River stocks. Second, the analysis simulates harvest rates in the ocean fisheries during the 1999 PST Agreement, which are higher than those currently allowed in the 2008 PST Agreement. Lastly, the analysis relies heavily on stock production parameters for Columbia River stocks that are not adequately explained in Appendix K. Also, model data sets have been created for virtually all Columbia River populations of Chinook and coho, whether they are entirely natural, entirely hatchery (segregated), or an integrated composite of natural and hatchery fish. The derivations of production parameters for each stock and the inherent assumptions behind them are never fully explained. This issue is vital regardless of the NEPA harvest alternative since one of the major factors that will determine the long term health of each of the stocks is its' production potential. Does the AHA model take into account the interaction of the wild and hatchery fish as the level of hatchery production goes up or down? Will the production parameters of th*e hatchery fish change as hatchery practices change? For example,* *will the introduction of* more wild fish into the hatchery broodstock change the production parameters for the hatchery fish? The assumptions about the underlying productivity of the stocks are a major part of this analysis that deserves more scrutiny.

2. *Are the mitigation requirements and responsibilities under the Mitchell Act adequately described in the DEIS?* **(WA, OR, ID, Tribes, AK)**

No. We do not find that the EIS adequately addresses the mitigation requirements and responsibilities within the Columbia River Basin. These requirements and responsibilities are not limited to the Mitchell Act, but also include a large number of other programs that are the subject of "policy direction" under the DEIS. The document should recognize the range of mitigation purposes of enhanced production and describe how actions / policies identified in the DEIS may impact the variety of mitigation requirements and responsibilities in both the short and long-term.

3. *What are the other alternatives that meet the purpose and need of the proposed action that were not included in the DEIS?* **(USFWS, NMFS)**

4. Can hatchery reform concepts other than percent of hatchery origin spawners (PHOS) and percent of natural origin broodstock (PNOB), such as natural rearing strategies, be used to develop alternatives that meet the purpose and need of the DEIS but maintain more production than Alternatives 3-5? **(Tribes, AK, OR, WA, ID)**

While reform of Columbia River basin hatcheries is widely considered to be a beneficial and desired action, focusing only on the genetics and intent to implement genetic standards as described in the draft Mitchell Act EIS is disappointing. The single minded focus on this technical issue and recommended application of the proposed genetic standards to all Columbia River basin hatcheries represents a failure by NMFS to address reform of Columbia River basin hatchery programs in a meaningful manner. Other technical issues (for example disease prevention and transmission, water quality and quantity) are completely ignored in the alternatives. There are a number of hatchery reforms that need to be evaluated and utilized in developing alternatives that meet the purpose and need while maintaining more production than those identified in the DEIS.

5. *What fisheries are assumed in the analysis to be mark-selective, and at what point in time?* **(OR, WA, ID, Tribes, AK, NMFS)**

Appendix K provides some detail regarding the mark-selective fisheries (MSFs) that were incorporated into the EIS fishery models for coho and Chinook. It gives a more detailed description of the assumptions used in the MSFs for coho than for Chinook. It also states that the model incorporates "*MSF only for spring chinook fisheries in the Columbia River below*

Bonneville Dam." Thus the modeling does not reflect recent expansion of MSF into ocean fisheries in 2010 or potential impacts that may result if the "policy direction" of significantly expanded MSFs were to be implemented. There is currently increasing concern over the mark rates experienced in MSFs. If hatchery production is reduced, the issues with observed mark rates and mortalities of wild stock release (potentially multiple releases in several fisheries) will be exacerbated.

6. *Were Native American tribes engaged in government to government consultations in development of the DEIS, including but not limited to the four Washington coastal treaty tribes and the four Columbia River treaty tribes?* **(Tribes)**

7. Are the impacts to all ocean fisheries in areas under management authority of the Pacific Council, the Pacific Salmon Commission, and the State of Alaska included in the analysis of each alternative in DEIS (harvest impacts to individual fishery strata, socioeconomic impacts, and the environmental justice analyses)? **(STT)**

    • If not, what is the list of fisheries not included and what is the relationship of Mitchell Act hatchery production to the stock composition of those fisheries? **(STT)**

As explained in the response to question 1 with the noted caveats, the approach taken appears to be a reasonable one for estimating the stock impacts that occur in the ocean fisheries. In other words, the model structure itself seems reasonable. However, the assumptions about the independence of the production from Columbia River and non-Columbia River stocks; the choice of ocean harvest rates derived from years under the 1999 PST Agreement instead of the 2008 PST Agreement; the estimated impacts from MSFs; and the AHA production parameters for Columbia River stocks could influence the model results for each of the NEPA harvest alternatives and should be investigated further.

8. *Are impacts in all Columbia River basin fisheries included in the DEIS, including tributary ceremonial and subsistence and recreational fisheries?* **(Tribes, OR, WA, ID)**

9. *Is production from all Columbia Basin hatcheries included in the analysis?* **(USFWS, OR, WA, ID, Tribes)**

10. *Is the methodology describing economic impacts complete and proper, including the use of consistent metrics?* **(SSC Economic and Salmon Subcommittees)**

11. *Were expected benefits to fisheries from increased wild production included in the economic analyses?* **(WA, OR, ID, Tribes, AK)**

No. The DEIS does not appear to include any substantive discussion of underlying assumptions with increased wild production in either the technical or economic analyses. The lack of focus on how recommended actions may actually benefit the wild salmon stocks of the Columbia River Basin or the users of these natural resources is a serious deficiency in the document.

12. *Were current fishery and hatchery management agreements used to estimate impacts (e.g., US v Oregon, Pacific Salmon Treaty Chinook Annex, US v Washington, Hoh v Baldrige, etc.)?* **(WA, OR, ID, Tribes, AK)**

The DEIS uses the 1999 Pacific Salmon Treaty (PST) agreement rather than the provisions contained in the 2008 revision. Thus the Chinook impacts under the current PST Chinook fishery provisions may not be estimated correctly. As detailed in Appendix K, the DEIS uses relatively simple models to project marine fishery catch levels and run sizes to the mouth of the Columbia River. There are 30 model stock groups in the PSC Chinook Model, 10 of which are from the Columbia River. The modeling of the 5 alternatives assumed constant abundance for the 20 non-Columbia River stock groups, while the 10 aggregated Columbia Rivers stocks were allowed to vary and various assumptions were applied to them, such as survival.

The analysis in Appendix K uses a harvest-rate as the center piece of the simplified approach as noted above. However, the 2008 PST agreement does not specify an underlying harvest-rate approach for the three Aggregate Abundance Based Management fisheries: West Coast Vancouver Island (WCVI), North BC (NBC) and Southeast Alaska (SEAK). Catch limits in all three are now tied to relative abundance, rather than a harvest-rate, e.g., at a given abundance index, a catch limit is the accounting benchmark and the harvest rate is whatever postseason analysis deems it to be. In addition, at all abundance levels the catch limits in WCVI and SEAK under the 2008 agreement are currently reduced by 30% and 15% respectively as compared to those in the 1999 agreement.

13. *Were impacts to commitments and expectations in the PST, US v Oregon, US v Washington, Hoh v Baldrige properly described in the DEIS?* **(WA, OR, ID, Tribes, AK)**

Under the PST Agreement, if any of the four alternatives in the DEIS other than alternative #1 are implemented, changes in Columbia River hatchery production of Chinook salmon will likely be inconsistent with expectations in the PST. For example, catch limits in the WCVI AABM fishery were cut by 30%, but it was agreed that no further reductions would be applicable to the table used to calculate this fishery's annual abundance-based catch limits. Changes in abundance of the Columbia River hatchery or wild stocks could significantly change the overall abundance and stock-age mixture in the WCVI fishery. Catches of Chinook in this fishery are dominated by Columbia River and Puget Sound stocks. Impacts on Puget Sound stocks, which are listed under the U.S. ESA, would most likely increase.

The approach in the MA-DEIS does not reflect what may happen if any but alternative #1 is implemented. For the other alternatives, effects on stock abundance, catch levels, exploitation rates and impacts to fisheries, fishers and economies are unknown. It appears to be a trial and error approach and could deliver very deleterious impacts to coastal fisheries and communities.

14. *Are there relevant sources of information omitted from socioeconomic analysis?* **(SSC Economic and Salmon Subcommittees)**

15. *Is the temporal scale of the impact assessment adequate?* **(WA, OR, Tribes, ID, AK)**

This question is somewhat vague. Does it mean to address whether a sufficient number of years were modeled or whether there was a sufficient stratification of time periods within each year? Since the PSC Chinook Model operates on a yearly time step, it is unlikely that the DEIS fishery model which is based upon it would be able to estimate impacts down to a finer scale than a year. In addition, the DEIS model was not set up to make yearly projections of future fishery impacts so it does not address that issue either.

16. *Are the natural salmon populations targeted for restoration, particularly those that become limiting factors in hatchery production, appropriately identified?* **(WA, OR, ID, Tribes, Council Staff)**

17. *Recognizing recent changes in the hatchery practices that have already occurred, what is the period used to decide the status quo alternative?* **(OR, USFWS, NMFS)**

18. *Are the DEIS alternatives consistent with adopted state recovery plans?* **(OR, WA, ID)**

Additional ADFG Comments:

Benefits from Mitchell Act Hatchery EIS Alternatives

A remarkable void in the NMFS draft Mitchell Act Hatchery EIS is a listing or description of possible benefits from the suggested alternatives. The three action alternatives (3-5) all involve setting genetic brood stock standards for hatcheries in the Columbia River basin. However, there is no description, either qualitative or quantitative that describes potential benefits were these standards achieved. Would productivity of natural spawners increase; if so, to what degree? The document devotes a small amount of text to the genetic risks that hatchery salmon pose to natural spawning salmon; yet devotes no effort to describing benefits to ESA-listed or non-ESA-listed salmon stocks were these standards adhered to by hatcheries within the Columbia River basin.

Appendix C:

Technical staff has spent time attempting to review Appendix C1. Hatchery Performance by

Alternative for Chinook Salmon and the following questions/issues have been raised:

The color coding indicating **Supporting**, **Consistent**, and **Not Consistent** needs explanation in the context of this DEIS. Are these ratings intended to convey current conditions or conditions under the proposed alternative at some time in the future; if so when? The concept behind the color coding and the terms: **Primary**, **Contributing**, and **Supporting** have an implied meaning for salmon stocks listed under the Endangered Species Act as described elsewhere in the EIS document. However, these same terms are used to label hatchery production associated with non-ESA listed stocks as well. For instance, the entries listed under Upper Columbia River Summer/Fall-run Chinook are all listed as primary, contributing, or stabilizing and yet these fish are not ESA listed. Federal labeling of these stocks in an ESA context is not appropriate. Details concerning individual hatchery programs can only be gleaned from information listed in Appendix C, yet the labeling and color coding provided is inadequate for review.

Scope:

We believe that the scope of the EIS should be scaled back to its original intent of providing guidance for utilization of Mitchell Act funds. The expansion of the document in 2009 to consider all hatchery programs in the Columbia River Basin has led to much confusion and an inferior document. Future examination of facilities and policies in the basin could be based on much better analysis of the overall operations of individual hatcheries, the mitigation requirements and responsibilities associated with facilities, and the variety of factors (habitat, water, etc) that must be taken into account to determine potential benefits to wild salmon production from hatchery actions.

To: **John Coon, Pacific Fishery Management Council (PFMC)**

From: **Allyson Purcell, National Marine Fisheries Service (NMFS)**

Date: **October 20, 2010**

Re: **Responses to PFMC Questions Related to the Draft Environmental Impact Statement (DEIS)**

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1. **Has the science used in the analysis been peer reviewed?**
   Yes. The analysis relies on peer reviewed literature (Chapter 6, References) and models (Section 4.2, Fish and Section 4.3, Socioeconomics). In addition, each resource section in the DEIS was peer reviewed by at least one expert in the subject matter.

2. **Are the mitigation requirements and responsibilities under the Mitchell Act adequately described in DEIS?**
   The text of the Mitchell Act is included verbatim in Section 1.1.1, The Mitchell Act. The Mitchell Act is "To provide for the conservation of the fishery resources in the Columbia River, establishment, operation, and maintenance of one or more stations in Oregon, Washington, and Idaho, and for the conduct of necessary investigations." The Mitchell Act does not identify specific mitigation requirements.

3. **What are the other alternatives that meet the purpose and need for action but were not included in the DEIS?**
   An incalculable number of actions – and combinations of actions – could be implemented with regards to Mitchell Act funding and the operation of hatchery programs in the Columbia River basin. As a result, each of the alternatives evaluated in the draft EIS (except for the No-action alternative) centers around a policy direction that is defined by a set of goals and/or principles. A great number of actions can be taken consistent with the goals and/or principles of each alternative. For example, implementing sliding scales for the management of adult fish is not evaluated as an alternative, but it is an action that is consistent with several of the five alternatives that were evaluated in detail within the DEIS. Likewise, increasing hatchery production levels would be consistent with the policy directions of Alternatives 3, 4 and 5 as long as impacts to listed natural-origin salmon ESUs or steelhead DPSs were reduced (In theory, even Alternative 2 would allow for added production if the amount of new production exceeded that lost from termination of Mitchell Act-funded production).

   Activities that are not considered to be within a reasonable range of potential funding or operational opportunities and therefore not meeting the purpose and need for action include the following: 1) construction of new hatchery facilities with Mitchell Act funds, 2) changes to the Mitchell Act Screens and Fishways Program, 3) habitat restoration, and 4) hatchery practices that would increase adverse effects on listed species (Section 1.2, Purpose and Need for Action).

A preferred alternative was not identified in the draft EIS. NMFS will receive comment on the draft EIS before developing a preferred alternative. The preferred alternative may be one of the alternatives evaluated in the draft EIS or it may be a combination of goals and/or principles from more than one of the alternatives evaluated in the draft EIS.

4. **Can hatchery reform concepts other than the proportion of hatchery origin spawners (pHOS) and proportion of natural origin broodstock (pNOB), such as natural rearing strategies, be used to develop alternatives that meet the purpose and need of the DEIS but maintain more production than Alternatives 3-5?**
   To clarify, neither pHOS nor pNOB were used in the alternatives. The alternatives are general statements of policy direction. They do not identify production levels or other specific implementation actions. This is because NMFS believes that specific hatchery actions should be determined on a hatchery-program-by-hatchery-program basis (Section 2.6, Identifying an Implementation Scenario). To analyze, illustrate, and compare the potential environmental effects of each alternative, however, an implementation scenario was developed for each alternative's policy direction. These implementation scenarios do include metrics for purposes of comparison.

   Each implementation scenario is one hypothetical example of how each hatchery program could be operated to meet the policy direction of the alternative. There are, however, multiple implementation scenarios that could be applied consistent with each alternative, and these implementation scenarios could include natural rearing strategies and increased hatchery production.

5. **What fisheries are assumed to be mark-selective and at what point in time?**
   Although mark-selective fisheries would be an action consistent with all of the alternatives, no new selective fisheries were initiated under any of the implementation scenarios.

6. **Were Native American Tribes engaged in the government to government consultations in development of the DEIS including the four Washington coastal treaty tribes and the four Columbia River treaty tribes?** NMFS is aware of concerns among some tribes that inadequate consultation occurred during development of the DEIS. NMFS has no comment on this assertion but is committed to working with the tribes throughout the EIS process.

7. **Are the impacts to all ocean fisheries in areas under management authority of the Pacific Council, the Pacific Salmon Commission, and the State of Alaska included in the analysis of each alternative in the DEIS?**
   The draft EIS considered impacts to fisheries to which Columbia River salmon meaningfully contribute. This includes fisheries in Southeast Alaska, British Columbia, Puget Sound/Strait of Juan de Fuca, North of Cape Falcon (Northern Oregon and Washington Coast), and South of Cape of Falcon (Oregon and California Coast) (Table 3-11). Impacts are summarized in Tables 4-88, 4-89, 4-90, 4-92, 4-93, 4-96, and 4-97.

Effects on the following Chinook salmon fisheries in the ocean and Puget Sound were evaluated:

Fishery no.	Fishery name
1	Alaska troll
2	North troll
3	Central troll
4	WCVI troll
5	WA/OR troll
6	Strait of Georgia troll
7	Alaska net
8	Noth net
9	Central net
10	WCVI net
11	Juan de Fuca net
12	Puget Sound North net
13	Puget Sound South net
14	Washington Coast net
15	Columbia River net
16	Johnstone Strait net
17	Fraser net
18	Alaska sport
19	North/Central sport
20	WCVI sport
21	Washington ocean sport
22	Puget Sound North sport
23	Puget Sound South sport
24	Strait of Georgia sport

Source: Appendix K, Chinook and Coho Salmon Fishery Modeling Approach for Application to the Mitchell Act EIS.

Effects on the following coho salmon fisheries in the ocean and Puget Sound were evaluated:

Fishery number	Coho FRAM Fishery Name	Abbrev Name
1	North California Coast Terminal Catch	No Cal Trm
2	Central California Coast Terminal Catch	Cn Cal Trm
3	Fort Bragg Sport	Ft Brg Spt
4	Fort Bragg Troll	Ft Brg Trl
5	KMZ Sport (Klamath Management Zone)	Ca KMZ Spt
6	KMZ Troll (Klamath Management Zone)	Ca KMZ Trl
7	Southern California Sport	So Cal Spt
8	Southern California Troll	So Cal Trl
9	South Oregon Coast Terminal Catch	So Ore Trm
10	Oregon Private Hatchery Terminal Catch	Or Prv Trm
11	South-Mid Oregon Coast Terminal Catch	SMi Or Trm
12	North-Mid Oregon Coast Terminal Catch	NMi Or Trm
13	North Oregon Coast Terminal Catch	No Ore Trm
14	Mid-North Oregon Coast Terminal Catch	Or Cst Trm
15	Brookings Sport	Brkngs Spt
16	Brookings Troll	Brkngs Trl
17	Newport Sport	Newprt Spt
18	Newport Troll	Newprt Trl
19	Coos Bay Sport	Coos B Spt
20	Coos Bay Troll	Coos B Trl
21	Tillamook Sport	Tillmk Spt
22	Tillamook Troll	Tillmk Trl
23	Buoy 10 Sport (Columbia River Estuary)	Buoy10 Spt
24	Lower Columbia River Mainstem Sport	L ColR Spt
25	Lower Columbia River Net (Excl Youngs Bay)	L ColR Net
26	Youngs Bay Net	Yngs B Net
27	Below Bonneville Oregon Tributary Sport	LCROrT Spt
28	Clackamas River Sport	Clackm Spt
29	Sandy River Sport	SandyR Spt
30	Below Bonneville Washington Tributary Sport	LCRWaT Spt
31	Above Bonneville Sport	UpColR Spt
32	Above Bonneville Net	UpColR Net
33	Area 1 (Illwaco) & Astoria Sport	A1-Ast Spt
34	Area 1 (Illwaco) & Astoria Troll	A1-Ast Trl
35	Area 2 Troll Non-treaty (Westport)	Area2TrlNT
36	Area 2 Troll Treaty (Westport)	Area2TrlTR
37	Area 2 Sport (Westport)	Area 2 Spt
38	Area 3 Troll Non-treaty (LaPush)	Area3TrlNT
39	Area 3 Troll Treaty (LaPush)	Area3TrlTR
40	Area 3 Sport (LaPush)	Area 3 Spt
41	Area 4 Sport (Neah Bay)	Area 4 Spt
42	Area 4/4B (Neah Bay PFMC Regs) Troll Non-treaty	A4/4BTrlNT
43	Area 4/4B (Neah Bay PFMC Regs) Troll Treaty	A4/4BTrlTR
44	Area 5, 6, 6C Troll (Strait of Juan de Fuca)	A 5-6C Trl
45	Willapa Bay (Area 2.1) Sport	Willpa Spt
46	Willapa Tributary Sport	Wlp Tb Spt
47	Willapa Bay & FW Trib Net	WlpaBT Net
48	Grays Harbor (Area 2.2) Sport	GryHbr Spt
49	South Grays Harbor Sport (Westport Boat Basin)	SGryHb Spt
50	Grays Harbor Estuary Net	GryHbr Net

Fishery number	Coho FRAM Fishery Name	Abbrev Name
51	Humptulips River Sport	Hump R Spt
52	Lower Chehalis River Net	LwCheh Net
53	Humptulips River Ceremonial & Subsistence	Hump R C&S
54	Chehalis River Sport	Chehal Spt
55	Humptulips River Net	Hump R Net
56	Upper Chehalis River Net	UpCheh Net
57	Chehalis River Ceremonial & Subsistence	Chehal C&S
58	Wynochee River Sport	Wynoch Spt
59	Hoquiam River Sport	Hoquam Spt
60	Wishkah River Sport	Wishkh Spt
61	Satsop River Sport	Satsop Spt
62	Quinault River Sport	Quin R Spt
63	Quinault River Net	Quin R Net
64	Quinault River Ceremonial & Subsistence	Quin R C&S
65	Queets River Sport	Queets Spt
66	Clearwater River Sport	Clrwtr Spt
67	Salmon River (Queets) Sport	Salm R Spt
68	Queets River Net	Queets Net
69	Queets River Ceremonial & Subsistence	Queets C&S
70	Quillayute River Sport	Quilly Spt
71	Quillayute River Net	Quilly Net
72	Quillayute River Ceremonial & Subsistence	Quilly C&S
73	Hoh River Sport	Hoh R Spt
74	Hoh River Net	Hoh R Net
75	Hoh River Ceremonial & Subsistence	Hoh R C&S
76	Makah Tributary Sport	Mak FW Spt
77	Makah Freshwater Net	Mak FW Net
78	Makah Ceremonial & Subsistence	Makah C&S
79	Area 4, 4A Net (Neah Bay)	A 4-4A Net
80	Area 4B, 5, 6C Net Nontreaty (Strait of JDF)	A4B6CNetNT
81	Area 4B, 5, 6C Net Treaty (Strait of JDF)	A4B6CNetTR
82	Area 6D Dungeness Bay/River Net Nontreaty	Ar6D NetNT
83	Area 6D Dungeness Bay/River Net Treaty	Ar6D NetTR
84	Elwha River Net	Elwha Net
85	West JDF Straits Tributary Net	WJDF T Net
86	East JDF Straits Tributary Net	EJDF T Net
87	Area 7, 7A Net Nontreaty (San Juan Islands)	A6-7ANetNT
88	Area 7, 7A Net Treaty (San Juan Islands)	A6-7ANetTR
89	East JDF Straits Tributary Sport	EJDF FWSpt
90	West JDF Straits Tributary Sport	WJDF FWSpt
91	Area 5 Marine Sport (Sekiu)	Area 5 Spt
92	Area 6 Marine Sport (Port Angeles)	Area 6 Spt
93	Area 7 Marine Sport (San Juan Islands)	Area 7 Spt
94	Dungeness River Sport	Dung R Spt
95	Elwha River Sport	ElwhaR Spt
96	Area 7B-7C-7D Net Nontreaty (Bellingham Bay)	A7BCDNetNT
97	Area 7B-7C-7D Net Treaty (Bellingham Bay)	A7BCDNetTR
98	Nooksack River Net	Nook R Net
99	Nooksack River Sport	Nook R Spt
100	Samish River Sport	Samh R Spt

Fishery number	Coho FRAM Fishery Name	Abbrev Name
101	Area 8 Skagit Marine Net Nontreaty	Ar 8 NetNT
102	Area 8 Skagit Marine Net Treaty	Ar 8 NetTR
103	Skagit River Net	Skag R Net
104	Skagit River Test Net	SkgR TsNet
105	Swinomish Channel Net	SwinCh Net
106	Area 8.1 Marine Sport	Ar 8-1 Spt
107	Area 9 Marine Sport (Admiralty Inlet)	Area 9 Spt
108	Skagit River Sport	Skag R Spt
109	Area 8A Stillaguamish/Snohomish Net Nontreaty	Ar8A NetNT
110	Area 8A Stillaguamish/Snohomish Net Treaty	Ar8A NetTR
111	Area 8D Tulalip Bay Net Nontreaty	Ar8D NetNT
112	Area 8D Tulalip Bay Net Treaty	Ar8D NetTR
113	Stillaguamish River Net	Stil R Net
114	Snohomish River Net	Snoh R Net
115	Area 8.2 Marine Sport	Ar 8-2 Spt
116	Stillaguamish River Sport	Stil R Spt
117	Snohomish River Sport	Snoh R Spt
118	Area 10 Marine Sport (Seattle)	Ar 10 Spt
119	Area 10 Net Nontreaty (Seattle)	Ar10 NetNT
120	Area 10 Net Treaty (Seattle)	Ar10 NetTR
121	Area 10A Net Nontreaty (Elliott Bay)	Ar10ANetNT
122	Area 10A Net Treaty (Elliott Bay)	Ar10ANetTR
123	Area 10E Net Nontreaty (East Kitsap)	Ar10ENetNT
124	Area 10E Net Treaty (East Kitsap)	Ar10EnetTR
125	Area 10F-G Ship Canal/Lake Washington Net Treaty	10F-G Net
126	Green/Duwamish River Net	Duwm R Net
127	Green/Duwamish River Sport	Duwm R Spt
128	Lake Washington-Lake Sammamish Tributary Sport	L WaSm Spt
129	Area 11 Marine Sport (Tacoma)	Ar 11 Spt
130	Area 11 Net Nontreaty (Tacoma)	Ar11 NetNT
131	Area 11 Net Treaty (Tacoma)	Ar11 NetTR
132	Area 11A Net Nontreaty (Commencement Bay)	Ar11ANetNT
133	Area 11A Net Treaty (Commencement Bay)	Ar11ANetTR
134	Puyallup River Net	Puyl R Net
135	Puyallup River Sport	Puyl R Spt
136	Area 13 Marine Sport (South Puget Sound)	Ar 13 Spt
137	Area 13 Net Nontreaty (South Puget Sound)	Ar13 NetNT
138	Area 13 Net Treaty (South Puget Sound)	Ar13 NetTR
139	Area 13C Net Nontreaty (Chambers Bay)	Ar13CNetNT
140	Area 13C Net Treaty (Chambers Bay)	Ar13CNetTR
141	Area 13A Net Nontreaty (Carr Inlet)	Ar13ANetNT
142	Area 13A Net Treaty (Carr Inlet)	Ar13ANetTR
143	Area 13D Net Nontreaty (South Puget Sound)	Ar13DNetNT
144	Area 13D Net Treaty (South Puget Sound)	Ar13DNetTR
145	Area 13F-13K Net Nontreaty (South PS Inlets)	A13FKNetNT
146	Area 13F-13K Net Treaty (South PS Inlets)	A13FKNetTR
147	Nisqually River Net	Nisq R Net
148	McAllister Creek Net	McAlls Net
149	13D-13K Tributary Sport (South PS Inlets)	13D-K TSpt
150	Nisqually River Sport	Nisq R Spt

Fishery number	Coho FRAM Fishery Name	Abbrev Name
151	Deschutes River Sport (Olympia)	Desc R Spt
152	Area 12 Marine Sport (Hood Canal)	Ar 12 Spt
153	Area 12-12B Net Nontreaty (Upper Hood Canal)	1212BNetNT
154	Area 12-12B Net Treaty (Upper Hood Canal)	1212BNetTR
155	Area 9A Net Nontreaty (Port Gamble)	Ar9A NetNT
156	Area 9-9A Net Treaty (Port Gamble/On Reservation)	Ar9A NetTR
157	12A Net Nontreaty (Quilcene Bay)	Ar12ANetNT
158	12A Net Treaty (Quilcene Bay)	Ar12ANetTR
159	12C-12D Net Nontreaty (Lower Hood Canal)	A12CDNetNT
160	12C-12D Net Treaty (Lower Hood Canal)	A12CDNetTR
161	Skokomish River Net	Skok R Net
162	Quilcene River Net	Quilcn Net
163	12-12B Tributary FW Sport	1212B TSpt
164	12A Tributary FW Sport (Quilcene River)	Quilcn Spt
165	12C-12D Tributary FW Sport	12C-D TSpt
166	Skokomish River Sport	Skok R Spt
167	Lower Fraser River Stock Terminal Catch	FRSLOW Trm
168	Upper Fraser River Stock Terminal Catch	FRSUPP Trm
169	Fraser River/Estuary Sport	Fraser Spt
170	Johnstone Straits Troll	JStrBC Trl
171	Northern British Columbia Troll	No BC Trl
172	North Central British Columbia Troll	NoC BC Trl
173	South Central British Columbia Troll	SoC BC Trl
174	NW Vancouver Island Troll	NW VI Trl
175	SW Vancouver Island Troll	SW VI Trl
176	Georgia Straits Troll	GeoStr Trl
177	British Columbia Juan de Fuca Troll	BC JDF Trl
178	Northern British Columbia Net	No BC Net
179	Central British Columbia Net	Cen BC Net
180	NW Vancouver Island Net	NW VI Net
181	SW Vancouver Island Net	SW VI Net
182	Johnstone Straits Net	Johnst Net
183	Georgia Straits Net	GeoStr Net
184	Fraser River Gill Net	Fraser Net
185	British Columbia Juan de Fuca Net	BC JDF Net
186	Johstone Strait Sport	JStrBC Spt
187	Northern British Columbia Sport	No BC Spt
188	Central British Columbia Sport	Cen BC Spt
189	British Columbia Juan de Fuca Sport	BC JDF Spt
190	West Coast Vancouver Island Sport	WC VI Spt
191	North Georgia Straits Sport	NGaStr Spt
192	South Georgia Straits Sport	SGaStr Spt
193	Alberni Canal Sport	Albern Spt
194	Southwest Alaska Troll	SW AK Trl
195	Southeast Alaska Troll	SE AK Trl
196	Northwest Alaska Troll	NW AK Trl
197	Northeast Alaska Troll	NE AK Trl
198	Alaska Net (Areas 182:183:185:192)	Alaska Net

Source: Appendix K, Chinook and Coho Salmon Fishery Modeling Approach for Application to the Mitchell Act EIS.

8. **Are impacts to all Columbia River basin fisheries included in the DEIS, including tributary C & S and recreational fisheries?**
   NMFS is unaware of any fishery that occurred in the basin in 2007 that is not included. Table 4-91 through Table 4-93 show potential impacts to recreational fisheries in the Columbia River basin. These impacts are discussed in Section 4.3.4, Harvest and Economic Value, and Section 4.3.5, Regional Economic Conditions. Effects on tributary C & S fisheries can be found in Section 4.4.4.2, Ceremonial and Subsistence Harvest.

9. **Is production for all Columbia River basin hatcheries included in the analysis?**
   Alternative 1 describes status quo operation of hatchery operations in the Columbia River basin (Section 2.5.1, Alternative 1 (No Action) as it existed in 2007. However, like the other alternatives, Alternative 1 does not identify hatchery production levels because the DEIS's alternatives are general and goal-oriented. This is because NMFS believes that specific hatchery actions should be determined on a hatchery-program-by-hatchery-program basis (Section 2.6, Identifying an Implementation Scenario). To analyze, illustrate, and compare the potential environmental effects of each alternative, a hypothetical implementation scenario was identified for each alternative. The implementation scenario for Alternative 1 included 2007 production levels for all Columbia River basin hatchery programs. The 2007 data was the most current data available when NMFS began modeling the implementation scenarios.

10. **Is the methodology describing economic impacts complete and proper, including consistent metrics? For example, are there more appropriate indices of fishery value that should be used rather than ex-vessel value?**
    As is typical in a socioeconomic analysis of fishery effects, the following metrics were used in the DEIS: 1) effects on the number of fish harvest, 2) ex-vessel value, 3) net economic value, 4) income, and 5) jobs (Section 4.3.2.3, Harvest and Economic Value, and Section 4.3.2.4, Regional Economic Conditions). These metrics were applied consistently across the alternatives.

11. **Were expected benefits from increased wild production included in the economic analysis?**
    Yes. The AHA and EIS harvest models were linked with output from each providing input to the other. Population-specific estimates of juvenile production served as the input to the harvest model, and harvest impacts output from the harvest model then became the final input needed to complete the life cycle in the AHA Model. NMFS requested [or expects] public comment on the use of these models.

12. **Were current fishery and hatchery management agreements used to estimate impacts?**
    It is neither feasible nor practicable to attempt to produce an EIS harvest analysis that would generate catch projections that would be directly comparable to observed historical catch levels. Such an effort would involve an extremely complex modeling approach. There is an immense potential for a wide variety of stock conditions, fishing patterns, and regulations that

could potentially occur in response to changes in production of Columbia River stocks under various EIS alternative scenarios. Justification would be required for myriad decisions that affect the distribution of harvest opportunity and assumptions regarding fisherman behavior. And, the results that would be produced would confound effects of fishing patterns and stock-age cohort abundance, greatly increasing the complexity of reporting and interpreting potential impacts of EIS alternatives.

A simple steady-state analysis was employed to provide information on how fishery impacts would be expected to change under EIS alternatives. Simulation models were developed separately for Chinook and coho using Microsoft Excel software. The models incorporate three major elements:

(a) Variation in abundance only for Columbia River stocks under the EIS alternatives. The abundance of all stocks originating outside the Columbia River are fixed at levels associated with base periods used in fishery planning models employed by the PSC and PFMC;

(b) Exploitation rates, patterns, and regulations characterized by base period data for the PSC and PFMC planning models; and

(c) Prescriptive rules to govern conduct of fisheries. These prescriptive rules include: (1) Pacific Salmon Treaty agreements for Chinook and coho in effect through 2008; (2) annual guidance for fishery management planning provided by the NMFS for ESA-listed Chinook and coho stocks; (3) the Columbia River Interim Management Agreement in effect through 2007; (4) the PFMC Framework Management Plan; and (5) MSF for coho only in PFMC ocean and Columbia River in-river fisheries; MSF only for spring Chinook fisheries in the Columbia River below Bonneville Dam.

13. **Were impacts to commitments in the PST, US v OR, US v Washington, and Hoh v Baldridge properly described in the EIS?** First, NMFS constructed the alternatives as policy statements, in part, to avoid the problem presented in determining whether any specific production regime is or is not compliant with these various agreements. NMFS recognized that, just as it takes all parties to these agreements to determine whether a proposal is consistent with these agreements, so too does it require all parties to determine the "impact" of a change to the *status quo.* As a result, the analysis does not attempt to do so, but states NMFS's expectation that all parties will ensure that their actions are consistent with the agreements.

14. **Are there relevant sources of information omitted from the socioeconomic analysis?** NMFS is not aware of any relevant sources of information that were omitted.

15. **Is the temporal scale of the impact assessment adequate?** NMFS believes it is.

16. **Are the natural salmon populations targeted for restoration adequately identified?**
    Appendix C through Appendix F identify each population as primary, contributing, stabilizing, or "not in the ESU." Within the alternatives, performance goals were applied to hatchery programs affecting primary and contributing populations.

17. **Recognizing recent changes in the hatchery practices that have already occurred, what is the period used to decide the status quo alternative?**
    Hatchery practices from 2007 are used to describe status quo conditions within the implementation scenario for Alternative 1 (No action – status quo). This was the most current data available when NMFS began modeling the implementation scenarios.

18. **Are the DEIS alternatives consistent with adopted state recovery plans?**
    Under each policy direction, performance goals are identified for hatchery programs according to the location of the hatchery programs and the type of salmon and steelhead populations that may be affected. For example, stronger performance goals are applied under some alternatives when the hatchery programs affect populations that have an important role in the recovery of listed DPSs/ESUs or are strongholds of non-listed ESUs or DPSs. Performance goals are intended to reduce the negative effects of hatchery programs on natural-origin salmon and steelhead populations. Two performance goals (in addition to the baseline conditions) were identified for use in this EIS: 1) a stronger performance goal and 2) an intermediate performance goal.

    Each population was designated as primary, contributing, or stabilizing. The Lower Columbia Fish Recovery Board (LCFRB) used these designations in the development of the Lower Columbia River Salmon Recovery and Fish & Wildlife Subbasin Plan (LCFRB 2004). The HSRG adapted the designations throughout the basin after discussions with hatchery managers, and they are applied in this draft EIS (Appendix C through Appendix F). In some cases, there may be differences between the HSRG classifications and what is found in the most current recovery planning documents. HSRG classifications will be replaced with current designations from recovery planning documents before any policy direction is implemented (Section 2.4, Alternative Development).

Agenda Item F.4.b
Supplemental MAC Report
November 2010

MITCHELL ACT COMMITTEE PROPOSED COMMENTS ON THE MITCHELL ACT HATCHERY DRAFT ENVIRONMENTAL IMPACT STATEMENT

The Pacific Fishery Management Council's ad hoc Mitchell Act Committee (MAC) met on November 3 and 4, 2010 to develop proposed comments on the Draft Environmental Impact Statement to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs (DEIS). The MAC reviewed the management entity and advisory body response to specific questions developed by the Council at its September meeting, took public comment, and developed a draft letter (MAC Attachment 1) for Council review and approval.

The MAC appreciates the responses and suggestions for comments provided by the management entities, Council advisory bodies, and public. These reports and comments are available in the Council record and should be considered in the National Marine Fisheries Service (NMFS) review of comments on the DEIS.

The management entity comments by representatives of the US Fish and Wildlife Service, Oregon Department of Fish and Wildlife, Alaska Department of Fish and Game, and NMFS are contained in Agenda Items F.4.b, Management Entity Comments; and F.4.b, Supplemental Management Entity Comments. Comments of the Scientific and Statistical Committee regarding the economic analysis are contained in Agenda Item F.4.b, Supplemental SSC Report. Comments of the Salmon Technical Team are contained in Agenda Item F.4.b, Supplemental STT Report. Comments of the Salmon Advisory Subpanel are contained in Agenda Item F.4.b, Supplemental SAS Report. Written public comments are contained in Agenda Item F.4.c, Public comment.

PFMC
11/05/10

Proposed Draft Comment Letter

November 5, 2010

William W. Stelle, Jr.
Regional Administrator
NMFS Northwest Region
7600 Sandpoint Way NE
Seattle, WA 98115

Re: Mitchell Act EIS

Dear Mr. Stelle:

Thank you for the opportunity to review the Draft Environmental Impact Statement to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs (DEIS) and for extending the comment deadline to allow a full Council review. The results of this DEIS process will likely have a profound influence on the policy direction for all anadromous production within the Columbia Basin and will affect how mitigation requirements for impacts to Columbia River salmon and steelhead stocks from the Columbia River hydroelectric system will be met. These issues are extremely important to Pacific Fishery Management Council (Council) fishery management and to the future of ocean and inriver fisheries.

The comments provided here are those of the Council and are not intended to represent the official policy positions of any of our member entities who will also separately provide additional specific comments on the DEIS. We recognize that developing the DEIS has been a laborious and complex project and that many of its descriptions and analyses are well done. We understand and acknowledge the need for a National Environmental Policy Act (NEPA) review of the hatchery operations in the Columbia Basin related to the potential impacts on fish listed under the Endangered Species Act (ESA). The focus of our comments has been to identify those aspects of the DEIS which we believe need to be changed or strengthened.

The Council's underlying premise is that we believe the preferred alternative must achieve the Mitchell Act's original intent and purpose, as well as recognize the requirements and responsibilities of other agreements, in addressing the environmental impacts and loss of salmon and steelhead spawning habitat and productivity resulting from the construction of the hydro power system in the Columbia River Basin. The devastating impacts to salmon productivity that resulted from the construction of the hydro power system that led to the passage of the Mitchell Act in 1938 have only been exacerbated over time with additional dam construction. Today, there is even a greater dependency on the production from Mitchell Act hatcheries by fishers that participate in Council managed fisheries. In addition, environmental pressures in the Columbia Basin have increased. Circumstances that resulted in passage of the Mitchell Act also contributed to the listings, in the late 20th and early 21st centuries, of a number of Columbia River salmon and steelhead species under the ESA. The Federal Government cannot walk away from its commitments and responsibilities to the Tribes, the States, and the citizens of this region to at least partially replace the loss of salmon and steelhead production that resulted from the construction of the Columbia River hydro power system.

The static funding for Mitchell Act since 1996 has crippled the ability of Mitchell Act funded programs to maintain production, and now status quo is represented as the highest production possible in the DEIS. Current production does not meet the minimum Mitchell Act mitigation obligation when it is put in a historical perspective. As with other hatchery mitigation commitments in the Basin, additional Mitchell Act funding is necessary to meet both conservation and mitigation obligations associated with Columbia Basin hatcheries.

Coordination of Federal actions is a key concern of the Council. For example, National Marine Fisheries Service (NMFS) is evaluating the approval of the *US v Oregon* hatchery programs under the ESA. The Council recommends that the Mitchell Act Hatchery Environmental Impact Statement (EIS) Record of Decision be made concurrent with completion of that ESA consultation process. In addition, the Council recommends that the ESA consultation for lower river hatcheries also be made concurrently with the Record of Decision. This approach enables a preferred alternative to be informed by the policies and agreements associated with salmon and steelhead recovery that have been, and will be, developed collaboratively among the co-managers, NMFS , regional entities, and other interests in the Basin.

The implementation scenarios associated with Alternatives 2-5 result in substantial reductions in hatchery production when compared to current hatchery production levels. These levels are inconsistent with the 2008 – 2017 *U.S. v. Oregon* Management Agreement, the 2008 Federal Columbia River Power System (FCRPS) Biological Opinion commitments, and expectations of the 2008 Pacific Salmon Treaty agreement. The Council strongly advises NMFS to ensure the final EIS provides broad environmental coverage for existing policies that were shaped by the region over the past five years, embraced by NMFS, and incorporated into broad recovery plans, federal court orders, and international agreements.

Given the potential effectiveness of combining hatchery reform practices with implementation of hatchery-selective fisheries and other adult management strategies, the Council is concerned that none of the implementation scenarios result in an increase in hatchery production. Such increases may be possible as a result of the current conservation and recovery efforts of the States and Tribes, including the lower river recovery plans. We believe that successful implementation of these efforts will allow for increased hatchery production in certain circumstances under all of the action alternatives in the DEIS.

The Council notes the reasons cited by NMFS for not including an implementation scenario that allows for an increase in production. Despite the obvious limitations and inadequacies to current Mitchell Act funding which supports production, the Council believes that a scientific basis exists to support increased or new production programs if properly aligned with wild populations to prevent increasing risks to recovery. NMFS should confirm that the scope of production for hatchery programs covered by Alternatives 1-5 in the DEIS and by the preferred alternative that would be identified in the final EIS include scenarios for increased production and associated facilities necessary for that increased production within programs addressing conservation and mitigation objectives. Alternatively, NMFS should expand the scope of the DEIS alternatives to include increased production opportunities. In the programmatic approach, NMFS should consider how Mitchell Act funding and production can be harmonized with the overall hatchery mitigation and conservation commitments in the Basin.

The preferred policy direction must articulate clearly how conservation goals will be met. As written, the DEIS analysis cannot be interpreted directly without assuming that features of the implementation scenarios, such as the fixed proportionate natural influence (PNI) and proportion of hatchery spawners (pHOS) standards, are actually the goals. The DEIS needs to provide for

NEPA coverage for both conservation and mitigation hatchery plans that include appropriate strategies to support recovery of the ESA listed populations on a watershed specific basis.

The preferred policy direction must reflect the differences in roles played by the evolutionary significant unit/distinct population segment (ESU/DPS) populations in achieving recovery objectives. The DEIS alternatives compare actions taken regionally rather than on a population basis. This appears to contrast with NMFS's statement of the importance of incorporating site-specific management actions to achieve conservation and survival of the species. Regional approaches mask potential efficiencies of this site-specific or watershed-specific approach to hatchery reform. Efficiencies with implementing hatchery reform action plans that are based on distinguishing characteristics of primary, contributing, and stabilizing populations or other population viability designations are not clearly identified within the DEIS. The Council recommends that NMFS define its preferred alternative considering these population and watershed differences.

Further, the Council is concerned that if standards or criteria for Mitchell Act funding are applied differentially by regions, then broad-based support for recovery plans by state, regional, tribal, local and private conservation entities will be undermined. If NMFS uses the NEPA process to define a preferred policy direction that provides umbrella environmental coverage for all Columbia Basin hatcheries, then that policy needs to embrace the entire variety of watershed approaches that are proposed to achieve recovery as well as opportunities for expanded hatchery production referenced above. These different approaches should not be applied only within a specific region, but should be associated with watershed-specific circumstances and approaches.

The following is a summary of the elements that the preferred alternative should accommodate:

- Acknowledge the different roles and priorities populations can have within an ESU/DPS (e.g., primary, contributing, and stabilizing) and then allow the hatchery programs to operate consistent with genetic and demographic risks managers are willing to take
- Recognize and factor in the Congressionally and legally mandated mitigation responsibility of hatchery programs in the Columbia Basin

- Increase conservation effectiveness while providing for sustainable fisheries into the future
- To the extent possible, establish a bridge towards the role of harvest in the overall implementation of effectiveness
- Be consistent with legally mandated agreements governing hatchery production in the Columbia, such as the *U.S. v. Oregon* 2008-2017 Management Agreement and the Columbia Basin Fish Accords.
- Be consistent with the determination and analysis of hatchery program effects in the recent 2008 FCRPS Biological Opinion and Supplemental Comprehensive Analysis
- Be consistent with adopted ESA Recovery Plans
- Be consistent with or reflect the best available science
- Be consistent with detailed hatchery genetic management plans (HGMP's) developed by the co-managers for ESA consultation that consider hatchery science review group (HSRG) recommendations, Hatchery Review Team recommendations, Technical Review Team information, and state, tribal, and federal policies that assess a hatchery program's effect (using empirical information – not models) on ESA listed fish
- Be flexible enough to consider new, developing and future risk management information and strategies as they become available
- Be consistent with Columbia River chinook salmon fishery mortalities and catch levels associated with the revised 2008 Pacific Salmon Treaty
- Provide opportunity for increased hatchery production and associated hatchery facilities necessary for hatchery programs that are aligned with the needs for ESA recovery goals.

There are clearly important updates to the analysis that need to be considered and incorporated into a final EIS. There is confusion among the public and management entities relative to the intent and purpose of this NEPA action that needs to be clarified. NMFS needs to update the analysis in a manner that allows the Mitchell Act hatcheries to be evaluated separately from the rest of the facilities in the Basin where there is not a direct funding linkage to NMFS. As the process continues, the Council believes NMFS must increase public understanding that the preferred alternative will accommodate increased production even if a supplemental DEIS is required to do so. Finally, NMFS should provide an opportunity for public comment on its' preferred alternative before the final EIS is completed and the Record of Decision is signed.

Thank you again for this opportunity to comment.

Sincerely,

Mark Cedergreen
Chairman

PFMC
10/05/10

SALMON ADVISORY SUBPANEL REPORT ON MITCHELL ACT HATCHERY DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS)

We hereby present our comments on the National Marine Fisheries Service (NMFS) "Draft Environmental Impact Statement regarding Columbia River Hatchery Operations and the Funding of Mitchell Act Hatchery Programs." First of all, we wish to thank the NMFS staff for the time they have spent answering questions and working with the Council to try to correct misunderstandings, provide background for decisions made in the Draft Environmental Impact Statement (DEIS), resolve issues and provide details to help the reader better understand this lengthy and complex document. That said, we are concerned about the number and variety of issues that have arisen in the course of our engagement with this document, and the different interpretations that have emerged in the weeks since its introduction. We strongly believe that a document that means what it says, and says what it means needs to be presented to the public, in order to obtain informed public comment and an effective and transparent regulatory process.

- Five alternatives are presented in the DEIS. All adversely impact harvest. We recommend that at least one additional alternative and possibly more need to be developed as a counterbalance to those with adverse harvest effects.

- All the alternatives, including those already in the DEIS, must address the express mitigation obligations of the Mitchell Act. Due to flat funding since 1996, more recent production does not meet the mitigation obligations of the Mitchell Act.

- We do not accept the reasoning on p. 1-13 that "Current and reasonably foreseeable appropriations under the Mitchell Act for hatchery production would preclude this option [of constructing new hatchery facilities]." Since the Mitchell Act itself states that, among other things, it was to provide for "…establishment, operation and maintenance of one or more stations in Oregon, Washington, and Idaho…" (DEIS p. 1-4), we do not see how NMFS can alter the express purpose of this legislation in this way without Congressional approval.

- We are most concerned that the document fails to acknowledge the tremendous progress made since 2007, including the 2008 US v. Oregon agreement, the renegotiated Pacific Salmon Treaty with Canada, the Lower Columbia Fish Recovery Plan, and the Oregon Salmon Recovery Plan, among other actions. We strongly object to 2007 being used as the baseline year in the DEIS. What is the effect on various stakeholders, agencies, fisheries and communities by failing to acknowledge these actions, and the larger ramifications for the international community and treaty tribes?

Finally, we find a number of serious errors, omissions, and inconsistencies in the DEIS that leaves the meaning of various portions open to interpretation. We do not accept these ambiguities and are not comfortable with oral interpretations by agency staff of passages that are not clear in the document. Our various groups will be responding to delineate specific issues, but we all agree that NMFS needs to revise and rewrite this document to clarify what is meant, correct errors, and reissue it for public comment.

Thank you.

PFMC
11/04/10

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON THE MITCHELL ACT HATCHERY DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS)

The Council requested that the Economics Subcommittee of the Scientific and Statistical Committee (SSC) review the "Draft Environmental Impact Statement (DEIS) to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs" for the purpose of responding to two questions:

- Is the methodology describing economic impacts complete and proper, including the use of consistent metrics?
- Are there relevant sources of information omitted from socioeconomic analysis?

Due to the late release of this document, there was insufficient time to set up a Subcommittee meeting prior to this Council meeting. The Chair of the Economics Subcommittee prepared a response to the questions. However, given the size of the DEIS and the complexity of the issues, the SSC did not have adequate time to review the DEIS or the Chair's response, which is attached to this statement for Council consideration (Appendix A).

Appendix A to Agenda Item F.4.b, Supplemental SSC Report on the Mitchell Act Hatchery Draft Environmental Impact Statement (DEIS)

The following comments are offered by the Chair of the SSC Economics Subcommittee regarding two questions posed by the Council regarding the "Draft Environmental Impact Statement to Inform Columbia River Basin Hatchery Operations and the Funding of Mitchell Act Hatchery Programs":

- Is the methodology describing economic impacts complete and proper, including the use of consistent metrics?
- Are there relevant sources of information omitted from socioeconomic analysis?

The economic analysis in the DEIS includes estimates of regional economic impacts (income and jobs) associated with hatchery operations and commercial and recreational fisheries under each alternative. The DEIS also provides estimates of major costs and benefits associated with each alternative – "costs" meaning the costs associated with hatchery operations and "benefits" measured by the net economic value of commercial and recreational fisheries. Economic impacts and economic costs and benefits are both standard and reasonable ways of comparing the DEIS alternatives.

Comments regarding estimated costs of hatchery program, best management practices (BMPs) and new weir construction, and associated effects on income and jobs are as follows:

- The general approach used to estimate hatchery program costs is reasonable, given available data. Methods used to estimate economic impacts (income and jobs) are also reasonable.

- Further clarification is needed regarding the scope of the BMPs included in alternatives 2-5 and whether all of the BMPs included in those alternatives are also included in the cost estimates. Items such as updating water intake screens, water supply alarms, back-up power generators, National Pollutant Discharge Elimination System (NPDES)-compliant water treatment systems, and fixing water intake structures appear to be included among the BMPs. However, the role of fish passage is less clear. For instance, the DEIS notes that "Several implementation measures would be incorporated under one or more of the alternatives' implementation scenarios…" and identifies "Update hatchery facilities to allow all salmon and steelhead of all ages to bypass or pass through hatchery-related structures" as one such measure (p 4-17). On the other hand, the Mitchell Act Fish Screens and Fishways Program – which is subject to a separate Congressional appropriation from the Mitchell Act Artificial Production Program – is identified in the DEIS as one of the activities "not considered to be within a reasonable range of funding potential or operational opportunities and that are not, therefore, envisioned within the alternatives in this DEIS" (p 1-13). Appendix J also appears to suggest that fish passage costs are not included in the DEIS – but for a different reason: "because it was determined that they would vary greatly depending on the specific site constraints, total flow requirements, facility size and location and related unforeseeable implementation issues" (DEIS Appendix J, p 8).

- In addition to clarifying which BMPs are included in the DEIS, methods used to derive cost estimates for those BMPs need to be more clearly documented. For instance, if fish passage is included, how were fish passage costs estimated? For BMPs for which the DEIS provides a range of per-unit cost estimates (e.g., $200K-$500K for updating water intake screen, $30K-$50K for back-up power generator, $100K-$1M for NPDES-compliant water treatment system, $50K-$1M for fixing water intake structure), which point estimates within these ranges were used to inform the cost estimates contained in the DEIS and why?

- Information regarding the derivation of total cost for new weirs (e.g., cost per weir) appears to be lacking in the DEIS.

- As acknowledged in the DEIS, costs associated with staffing BMPs (other than security staff) and staffing weirs were not estimated. Omission of these costs causes some under-estimation of job and income impacts for alternatives 2-5 relative to alternative 1. However, these omissions are not likely to be consequential relative to the magnitude of other costs included in the DEIS.

Comments regarding the analysis of commercial and recreational fishery effects are as follows. These comments pertain to the economic implications of the harvest projections provided in the DEIS. They do not pertain to the harvest projections themselves, which were derived from non-economic models and are therefore outside the scope of the economic questions posed by the Council to the SSC.

- The analysis of commercial fishery effects focuses on harvest, and the exvessel value, net economic value, and economic impacts (jobs and income) associated with that harvest. The analysis of recreational fishery effects also focuses on harvest, and the number of angler trips, trip expenditures, net economic value, and economic impacts (jobs and income) associated with that harvest. These are all reasonable parameters to use in analyzing economic effects.

- According to Appendix J of the DEIS, "The Research Group Mitchell Act DEIS Appendix Table B-2" provides the basis for almost all of the fishery effects (except harvest). Appendix I of the DEIS ("Draft Socioeconomics Resource Report Submitted by The Research Group to NMFS 2008") is authored by The Research Group but does not contain a Table B-2. Additional documentation regarding Table B-2 and how it was derived is needed to evaluate the basis of the fisheries analyses.

In summary: Two methodologies are used in the DEIS to describe economic effects of the alternatives: regional economic impact analysis (jobs and income) and cost-benefit analysis (hatchery costs and net economic value to fisheries). Both are appropriate metrics for evaluating the alternatives. The general approach used to estimate hatchery program costs is reasonable, given available data. Methods used to estimate economic impacts (income and jobs) associated with hatchery operations are also reasonable. However, information (data sources, documentation of methods) is incomplete in the following areas: (1) exactly which BMPs are included under alternatives 2-5, (2) methodologies used to estimate BMP costs, (3) methodology used to estimate cost of new weirs, and (4) data sources and methods used to evaluate many of the fishery effects. With regard to (4), the DEIS cites a Table B-2 (produced by The Research Group) as the basis for much of the fisheries analysis. However, review of the fisheries analysis was not possible, as Table B-2 is not contained in the DEIS.

PFMC
11/03/10

SALMON TECHNICAL TEAM ON MITCHELL ACT HATCHERY DRAFT ENVIRONMENTAL IMPACT STATEMENT

The consideration of fishery impacts in the Mitchell Act Draft Environmental Impact Statement (DEIS) is described in Appendix K (pages 1063-1124 of the DEIS). This analysis was performed by Gary Morishima and Larry Lestelle. They apparently relied heavily on the Pacific Salmon Commission (PSC) Chinook and coho models and baseline data to configure and parameterize simplified models, implemented in spreadsheets, for the purpose of analyzing impacts of alternative scenarios on fisheries.

For the coho model, Fishery Regulation Assessment Model (FRAM) fisheries were used. These included troll fisheries from the southern extent of fishing in California to Northwest Alaska, sport fisheries from the southern extent of fishing through northern British Columbia, and net fisheries from the Columbia River through Alaska. This represents complete coverage of all fisheries under the jurisdiction of the Pacific Fishery Management Council, the Pacific Salmon Commission, and the State of Alaska where Columbia River coho are likely to be encountered. It is worth noting that the low contribution rates to fisheries in British Columbia is a consequence of a lack of coho fishing opportunity off the West Coast of Vancouver Island to protect critically depressed Upper Fraser coho stocks. If Canada resumes fishing to the limits allowed by the Pacific Salmon Treaty, the contribution to Canadian fisheries would no longer be negligible.

For the Chinook model, the Northern extent of fisheries included was Southeast Alaska, and the southernmost fisheries were Washington/Oregon troll, Washington ocean sport, and Columbia River net. These are fisheries from the PSC Chinook model, which has a focus on stocks and fisheries that are subject to the Pacific Salmon Treaty. In the PSC Chinook model, the Washington/Oregon troll fishery and the Washington ocean sport fishery only include impacts in Oregon that occur north of Cape Falcon, and do not include impacts to PSC stock that occur South of Cape Falcon. This is similar to the assumption in Council processes that ocean fishery impacts on Sacramento Fall Chinook are negligible north of Cape Falcon.

Using FRAM base period data, Columbia River Chinook historical contribution rates of Columbia River Chinook stocks to individual FRAM fisheries south of Cape Falcon, and the total catch south of Cape Falcon, are shown in Table 1. Under base period conditions, Columbia River Chinook contributed 9.5 percent of the Chinook impacted by Oregon troll fisheries between the Klamath management zone (KMZ) and Cape Falcon, and 13.5 percent of the Chinook impacted by Oregon recreational fisheries between the KMZ and Cape Falcon. Overall, Columbia River Chinook contributed 2.5 percent of the total Chinook impacted in ocean fisheries South of Cape Falcon. Most of these contributions are from tule stocks, and Mitchell Act hatcheries are responsible for the bulk of that production.

However, recent conditions have differed substantially from those of the base period. The depressed abundance stock from the Central Valley in California has resulted in far fewer California Chinook to dilute the contribution of Columbia River stocks. Recent GSI data from Project CROOS in Oregon from 2006, 2007, and 2010, and the ongoing non-lethal sampling in

California reflect substantially higher contributions of Columbia River stock to fisheries south of Cape Falcon (Table 2).

Table 1. Contribution rate of Columbia River stocks to Chinook ocean fisheries under FRAM base period conditions. Contribution rates are expressed as the percentage of fishery impacts accounted for by Columbia River stocks.

Fishery	Contribution of Columbia River stocks
Central OR Troll	9.5%
Central OR Sport	13.5%
KMZ Troll	3.9%
KMZ Sport	7.2%
S. Calif. Troll	0.0%
S. Calif. Sport	0.0%
Total South of Falcon Troll	2.5%
Total South of Falcon Sport	2.0%

Table 2. Proportion of Chinook salmon consisting of Columbia River stocks by catch area based on genetic stock identification (GSI) from Project CROOS. Catch areas are: NOC – Cape Falcon to Florence S jetty (except 2006 included a few samples from Reedsport), SOC – Florence S jetty to Humbug Mtn., KMZ – Humbug Mtn. to the OR/CA border.

Catch Area	NOC	SOC	KMZ
2006			
Lower River fall	1.8%		
lower river spring	0.7%		
Deschutes River fall	0.8%		
Mid river tule	1.1%		
upper river summer/fall	3.0%		
Snake River fall	0.5%		
Willamette	0.1%		
total	7.9%		
2007			
Lower River fall	6.3%	0.6%	1.2%
lower river spring	3.2%	0.0%	0.0%
Deschutes River fall	3.2%	0.9%	0.4%
Mid river tule	7.7%	0.9%	0.0%
upper river summer/fall	10.8%	5.2%	2.0%
Snake River fall	1.8%	0.9%	0.4%
Willamette			
total	33.0%	8.5%	4.0%
2010			
Lower River fall	15.1%	8.6%	2.9%
lower river spring			
Deschutes River fall	1.3%	1.4%	0.0%
Mid river tule	26.0%	14.3%	11.4%
upper river summer/fall	10.1%	9.4%	5.4%
Snake River fall	6.8%	2.3%	8.6%
Willamette	0.7%	0.6%	2.3%
total	59.9%	36.5%	30.6%

PFMC
11/3/10

Statement of Salmon For All
Concerning the Mitchell Act DEIS
Astoria, Oregon
September 30, 2010

Good evening. My name is Hobe Kytr. I am the nonprofit administrator for Salmon For All, a nonprofit trade association of Columbia River commercial fishermen and processors, representing the lower river non-Indian gillnet fleet.

The Mitchell Act originally was enacted by congress in May of 1938 in response to the very real threat to the Columbia River's once mighty salmon runs posed by the construction of Bonneville Dam, the impending Columbia Basin Project, and the projected continuing development of the Columbia River Basin over the next several decades, including but not limited to large federal hydroelectric dam projects. By 1938, a large percentage of the once extensive habitat available to Columbia River salmonids had been lost behind dams built without fish passage. Work was continuing on Grand Coulee Dam, scheduled for completion in 1941, which would cut off the upper third of the Columbia River Basin from fish passage forever. Beginning in 1939, the Grand Coulee Fish Maintenance Program began efforts to salvage what could be saved of the salmon runs of the upper Columbia River by trapping fish at Rock Island Dam and hauling them in tanker trucks to what little habitat was still available in the Okanogan, Entiat, Methow, and Wenatchee Rivers. Fish culturists from the US Fish & Wildlife Service also sought to transform the upper river runs into composite, blended stocks suitable for artificial propagation. This is the context of desperate need in which the Mitchell Act legislation emerged.

In the best of all possible worlds, one would have hoped that more care should have been taken to preserve salmonid spawning habitat in the Columbia River Basin. But that's not what happened. Hydropower development, federal and otherwise, has turned the Columbia River into the most dammed river in the world. Irrigation projects transformed the Columbia Plateau into one of the most productive agricultural regions in the world, but also lured countless millions of migrating salmonids into unscreened irrigation ditches that proved to be dead-end death traps. Logging, pollution, industrial and ever encroaching urban development all took their toll west of the Cascades as well. In desperate attempts to save lower Columbia River Chinook and coho salmon, Mitchell Act hatcheries became the repositories in which their genetic legacy still resides.

Much has been said and written about what recovery of the Columbia River's populations of salmon and steelhead would look like, and what it would take to achieve that goal, insofar as it is possible. Those of us who represent various constituencies of the harvest community are perhaps the strongest proponents of Columbia River salmonid recovery. We have the most at stake in this effort, the most to gain if it succeeds, and the most to lose if it does not. But, none of the five options presented in the Mitchell Act Draft Environmental Impact Statement will help us advance towards recovery.

P O Box 56 • Astoria, Oregon 97103-0056 • (503) 325-3831 • FAX (503) 325-2725
info@salmonforall.org • www.salmonforall.org

In fact, all the options presented in the Mitchell Act DEIS lead us away from Columbia River salmonid recovery. By defining the status quo as the conditions present in 2007, Option One undoes all the advances in hatchery reform during the past three years, including successful supplementation programs instituted by the Columbia River Treaty Tribes as co-managers of the fishery. All the options presented fail to live up to federal treaty trust obligations under the 2008-2017 *US v. Oregon* Management Agreement and the 2008 renewal of the Pacific Salmon Treaty. Not one of the Options is consistent with Washington's updated 2010 Lower Columbia Salmon Recovery and Fish and Wildlife Subbasin Plan, or with the Conservation and Recovery Plan for Oregon's Populations of Lower Columbia Salmon and Steelhead recently approved by the Oregon Fish & Wildlife Commission. It is dispiriting to find that, all the while NMFS has been directing the states, tribes, and regional councils to engage in recovery planning, that the agency itself has been working on a Draft Environmental Impact Statement for Mitchell Act hatcheries that negates all the effort that has gone into the recovery planning mandated by NMFS.

The errors and omissions in the Mitchell Act DEIS are too numerous to reference here in any detail, but they are seriously disturbing. The coho and Chinook modeling in Appendix K use the wrong parameters with reference to the 2008-2117 *US v. Oregon* Management Agreement, the wrong allocation formulae for the non-Indian commercial and recreational mark-selective fisheries for spring Chinook, and the wrong mortality rate for the tangle net fishery. Even if the data on smolt production in the Columbia basin used in Appendix K were correct, and there is good reason to suspect they are not, the conclusions derived from the calculations in the modeling exercise still would be so erroneous that they would be useless to anyone. Appendix I, the Socioeconomic Resource Report, was never peer-reviewed nor completed, meaning that not only does it not live up to accepted academic standards, it does not meet NOAA Fisheries' own policy on peer review and data quality. The data on environmental justice communities in Tables 3-26, 3-27, and 3-28 list the wrong census data, and omit data from the four poorest counties in the states of Washington and Oregon, where the majority of our fishermen just happen to reside. These are only a few of the glaring deficiencies noted in the DEIS.

At this point in time, it is quite clear that the Mitchell Act Draft Environmental Impact Statement was not ready for public review. We call for the National Marine Fisheries Service to withdraw the DEIS until it actually has engaged in the full consultation process that already should have taken place with the tribes, states, and agencies that co-manage Columbia River fisheries. The data and conclusions in the Mitchell Act DEIS are of no use to those constituencies who are most likely to be affected by the draconian cuts proposed for Columbia River salmonid production levels. We reject the listed range of options that call for far fewer fish for the Columbia River Basin, which threaten to leave us all with reduced and failing fisheries. Let us instead embrace hope, and work together for increased abundance, leading to genuine recovery for Columbia River salmonids wherever it is possible to achieve that worthy goal. Finally, we remind the National Marine Fisheries Service that the mitigation obligations undertaken by the federal government in 1938, which were renewed and expanded in 1946, have not ended. The dams are still there, lost habitat is still lost, degraded habitat has only begun to be rehabilitated, and the naturally spawning salmonid stocks upon which recovery depends are not yet recovered, nor will any of the options presented in the DEIS make them more likely to do so.

Thank you for the opportunity to provide testimony. Salmon For All will provide detailed written comments on the Mitchell Act DEIS before the deadline for submitting public comment.

The DAILY ASTORIAN

Thursday, September 30, 2010

Be there

National Marine Fisheries assumes Columbia fish hatcheries will be cut

Thursday, September 30, 2010

What happens if Columbia River salmon hatchery operations are cut? In the absence of unplanned and unattainable habitat restoration, salmon runs will begin dwindling. Generations-long agreements will be trashed. Many people who have built lives around fishing will be out of jobs. Salmon will have lost their most passionate and knowledgeable advocates.

Why is this even a question? A federal hearing in Astoria from 5:30 to 7:30 p.m. today at the Columbia River Maritime Museum looks at future alternatives that all assume cutbacks in hatcheries. This is a matter of deep concern. Anyone who cares about salmon and our economy should attend.

News this year has included remarkable success stories about a number of upriver runs that were once given little chance of surviving into the 21st century. There have been hundreds of thousands of chinook in the Snake River. coho are back to viability in the Yakima River. Hanford Reach fall chinook returns are inspirational.

Hatcheries are vital to all these runs and many others, either by directly producing the fish or by surrounding naturally spawning salmon with a large protective cushion of fish specifically meant to be caught. This system is far from perfect. Salmon advocates will always wish that dams on Snake and upper reaches of the Columbia either had not been built or had at least included far better provisions for salmon passage.

In fact, the conversion of the Columbia into a hydropower system starting in the 1930s was known almost from the very start to threaten salmon. You cannot throw up a series of huge concrete barriers and expect salmon runs to prosper. It was obvious that fishing industry, towns like Astoria, and the Columbia Basin's many vibrant salmon-based tribal cultures were being sacrificed in order to provide electricity for cities and irrigation water for farms.

To mitigate for this fact, the Mitchell Act set up a series of federal hatcheries. Despite decades of stagnant funding, they continue to bring millions of young salmon to life. This results in hundreds of thousands of returning adults. This doesn't compare to the millions that came back predams, but it is something.

Now, the National Marine Fisheries Service (NMFS) is starting an environmental impact statement (EIS) process. Initially directed only at examining federal hatchery processes and funding, it was quietly expanded to include all hatcheries on the river system. This blindsided fishing communities, tribes and industries.

Problems with the draft EIS are rife. They start with the biased assumption that hatcheries should be cut back in some way. Hatcheries, especially those operated by the upriver treaty tribes, are vastly improved over what they were only 10 or 20 years ago. They produce healthy, viable fish. Can hatcheries be operated even more smartly? Very possibly so. But cutting federal hatcheries and interfering in the operations of others is no way to go.

Beyond this, the draft EIS is inconsistent with hard-won Oregon and Washington salmon recovery plans, with Canadian and tribal treaty obligations and with the fisheries allocation process south of Cape Falcon. All these fundamental problems mean the draft EIS must be withdrawn. NMFS should start over from scratch, without bias, and include everybody. Hatchery operations must continue in the meantime.

In important ways, fishing interests have come a long way in recent years. Commercial, tribal, charter, sport and conservation groups see eye to eye in some key ways. Foremost among these is knowledge that strong salmon runs are good for everyone, and fights are bad for everyone. Hatcheries are an indispensable tool. They must be supported and defended.

2010 SALMON METHODOLOGY REVIEW

Each year, the Scientific and Statistical Committee (SSC) and Salmon Technical Team (STT) complete a methodology review to help assure new or significantly modified methodologies employed to estimate impacts of the Council's salmon management use the best available science. The Methodology Review is also used as a forum to review updated stock conservation objective proposals. This review is preparatory to the Council's adoption, at the November meeting, of all anticipated methodology and conservation objective changes to be implemented in the coming season, or in certain limited cases, of providing directions for handling any unresolved methodology problems prior to the formulation of salmon management options in March. Because there is insufficient time to review new or modified methods at the March meeting, the Council may reject their use if they have not been approved the preceding November.

This year the SSC and STT are expected to report on factors affecting Fishery Regulation Assessment Model (FRAM) bias when there are multiple fisheries in the time step (Agenda Item F.5.a, Attachment 1), evaluation of bias-correction methods applicable to Coho FRAM (Agenda Item F.5.a, Attachment 2), Oregon coastal natural coho abundance predictor (Agenda Item F.5.a, Attachment 3), evaluation of indicator stock groups for Columbia River summer Chinook (Agenda Item F.5.a, Attachment 4), and a progress report on abundance based management approaches for Lower Columbia River natural tule Chinook (Agenda Item F.5.a, Supplemental Attachment 5).

Council Action:

1. **Approve methodology changes as appropriate for implementation in the 2011 salmon season.**
2. **Provide guidance, as needed, for any unresolved methodology issues.**

Reference Materials:

1. Agenda Item F.5.a, Attachment 1: Bias in the Estimation of Impacts of Simultaneous Mark-Selective and Non-selective Fisheries on Ocean Salmon-Sep 23 2010 Draft.
2. Agenda Item F.5.a, Attachment 2: Bias-corrected Estimates of Mortality in Mark-selective Fisheries for Coho Salmon.
3. Agenda Item F.5.a, Attachment 3: Forecast Models for Oregon Coastal Natural Coho Salmon (*Oncorhynchus kisutch*) Adult Recruitment.
4. Agenda Item F.5.a, Attachment 4: Salmon Methodology Review: Coded-Wire Tag Representation for Columbia River Summer Chinook in FRAM.
5. Agenda Item F.5.a, Supplemental Attachment 5: Progress Report on Abundance Based Management Approaches for Lower Columbia River Natural Tule Chinook.
6. Agenda Item H.1.b, Supplemental SSC Report.
7. Agenda Item H.1.b, Supplemental STT Report.

Agenda Order:

a. Agenda Item Overview — Chuck Tracy
b. Reports and Comments of Advisory Bodies and Management Entities
c. Public Comment
d. **Council Action**: Adopt Final Methodology Changes for 2011

PFMC
10/14/10

Bias in the Estimation of Impacts of Simultaneous Mark-Selective and Non-selective Fisheries on Ocean Salmon

Henry Yuen
U.S. Fish and Wildlife Service
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

and

Robert Conrad
Northwest Indian Fisheries Commission
6730 Martin Way E.
Olympia, WA 98516

Abstract

In mark-selective salmon fisheries, current management models produce biased estimates of the mortalities in those fisheries and concurrent non-selective fisheries. When a non-selective fishery is prosecuted in the same time and area as a mark-selective fishery, the non-selective fishery harvests fewer marked fish and more unmarked fish than expected because of the increase in the unmarked-to-marked fish ratio caused by the selective fisheries in addition to the increased probability of an unmarked fish encountering the gear more than once due to the required release on all unmarked fish. This bias is an increasing function of the harvest rate on marked fish. The expected exploitation rates must also take into account mark-recognition errors where marked fish are released by mistake and unmarked fish are landed by mistake. This mark-recognition error adjustment is a function of unmarked-to-marked fish ratios. We illustrate these effects and describe their magnitude.

Introduction

The coded-wire tag (CWT) sampling program on the west coast of the United States and Canada allows fishery managers to estimate the exploitation rates on hatchery salmon stocks (Johnson 1980). This information is then used to estimate the exploitation rates of wild untagged salmon stocks with similar ocean and fishery distributions. Hatchery fish tagged with a CWT are also marked with an adipose fin clip to facilitate their identification by fishers and catch samplers. There are few tagging programs on wild stocks and therefore most fish with an adipose fin clip are hatchery origin.

As early as 1991, numerous wild salmon species and stocks in Puget Sound, the Columbia River, and in California were being listed for protection under the Endangered Species Act (ESA), starting with Snake River sockeye salmon. In 1998, declines in the Skeena and Thompson River coho population led to mandatory non-retention of wild coho in British Columbia fisheries (Irvine and Bradford 2008). Where ever wild and hatchery fish are harvested together, any limitation on wild harvest rates was essentially a limitation on the entire fishery. In order to provide meaningful fisheries on abundant hatchery fish, the Washington State Legislature directed its state hatcheries to begin mass marking, using adipose fin clips, coho (*Oncorhynchus kisutch*) in 1997 and Chinook (*O. tshawytscha*) in 1998 (Ashbrook 2008). Congress also directed the US Fish and Wildlife Service to implement a system of mass marking starting in 2003 for all salmon intended for harvest and released from Federally operated or funded hatcheries in Washington and Oregon. Wild fish and any hatchery fish intended for conservation are not marked allowing fishery managers to prosecute a mark-selective fishery (MSF) where marked hatchery fish are landed and unmarked natural origin or hatchery fish that are produced for stock rebuilding purposes are released. In 1998, Canada initiated its mark-selective salmon fisheries program for coho.

Harvest limits for coho and Chinook salmon are set by the Pacific Fishery Management Council (PFMC) in Federal waters off the coasts of California, Oregon, and Washington (PFMC 1999) and by the Pacific Salmon Commission (PSC) for ocean fisheries in southeast Alaska and Canada. All management agencies (state, Tribal, and Canada Department of Fisheries and Oceans) require the accounting of all sources of mortality including landed mortality (catch), incidental (non-landed) mortalities due to a fish being handled and released, and drop-off mortality (from the gear prior to landing), and mortality due to mark-recognition error (releasing a marked fish when it should have been retained) and mark-retention error (landing an unmarked fish when it should have been released).

Salmon management models are used annually by fisheries management agencies for pre-season prediction of impacts for a proposed suite of fishery regulations and for post-season assessment of completed fisheries. The Fishery Regulation Assessment Model (FRAM) currently used by the PFMC and co-managers for salmon fisheries in Washington marine waters is an example (PFMC 2008). Currently, these models are single-pool, deterministic models that operate on discrete time steps whose length varies from one month (e.g., coho during the summer months) to several months (e.g., Chinook). All fisheries during a time step are assumed to operate on a single pool of fish simultaneously. The pool of fish consists of all stocks that have been caught historically in the fishery as estimated from coded-wire tag recoveries (Nandor et al. 2010). Historical exploitation rates estimated from CWTs recovered during a base period when salmon abundances were relatively high and fisheries were widely distributed in both time and area are the basis for the predictions by these models (Pacific Salmon Commission 2005).

An assumption common to all these models prior to the implementation of mark-selective fisheries was that the exploitation rate for specific marked salmon stocks (called indicator stocks) was representative of the exploitation rate for unmarked stocks with similar life-histories and ocean distributions. With the advent of mark-selective fisheries, the models were restructured so that the exploitation rates for marked stocks were used to represent the encounter rate in mark-selective fisheries for the unmarked stocks that they represent (PFMC

2008). These encounter rates are used to produce stock-specific estimates of the number of encounters of unmarked fish to which an estimate of the release- mortality rate was applied to estimate mortalities due to the catch and release of unmarked salmon in mark-selective fisheries. In these simple models, unmarked mortality (m_U) is a function of the encounter (λ_U) and release-mortality rates (δ). The encounter rate in turn is linearly related to the exploitation rate on the marked indicator stock used to represent the unmarked stock (ER_M). The exploitation rate on the unmarked fish (ER_U) is the sum of the unmarked mortalities (see Table 1 for a list of the parameters and their values), i.e.

$$\lambda_U = ER_M. \qquad (1)$$

$$m_U = \lambda_U \times \delta \qquad (2)$$

$$ER_U = \frac{\sum_{f=1}^{F} m_{U,f}}{U} \qquad (3)$$

where F = total number of fisheries (e.g., 3).

Table 1. Parameters and variables used in the selective-fishery model.

Parameter	Definition and value(s)
A	Adjustment for marked fish released by mistake and unmarked fish landed by mistake: 0.990099 for 3:1 unmarked-to-marked starting cohort ratios, 1.030928 for 1:1, and 1.045296 for 1:3. γ = 0.95 and ζ = 0.98 in all unmarked-to-marked ratios.
b	Multiple-encounter parameter that determines the increase in the release-mortality rate with successive releases. Set to 1.0 (i.e., no increase) or 0.843 (representing a 25% increase)
α	Drop-off mortality per handle rate (i.e., landed + released fish) rate: the probability that a hooked fish escapes and dies before being brought to the boat. Set to 0.0 (none) or 0.05.
ER	Target exploitation rate for all three simultaneous fisheries combined where landings include marked and unmarked fish (either targeted or by accident). Range from 0.1 to 0.4 in 0.1 increments.
M	Initial number of marked fish. Range from 100,000 to 300,000.
$m_{i,f}$	Number of unmarked ($i = U$) or marked ($i = M$) mortalities in

	fishery *f*.
R	Starting ratio of unmarked fish to marked fish. Set to 1:3, 1:1, and 3:1.
RMR	Effective release-mortality rate that can account for an increase in the release-mortality rate δ when a fish is released more than once.
U	Initial number of unmarked fish. Range from 100,000 to 300,000.
γ	Mark-recognition rate: the probability that a marked fish that is brought to the boat is properly identified as a marked fish and retained. Set to 1.0 (for all non-selective fisheries or when assuming perfect recognition rate) or 0.95.
δ	Release-mortality rate: probability that a fish dies after its first release. Values of 0.14 and 0.26 were used for the two mark-selective fisheries modeled.
ζ	Recognition rate for unmarked fish: the probability that an unmarked fish brought to the boat is recognized as unmarked and released in a MSF. Set to 1.0 (for all NSF fisheries or when assuming perfect recognition rate) or 0.98.
λ	Expected encounter rate of a fish with the gear.
π_f	Proportion of total landings for the marked cohort in all fisheries that occurred during fishery *f*. Set to total MSF-to-NSF target exploitation rate ratios of 1:2, 1:1, and 2:1. Of the two MSF, the target exploitation rate of the MSF with δ = 0.14 was arbitrarily double that of the one with δ = 0.26.

Lawson and Sampson (1996) demonstrated that in a mark-selective fishery, the mortality rate of unmarked fish is an increasing function of the apparent harvest rate and the release-mortality rate. This results in the total number of unmarked mortalities in mark-selective fisheries being underestimated in models relying on the linear relationship between exploitation rate and release-mortality rate. Any combination of simultaneous mark-selective and non-selective fisheries (NSF) greatly increases the complexity of estimating mortalities for both unmarked and marked stocks. For example, a mark-selective troll fishery and a mark-selective recreational fishery each with different release-mortality rates, operating in the same area and during the same time step as a non-selective troll fishery. The dynamic interactions between the competing fisheries are best explored with an individual-based simulation model that monitors the fate of each fish vulnerable to the fisheries.

Methods

Our simulation model builds upon the individual-based model in Lawson and Sampson (1996) with the following modifications:

- We used a power function to calculate the increase in effective release-mortality rate with each successive encounter.

$$\boldsymbol{RMR} = \delta^{b^{\text{number of times released}}} \qquad \textbf{(4)}$$

where *b* = multiple-encounter mortality parameter (Figure 1). For the simulations we used values of 1.0 or 0.843 for *b,* which are the equivalent of no increase and about a 25% increase (Δ = 0.25 in Figure 4 of Lawson and Sampson 1996) in effective release-mortality rate with successive releases.

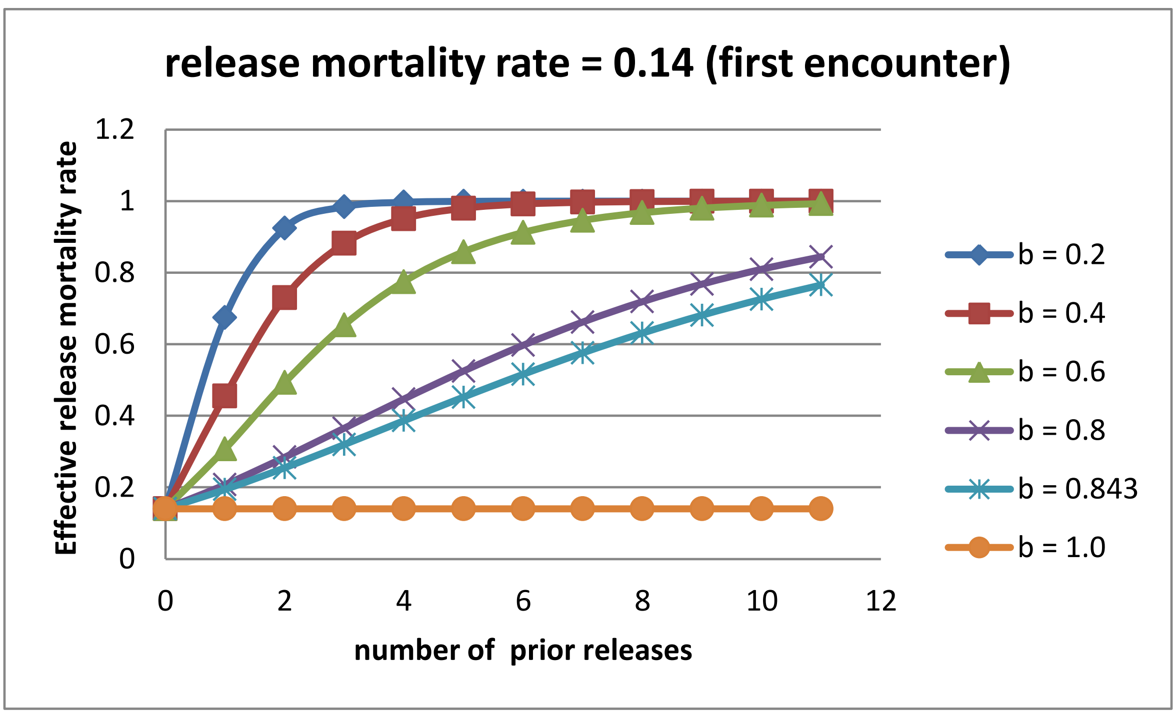

Figure 1. Increasing effective release-mortality rate as a power function of successive releases (relationship for the initial Washington ocean sport release-mortality rate of 0.14).

- There were three fisheries operating simultaneously in our model: MSF 1 (e.g., sport) with δ = 0.14, and MSF 2 (e.g., non-Indian troll) with δ = 0.26, and NSF (e.g., Treaty Indian troll).

- In both Lawson and Sampson (1996) and our models, there is either a catch quota or a target harvest rate. Each fishery in our model will achieve its own unique catch quota (i.e., assume perfect management), as opposed to a common catch quota for the pool of fisheries. The corresponding target exploitation rate in each fishery, based either on the marked fish only in a mark-selective fishery or on both marked and unmarked fish in a non-selective fishery, can be calculated from the catch quota and the corresponding starting cohort size. Neither our model nor Lawson and Sampson (1996) were designed to model a fishery based on length of season or fishing effort.

- In both Lawson and Sampson (1996) and our models, there is a fish population with *U* unmarked and *M* marked fish available to all fisheries operating during the modeled time period (and area). While the model is running, individual fish are selected at random and the ensuing chain of events depends on the following (see Table 2 for pseudo code). Is this fish alive? If not, select another fish at random. If yes, then (in our model) select a fishery at random according to the distribution of catch quotas among the fisheries.
    - Is this fish a "drop-off" mortality with a probability of α (See Table 1 for list of parameters and their values)? If yes, tally as a mortality and select another fish.
    - If a NSF, tally as a mortality and select another fish.
    - If a MSF, look up the number of prior encounters for this fish and increase the effective release-mortality rate according to Equation 4. Does the fisher correctly recognize it as a marked or unmarked fish with a probability of γ and ζ, respectively? If the fish was released either because the fisher recognized an unmarked fish or did not correctly recognize a marked fish, did the fish survive gear-related injuries with a probability of (1- *RMR*)? If the fish survived all of the above it was returned to the population, otherwise it was tallied as a mortality. Repeat the process until the target exploitation rate or catch quota for each fishery is achieved. A complete capture history was maintained for each fish in the population that recorded each encounter, the fishery it occurred in, and the fate of that encounter: drop-off mortality, landed catch, release and survival, or release mortality.

Table 2. Pseudo code for chain of events in mark-selective fisheries and consequences.

1. Assign each fish in the population with a unique identification number and set its flag as either marked or unmarked according to the marked proportion.
2. Specify the release-mortality rate, e.g., 0.14 for ocean sport fisheries.
3. Specify the target marked harvest rates, e.g. 0.1, 0.2, 0.3, or 0.4.
4. Initialize the number of encounters for each fish to zero.
5. Select a fish at random from combined pool of marked and unmarked fish (i.e., draw first random number – this simulates being caught by the gear).
6. If fish is alive then
    - a. Select a fishery at random.
    - b. Increase number of encounters (fish) + 1.
    - c. Draw second random number from probability between 0 and 1. If second random number < drop-off/encounter rate then (note: 0.047619 drop-off/encounter = 0.05 drop-off/handle).
        - i. Drop-off mortality.
        - ii. Go to step 5.
    - d. Else not a drop-off and fish is unmarked then
        - i. Draw third random number from probability between 0 and 1. If probability < unmarked recognition rate (0.98) then
            - a. Unmarked fish is correctly identified and released.
            - b. Use Equation 4 to calculate effective release-mortality rate.
            - c. Draw fourth random number from probability between 0 and 1. If fourth random number < effective release-mortality rate then unmarked release mortality.
            - d. Go to step 5
        - ii. Else unmarked fish incorrectly identified as marked
            - a. Unmarked fish landed by mistake.
            - b. If accumulated landed fish = target marked harvest rate, then stop fishery.
            - c. If accumulated landed fish < target marked harvest rate then go to step 5.
    - e. Else not a drop-off and fish is marked then
        - i. Draw third random number from probability between 0 and 1. If probability < mark-recognition rate (0.94) then
            - a. Marked fish correctly identified and landed.
            - b. If accumulated landed fish = target marked harvest rate, then stop fishery.
            - c. If accumulated landed fish < target marked harvest rate then go to step 5.
        - ii. Else marked fish incorrectly identified as unmarked
            - a. Marked fish released by mistake.
            - b. Use Equation 4 to calculate effective release-mortality rate.
            - c. Draw fourth random number from probability between 0 and 1. If probability < effective release-mortality rate then marked fish release mortality.
            - d. Go to step 5.

- Lawson and Sampson (1996) modeled drop-offs with two parameters, drop-off rate X drop-off mortality rate, which implies an opportunity for subsequent encounter if the fish survived the drop-off. We simply modeled the probability of being a drop-off mortality (α).

We examined total exploitation rates (across all three modeled fisheries) from 0.10 to 0.40 in increments of 0.10. For each MSF, the target exploitation rate is multiplied by the marked cohort size (*M*) to specify a marked-catch quota for the fishery. For the non-selective fishery, the catch quota is specified as the product of the target exploitation rate for the marked cohort and the sum of *M* and *U*. Because the marked cohort is used as an indicator stock for the unmarked cohort, any target exploitation rate specified for the marked cohort is also the target for the unmarked cohort. The simulations were run until the individual catch quotas in each fishery were met.

We simulated each of the three fisheries operating alone as a base model for comparison in addition to simulating all three operating concurrently on the same pool of fish (Table 3). Each simulation began with an initial population of 400,000 total fish. Simulations were run using three different unmarked-to-marked fish ratios, 1:1, 1:3, and 3:1, to divide the initial pool into unmarked and marked fish cohorts. There were also three different total MSF-to-NSF harvest rate ratios, 1:2, 1:1, and 2:1. In one of the MSF, $\delta = 0.14$ (e.g., sport fishery) and in the other $\delta = 0.26$ (e.g., troll fishery). In all of the simulations, the target exploitation rate of the MSF with $\delta = 0.14$ was arbitrarily double that of the one with $\delta = 0.26$.

We ran simulations with four levels of increasing complexity (Table 3).

- Drop-off mortality rate = 0, mark and unmarked recognition rate = 1.0. The expected mortalities, m_f, in fishery *f* was calculated from the total expected encounters, e.g., *M x ER*, and the proportion of the total mortalities in all fisheries that occurred in fishery *f*, (π_f). In a non-selective fishery, *RMR* = 1.

$$m_{M,f} = M \times ER_M \times \pi_f \tag{5}$$
$$m_{U,f} = U \times ER_M \times \pi_f \times RMR \tag{6}$$

- Drop-off mortality rate, *d*, = 0.05, mark and unmarked recognition rate = 1.0. The expected mortalities were adjusted for drop-off per handle, d_f, as follows where γ = ζ = 1.

$$m_{M,f} = M \times ER_M \times \pi_f \times (\gamma + d_f) \tag{7}$$
$$m_{U,f} = U \times ER_M \times \pi_f \times (\zeta \times RMR + d_f) \tag{8}$$

- Drop-off mortality rate = 0.05, 0.95 mark-recognition rate and 0.98 unmarked-recognition rate. Because catch quota is the sum of marked catch plus unmarked fish landed by mistake, the expected marked encounter rate had to be adjusted for unmarked landings and the expected unmarked encounter rate had to be adjusted for marked releases. The mark-recognition error adjustment, A, was a function of the U:M ratio, marked recognition rate, and unmarked recognition rate and was found by solving for the mark-recognition error adjustment that resulted in the marked and unmarked landings equal to the catch quota. The FRAM model, however, does not have the mark-recognition error adjustment A.

$$m_{M,f} = M \times ER_M \times A_{U:M,\gamma,\zeta} \times \pi_f \times (\gamma + d_f + (1-\gamma) \times RMR) \quad (9)$$

$$m_{U,f} = U \times ER_M \times A_{U:M,\gamma,\zeta} \times \pi_f \times (\zeta \times RMR + d_f + (1-\zeta)) \quad (10)$$

- Drop-off mortality rate = 0.05, 0.95 mark-recognition rate and 0.98 unmarked-recognition rate, and b = 0.843 which will produce a 25% increase in release-mortality rate with each subsequent encounter. RMR was calculated using Equation 4.

Table 3. Summary of simulated multiple-encounter scenarios. All scenarios were repeated with each fishery operating alone (base model) and all three fisheries operating in the same time step.

Simulation Model Summary	Release-mortality rates	Drop-off mortality per handle rate, mark-recognition rate, unmarked-recognition rate	Increase in release-mortality rate with each subsequent encounter
Release mortality only	δ = 0.14 and 0.26	α = 1.0, γ = 1.0, ζ = 1.0	b = 1.0
Add drop-off	δ = 0.14 and 0.26	α = 0.05, γ = 1.0, ζ = 1.0	b = 1.0
Add mark-recognition error	δ = 0.14 and 0.26	α = 0.05, γ = 0.95, ζ = 0.98	b = 1.0
Add increased release-mortality rate	δ = 0.14 and 0.26	α = 0.05, γ = 0.95, ζ = 0.98	b = 0.843

We calculated the mean relative bias from the difference in unmarked ER (Equation 3) from our simulations (model) and the expected values (Equations 5 through 10)

$$bias = \frac{\sum \frac{ER(model) - ER(expected)}{ER(expected)}}{n} \quad (11)$$

where n = number of simulations.

Results

We ran at least 25 simulations per scenario and up to 250 simulations when R = 3:1 (all levels of MSF:NSF ratios) and when R = 1:1 if the MSF:NSF ratio was less than 2:1. In those instances, especially at the lower target exploitation rates, the numbers of marked encounters were not large enough to produce stable results.

When a fishery operates alone and landings and release mortalities are the only sources of mortality, any biases in estimated exploitation rate are due to the accounting of multiple encounters (Figure 2). The scenario in the upper panel of Figure 2 represents a typical MSF observed in ocean coho salmon fisheries where the starting unmarked-to-marked cohort ratio is less than 1 and the combined MSF exploitation rate is less than that of the non-selective fisheries. When comparing the various scenarios, there should be a range from no bias (except for random noise) in the non-selective fishery to greater bias in the fisheries with the lower release-mortality rates (δ). Biases should increase with exploitation rate, an indicator of multiple encounter rates. Given a range of target total exploitation rates from 0.1 to 0.4 in the simulation behind Figure 2, the average number of fish with multiple encounters ranged from 144 to 2,424, respectively and the maximum number of encounters per fish ranged from 3 to 4, respectively. Neither the trend in the MSF-to-NSF exploitation rate ratios nor the trend in unmarked-to-marked ratios affects the relationship between bias and expected estimated exploitation rate.

Adding drop-off as a source of mortality to a fishery operating alone does not change the results shown in Figure 2. Adding mark and unmarked recognition error rates as a source of mortality to the same fishery reduces the biases in the MSF (Figure 3). When the unmarked-recognition error is greater than the mark-recognition error and the catch quota includes unmarked fish landed by mistake, the required number of marked encounters in a MSF declines as a result of unmarked fish landed by mistake. The number of unmarked encounters also declines because of its relationship to the marked encounter rate (Equation 10). Increasing the release-mortality rate with successive encounters produces greater biases in the MSF (Figure 4).

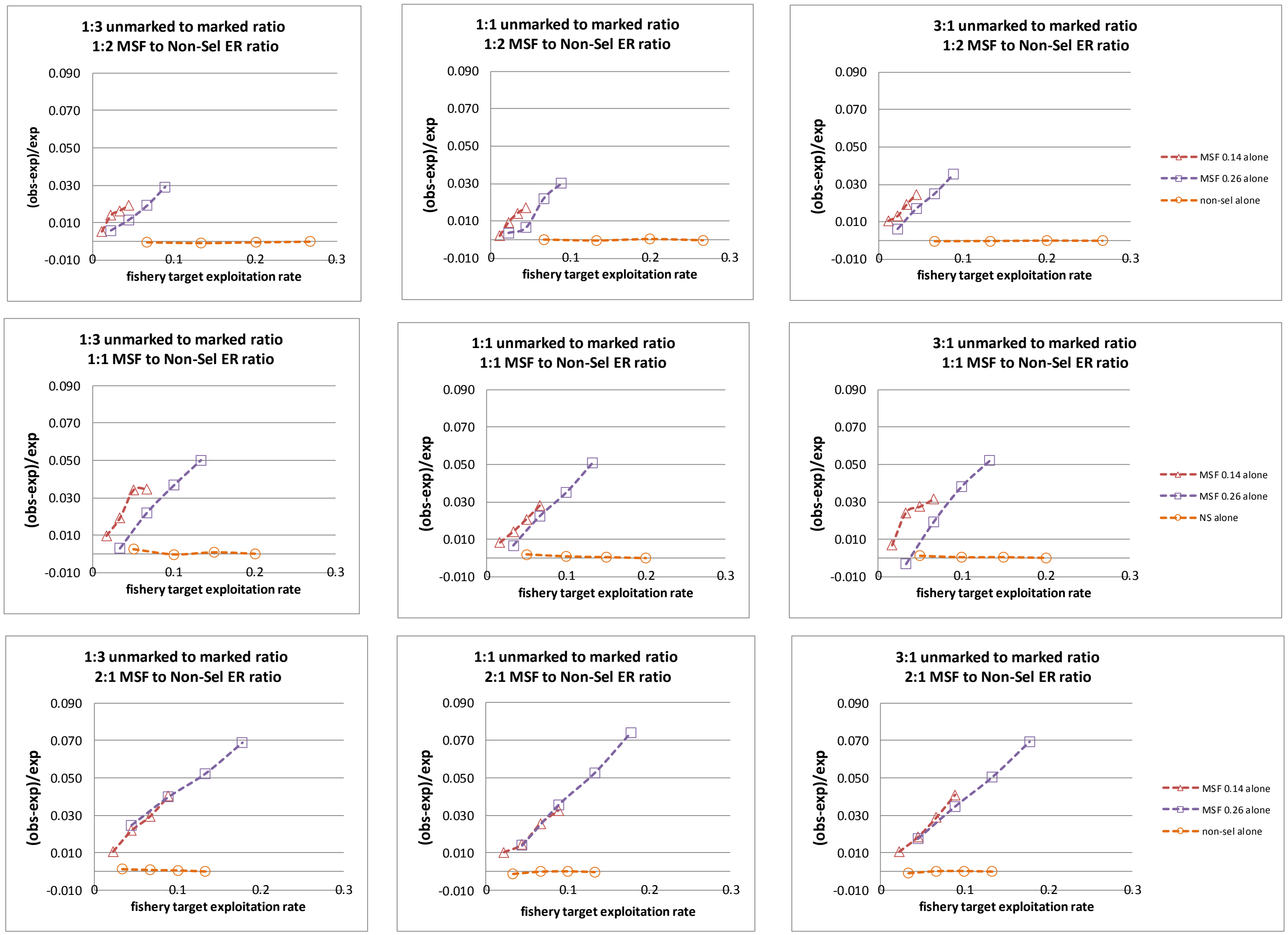

Figure 2. Bias in estimated unmarked exploitation rates in two MSF (δ = 0.14 and 0.26 respectively) and one non-selective fishery operating alone with landings and release mortality as the only sources of mortality. Note when the MSF-to-NSF exploitation rate ratios change, the target exploitation rates will also change.

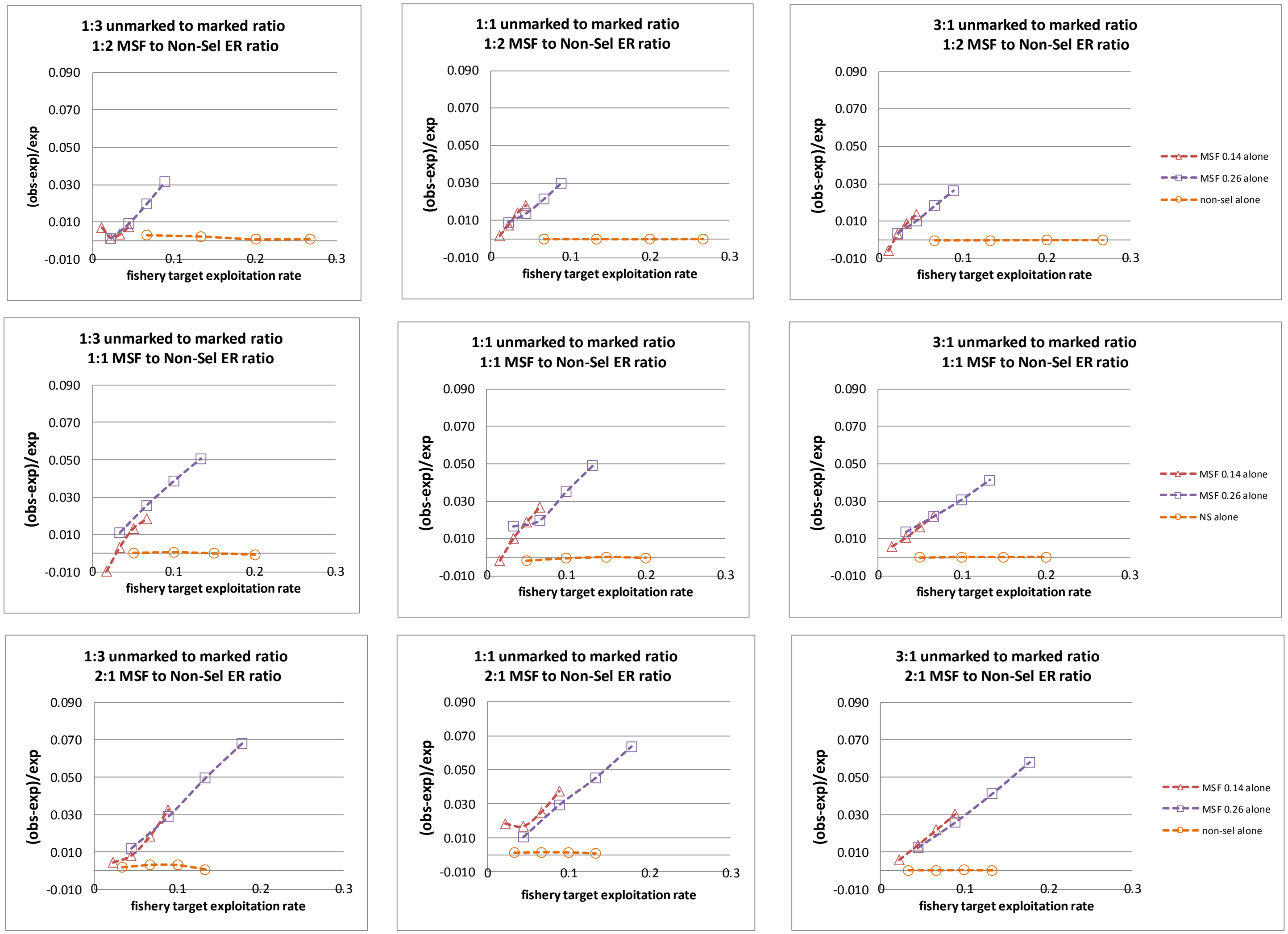

Figure 3. Bias in estimated unmarked exploitation rates in two MSF (δ = 0.14 and 0.26 respectively) and one non-selective fishery operating alone with landings, drop-offs, release mortality, plus mark and unmarked recognition errors as the sources of mortality. Note when the MSF-to-NSF exploitation rate ratios change, the target exploitation rates will also change.

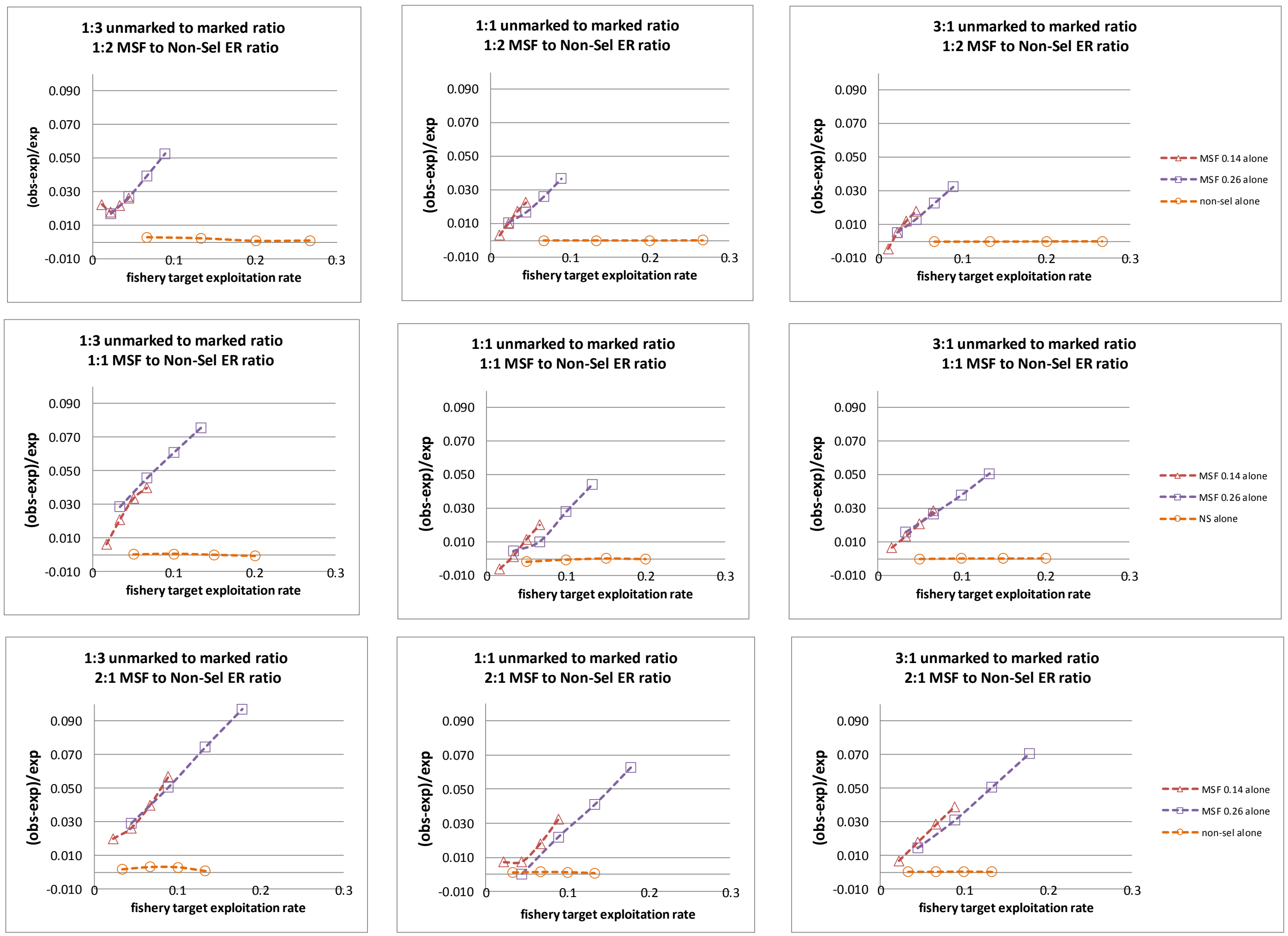

Figure 4. Bias in estimated unmarked exploitation rates in two MSF (δ = 0.14 and 0.26 respectively) and one non-selective fishery operating alone with landings, drop-offs, mark and unmarked recognition errors, and increasing release mortality with successive encounters as the sources of mortality. Note when the MSF-to-NSF exploitation rate ratios change, the target exploitation rates will also change.

With landings and release mortalities as the only source of mortality, operating MSF and NSF simultaneously in the same time period and area increases the unmarked-to-marked fish ratio from the removal of more marked than unmarked fish by the MSF.   In the upper left panel of Figure 5 the starting unmarked cohort proportion was 0.333 and the ending proportions were 0.343, 0.353, 0.366, and 0.381 after the simultaneous fisheries achieved a combined target exploitation rate of 0.1, 0.2, 0.3, and 0.4, respectively. Not only did this increase the biases in the MSF, it also introduced a bias in the NSF where none existed when the non-selective fishery was prosecuted in isolation. This bias in the estimated exploitation rate for the unmarked cohort in the non-selective fishery can be as large as the analogous bias present in the mark-selective fisheries.

For reasons that we do not understand, adding drop-off mortality to simultaneous fisheries increased the biases in the MSF when the unmarked-to-marked fish ratio was 1 or less and decreased it when the ratio was greater than 1 (Figure 6). Adding mark and unmarked recognition errors to simultaneous fisheries had the effect of reducing the number of marked encounters required to achieve a catch quota because of unmarked fish landed by mistake and consequently reducing the biases among the MSF if the unmarked-to-marked fish ratio was less than or equal to 1 but not in the non-selective fishery regardless of the unmarked–to-marked fish ratio (Figure 7). There is no noticeable effect on the bias in the non-selective fisheries. Adding increased release-mortality rate with successive encounters to simultaneous fisheries produced a relatively small increase in the biases among the MSF (Figure 8).

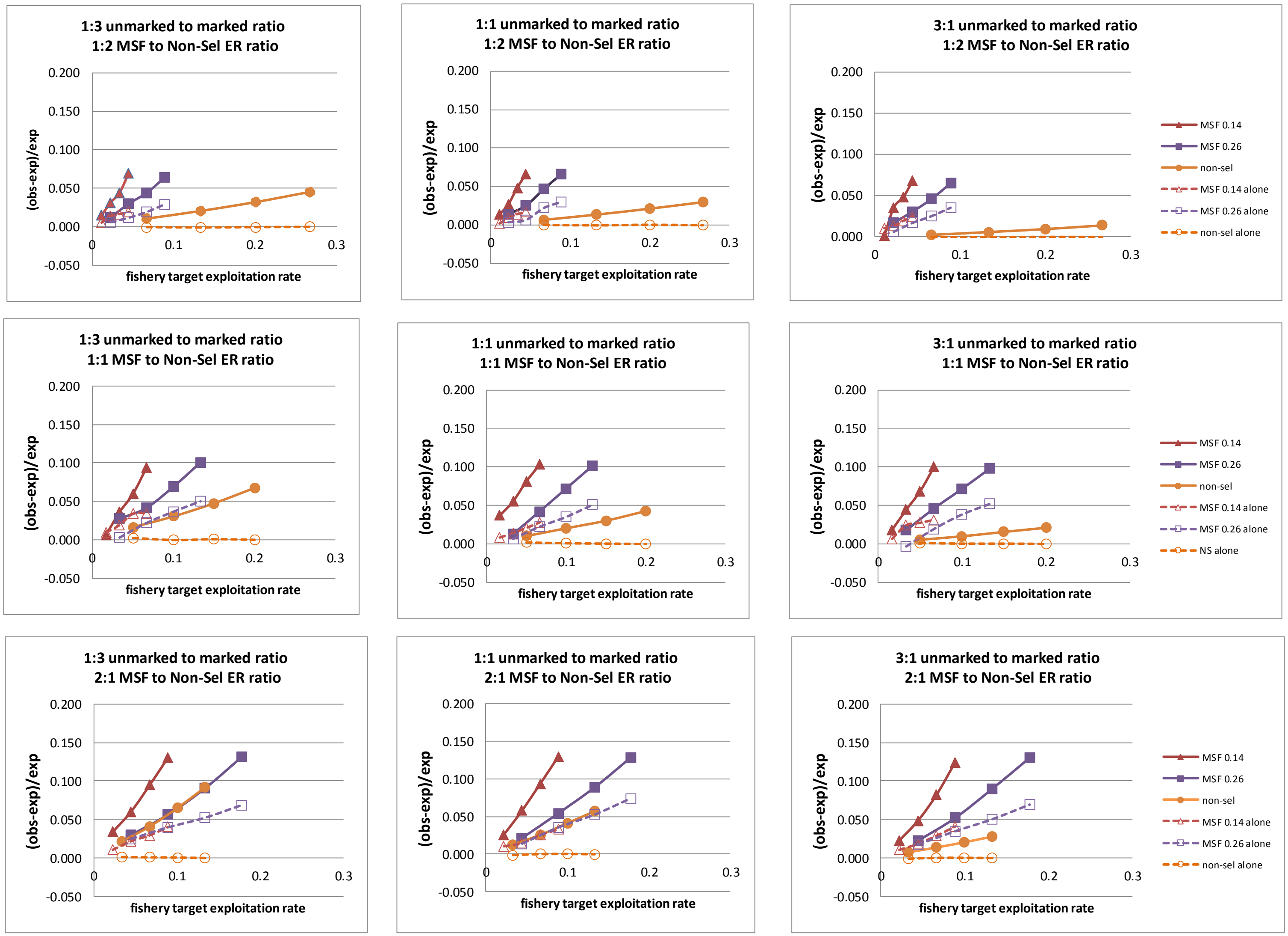

Figure 5. Bias in estimated unmarked exploitation rates in two MSF (δ = 0.14 and 0.26 respectively) and one non-selective fishery operating simultaneously and alone with landings and release mortality as the sources of mortality. Note when the MSF–to- NSF exploitation rate ratios change, the target exploitation rates will also change.

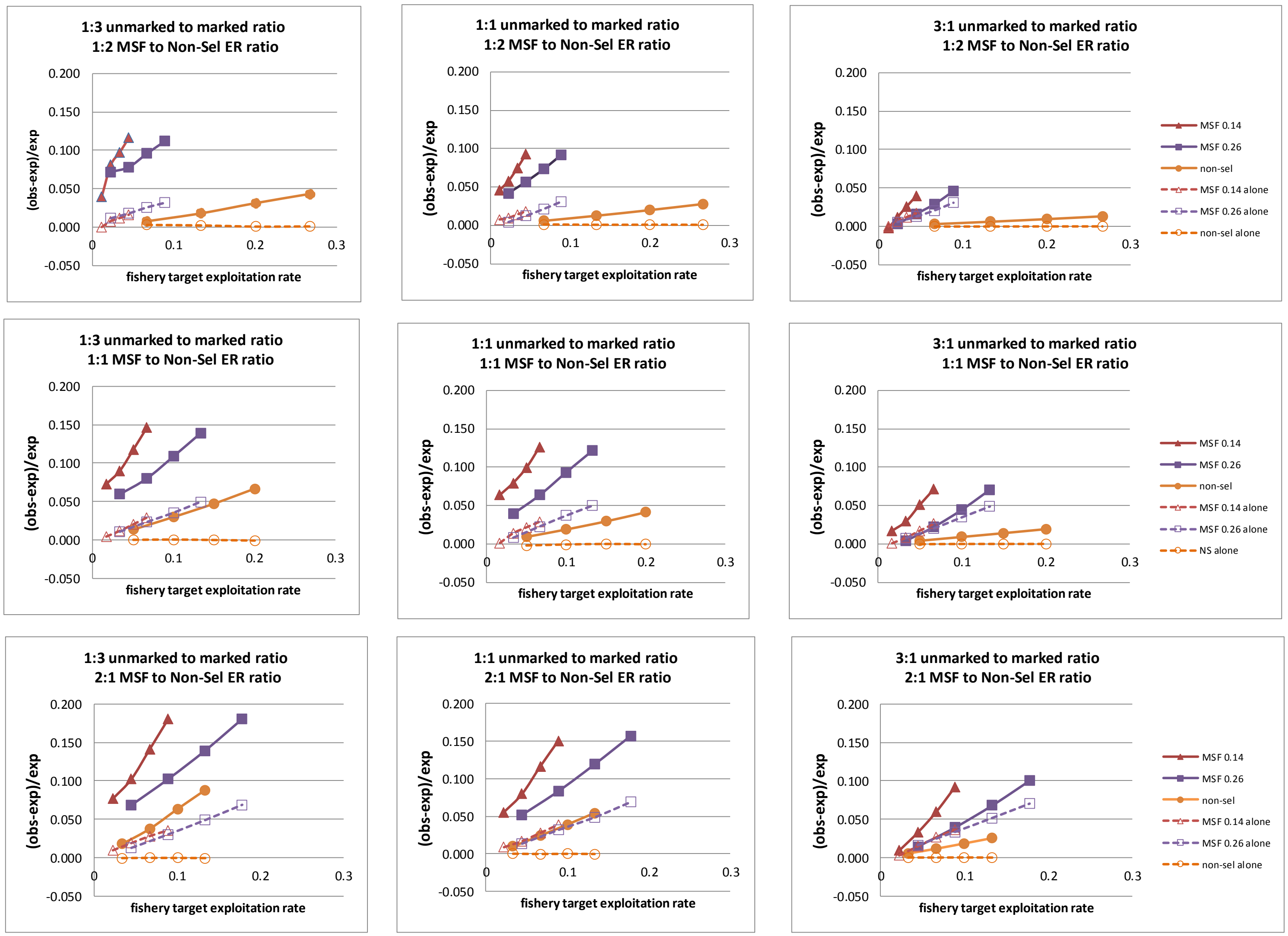

Figure 6. Bias in estimated unmarked exploitation rates in two MSF (δ = 0.14 and 0.26 respectively) and one non-selective fishery operating simultaneously and alone with landings, release mortality, and drop-off as the sources of mortality. Note when the MSF-to-NSF exploitation rate ratios change, the target exploitation rates will also change.

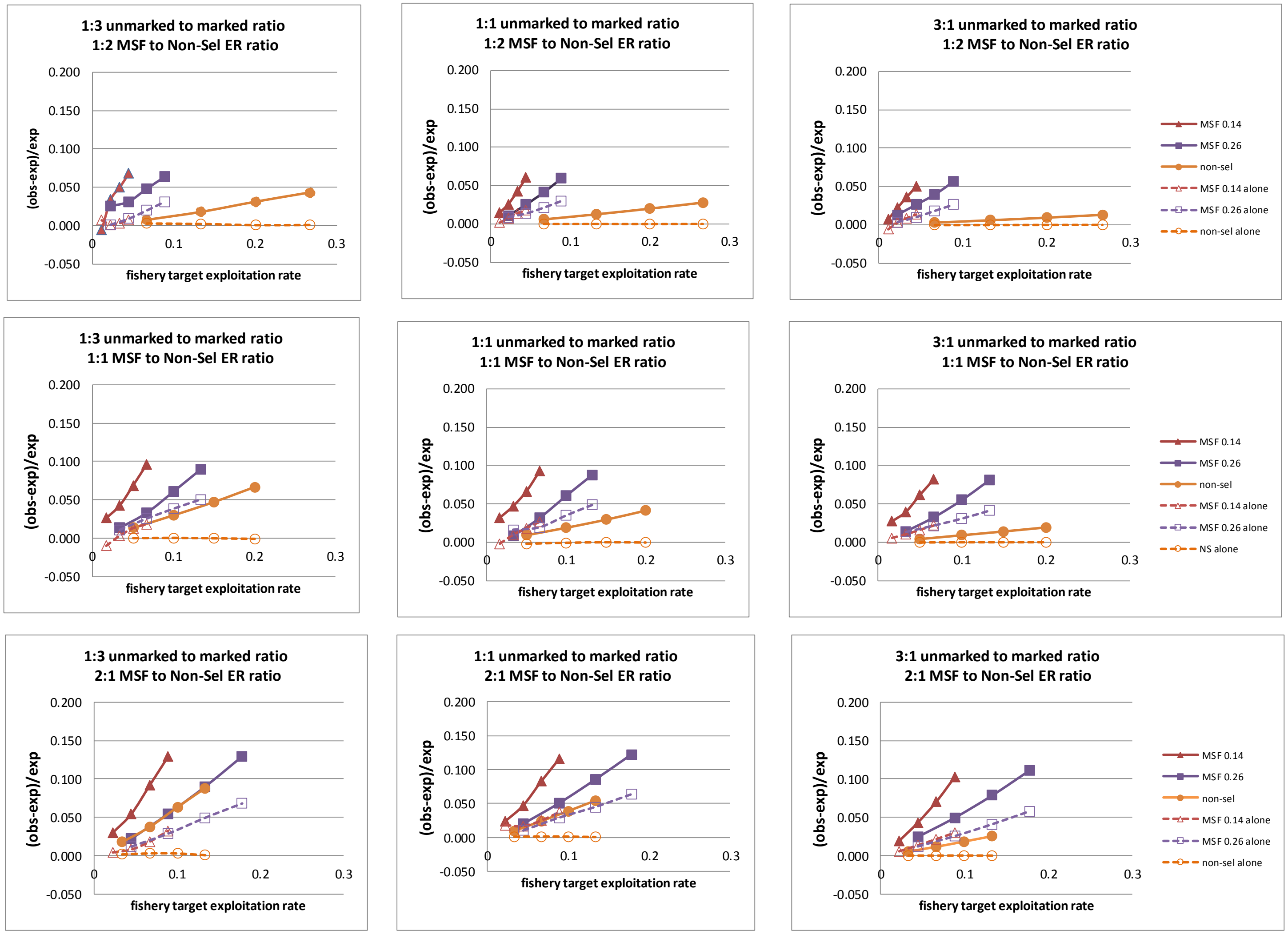

Figure 7. Bias in estimated unmarked exploitation rates in two MSF (δ = 0.14 and 0.26 respectively) and one non-selective fishery operating simultaneously and alone with landings, release mortality, drop-off, and mark and unmarked recognition errors as the sources of mortality. Note when the MSF-to-NSF exploitation rate ratios change, the target exploitation rates will also change.

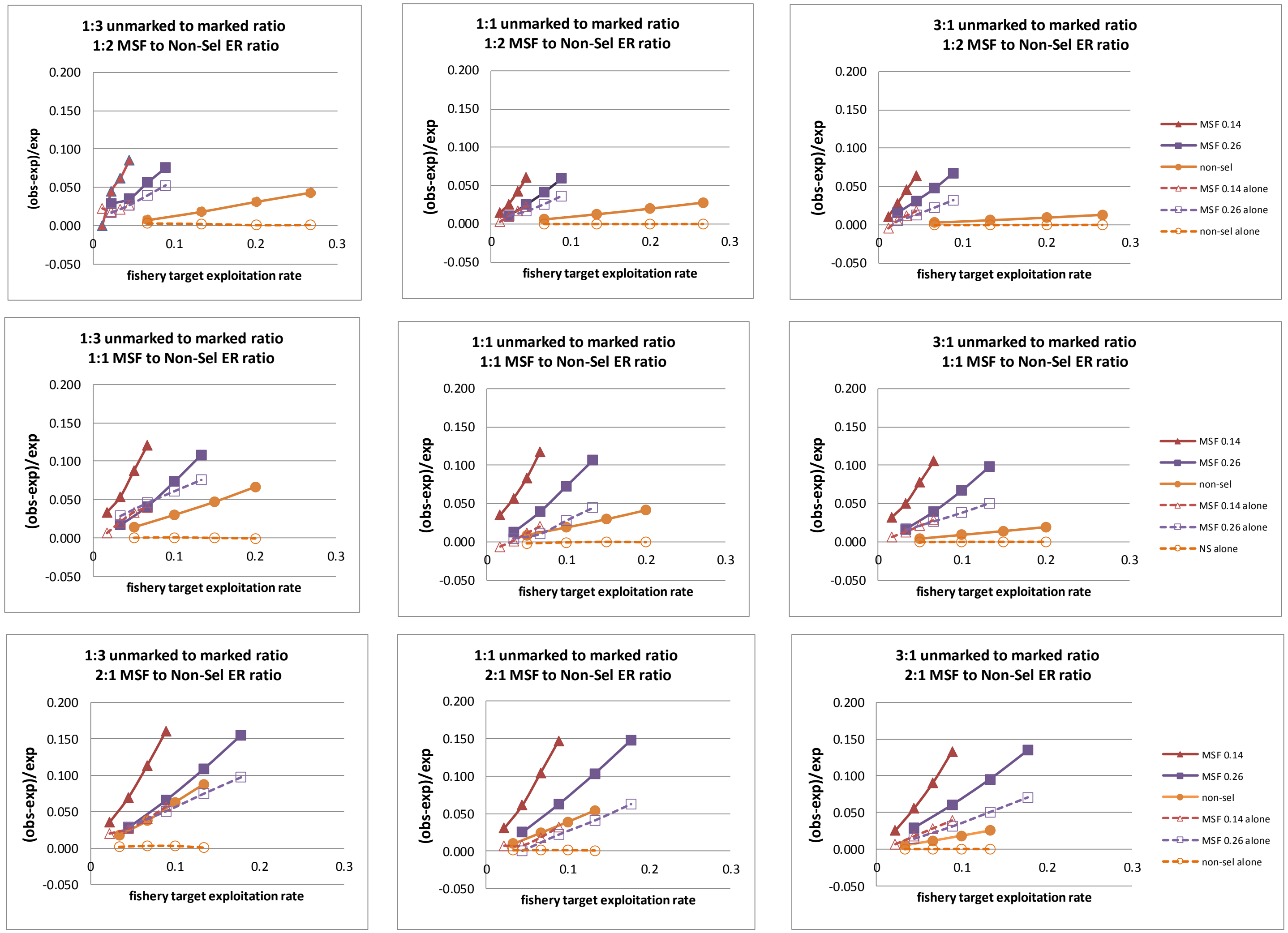

Figure 8. Bias in estimated unmarked exploitation rates in two MSF (δ = 0.14 and 0.26 respectively) and one non-selective fishery operating simultaneously and alone with landings, release mortality, drop-off, mark and unmarked recognition errors, increasing release mortality with successive encounters as the sources of mortality. Note when the MSF-to-NSF exploitation rate ratios change, the fishery target exploitation rates will also change.

Discussion

The unmarked-to-marked fish ratios in our simulations bracket those reported for historical mark-selective fisheries in Washington. If we had to choose, the 1:1 ratio would be closest to the 43% to 58% legal size Chinook marked encounter rate in Washington Marine Areas 5 and 6 between 2003 and 2009 (WDFW Multi-year Report Workgroup 2008, McHugh et al. 2009, and Baltsell et al. 2010). Similarly, the unmarked-to-marked coho encounter ratio in the 2009 recreational fishery off the coast of Washington was slightly greater than 1:1. A Chinook management area with the potential for simultaneous MSF and NSF would be Washington Marine Areas 3 and 4. Assuming the non-Indian troll and sport fisheries would be MSF and the treaty Indian troll fishery would be NSF, the 2010 catch quotas were approximately 17,000 and 25,000 respectively for the May-June time period and 16,000 and 26,000 for the July-September time period. The 1:1 unmarked-to-marked ratio and MSF < NSF scenario for Chinook corresponds to the upper middle panels in Figures 2-8. In coho fisheries off the Washington coast, most of the landings of marked coho occur in the MSF and the lower middle panels would be most representative of actual management scenarios.

Because all of the management models in use, FRAM, the Pacific Salmon Commission's Chinook Models, as well as the US v. Oregon Technical Advisory Committees Chinook harvest models require the accounting of all fishery-related mortalities, we focus our discussion on the upper middle panel of Figure 8 for Chinook, enlarged as Figure 9. Almost all of the historical target exploitation rates for individual Chinook MSF were less than 0.2 and our simulations were within that range. The biases for a MSF with a release-mortality rate of 0.14 (e.g., ocean sport) in a simultaneous fishery, was about three times greater than if the fishery was prosecuted in isolation. The difference in biases for a MSF with a higher release-mortality rate of 0.26 (e.g., ocean troll) was ambiguous at the lower exploitation rates, e.g., 0.01, and clearly greater at exploitation rates of 0.02 and higher. For example at a target exploitation rate of 0.07, the bias from being in a simultaneous fishery was 0.041, not quite double the 0.026 bias from being prosecuted alone. Finally, prosecuting a non-selective fishery in the same time step and area with one or more mark-selective fisheries will introduce a bias in the estimated mortalities where none existed if the same non-selective fishery was prosecuted alone. For coho, we turn our attention to the lower middle panel of Figure 8, enlarged as Figure 10. The results are similar to those for Chinook except there is no ambiguity in the differences between fishing simultaneous with other fisheries and fishing in isolation for the fishery with the higher, 0.26, release-mortality rate.

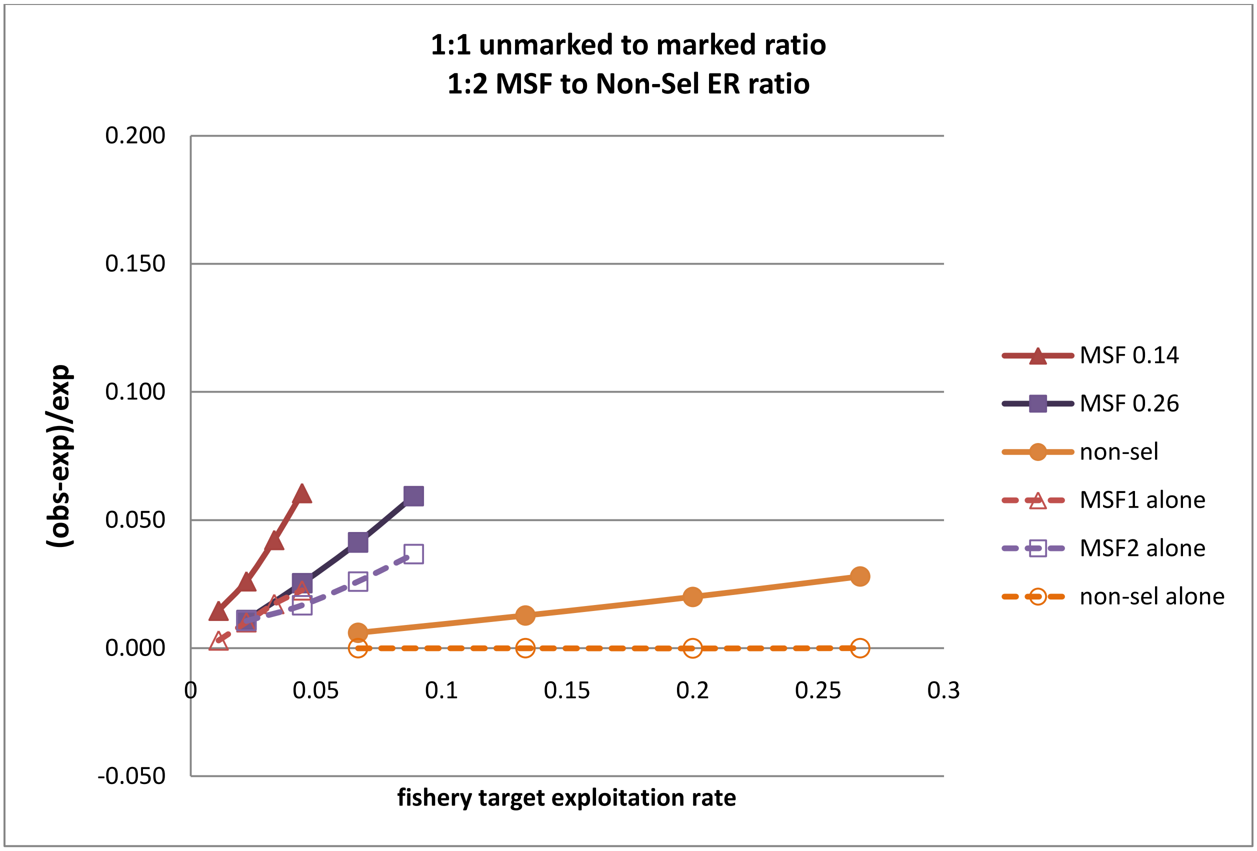

Figure 9. Scenario with unmarked-to-marked fish ratios close to 1 and MSF target exploitation rates less than that for the NSF is most representative of historical Chinook mark-selective fisheries.

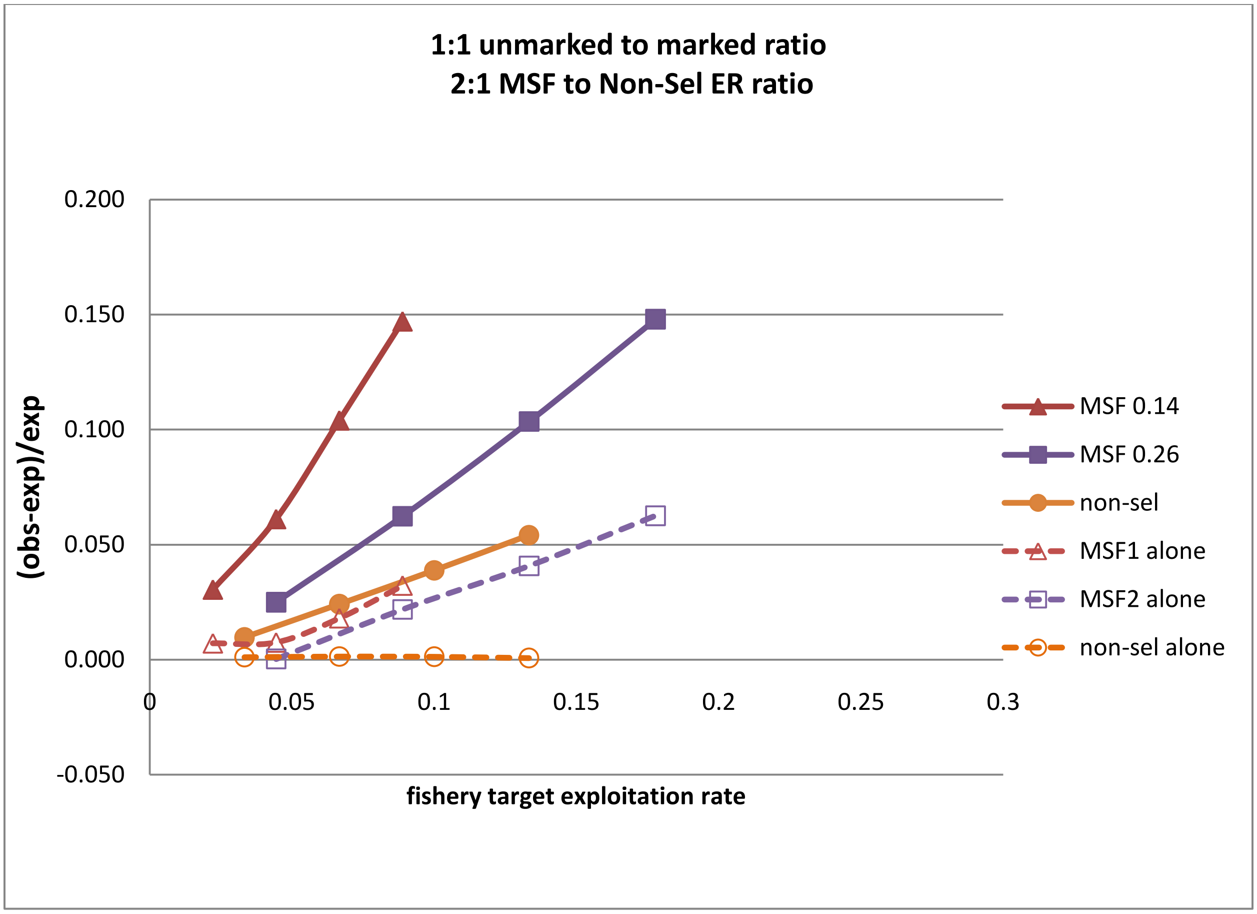

Figure 10. Scenario with unmarked-to-marked fish ratios close to 1 and MSF target exploitation rates greater than that for the NSF is most representative of historical coho mark-selective fisheries.

We had to solve for the mark-recognition error adjustment for marked fish released by mistake and unmarked fish landed by mistake because we were unable to describe the relationship between the mark-recognition error adjustment, R, γ and ζ. A weighted reciprocal of the recognition rates, $(M/\gamma + U/\zeta)/(M+U)$ works only when $\gamma = 0.95$ and $\zeta = 1$.

FRAM does not have the mark-recognition error adjustments for marked fish released by mistake and unmarked fish landed by mistake and its estimates of mortality would have been less than that estimated from Equation 10, especially at the lower exploitation rates, higher unmarked-to-marked fish ratios and higher MSF-to-NSF exploitation rate ratios. These latter two conditions are also not typical of historical mark-selective fisheries. If we used the FRAM model as our benchmark, some of the biases would have extended into the negative range as shown in Figure 11, creating a scaling problem when comparing simultaneous fisheries with isolated fisheries. Nevertheless, the trends are persistent and methods to correct the biases in the FRAM model are being proposed in a separate report.

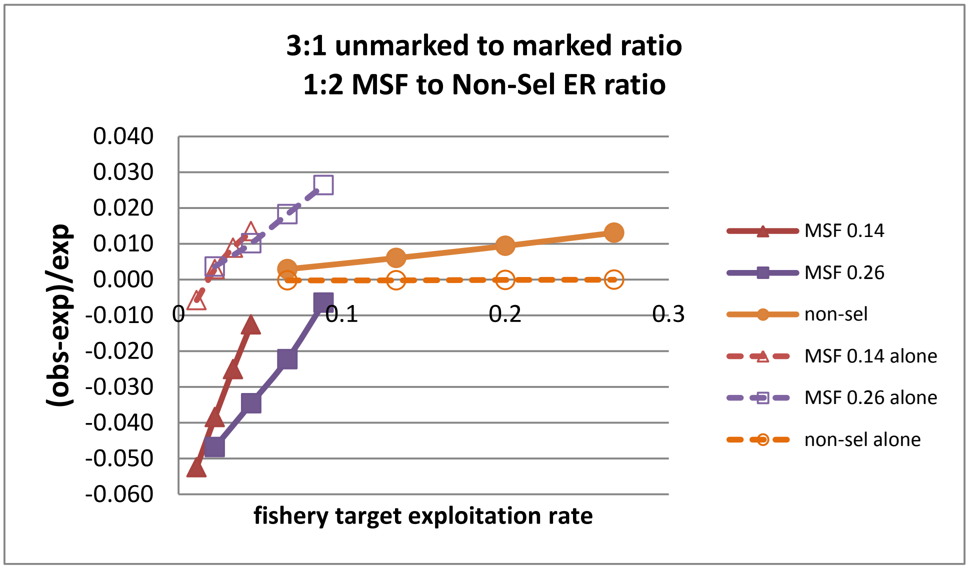

Figure 11. The FRAM model does not have a mark-recognition error adjustment for marked fish released and unmarked fish landed by mistake and therefore some of the estimated biases would be on the negative scale especially at the lower exploitation rates, higher unmarked-to-marked fish ratios and higher MSF-to-NSF exploitation rate ratios.

In the FRAM model there are multiple time steps, e.g., May-June, July-September, etc. At the end of each time step, natural mortality is applied to the escapement and the result is the starting cohort size for the next time period. The potential to propagate bias over multiple time steps will be investigated in a separate report.

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Agenda Item F.5.a
Attachment 2
November 2010

Bias-corrected Estimates of Mortality in Mark-selective Fisheries for Coho Salmon

Robert H. Conrad
Northwest Indian Fisheries Commission
6730 Martin Way East
Olympia, WA 98516

and

Henry Yuen
U.S. Fish and Wildlife Service
1211 SE Cardinal Court, Suite 100
Vancouver, WA 98683

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Abstract

The current Fishery Regulation Assessment Models (FRAM) used in the pre-season planning process to project mortalities during proposed coho and Chinook salmon fisheries produce biased estimates of the mortalities occurring in mark-selective fisheries and concurrent non-selective fisheries. The bias is caused by unmarked fish encountering fishing gear more than once in a modeled time step due to the required release of all unmarked fish and by the change in the unmarked-to-marked fish ratio resulting from the selective removal of marked salmon by the mark-selective fishery. Biased estimates of mortalities in non-selective fisheries operating during the same time step as mark-selective fisheries occur because of the increasing unmarked-to-marked ratio in the common pool of salmon being fished. Bias-corrected methods to estimate the total number of unmarked and marked salmon mortalities in these fisheries are proposed. FRAM estimates and bias-corrected estimates are compared to simulation results to evaluate bias and to assess the effectiveness of the bias-corrected methods. Within a model time step, the proposed bias-corrected methods correct for the majority of the bias in the current FRAM estimates of exploitation rates for the unmarked and marked cohorts under the assumptions used for their development. The feasibility of implementing the proposed bias-corrected methods into the coho FRAM should be evaluated during the next management cycle.

Introduction

Mark-selective fisheries for coho salmon (*Oncorhynchus kisutch*) were introduced as a management tool in 1998 off the Washington coast (PFMC 1999a). Regulations for mark-selective fisheries permit the retention of legal-size coho which have had their adipose fin removed (marked) and require the release of all coho salmon with an adipose fin (unmarked) that are brought to the boat. An on-going program in Washington State which removes the adipose fin from the majority of hatchery-produced coho (mass marking) means that most coho salmon without an adipose fin are hatchery produced while most salmon with an adipose fin are of natural origin (PSMFC 1992). The objective of mark-selective fisheries is to provide meaningful fisheries on abundant hatchery salmon while minimizing the impact on wild salmon.

The Fishery Regulation Assessment Model (FRAM) is used by the Pacific Fishery Management Council (PFMC) during the pre-season planning process to project mortalities during proposed coho and Chinook salmon fisheries. FRAM is a single-pool, deterministic model that has discrete time steps that vary in length from one month to several months (PFMC 2008a). All fisheries during a time step are assumed to operate simultaneously on a single pool of fish. The pool of modeled fish consists of all stocks that have been caught historically in the fishery as estimated from coded-wire tag (CWT) recoveries (Nandor et al. 2010). Historical exploitation rates estimated from CWTs recovered during a base period when salmon abundances were relatively high and fisheries were widely distributed in both time and area are the basis for the FRAM predictions of fishery mortalities by stock (Pacific Salmon Commission 2005). Details for the methods and algorithms used in FRAM are presented in PFMC (2008b). PFMC (2007) provides a description of the base-period data used for the coho FRAM.

Prior to the implementation of mark-selective fisheries, a key FRAM assumption was that the exploitation rate for specific marked salmon stocks (sometimes called indicator stocks) was representative of the exploitation rate for unmarked stocks (typically wild stocks) with similar life histories and ocean distributions. With the advent of mark-selective fisheries, the model was restructured so that the exploitation rates for these marked indicator stocks were used to estimate the encounter rates in mark-selective fisheries for the unmarked stocks that they represent (PFMC 2008b). These encounter rates are used to produce stock-specific estimates of the number of encounters of unmarked fish in a mark-selective fishery which, combined with an estimate of the release-mortality rate, provide estimates of the mortalities due to the catch and release of unmarked salmon. In FRAM, the exploitation rate on the unmarked stock is a linear function of the exploitation rate on the marked indicator stock used to represent the unmarked stock and the release-mortality rate.

Lawson and Sampson (1996) demonstrated that in a mark-selective fishery, the actual mortality rate of unmarked fish is an increasing function of the apparent harvest rate on the marked fish and the release-mortality rate. This causes the total number of unmarked mortalities in mark-selective fisheries to be underestimated by models relying on the linear relationship between exploitation rate and release-mortality rate. The Lawson and Sampson analysis examined the dynamics occurring within a single mark-selective fishery during what is equivalent to a single time step. Based on this analysis, the Scientific and Statistical Committee (SSC) of the PFMC recommended "limiting exploitation rates in each modeled selective fishery to 10%, with a maximum 30% overall exploitation rate" (see SSC minutes from the November 2009 PFMC meeting). This recommendation is based on a qualitative assessment that, at these levels, bias in estimated exploitation rates of the unmarked cohort should be minimal.

Any combination of mark-selective and non-selective fisheries operating concurrently during a time step greatly increases the complexity of estimating mortalities for both unmarked and marked cohorts. For example, a mark-selective troll fishery and a mark-selective recreational fishery each with different release-mortality rates, can occur during the same time step as a non-selective troll fishery. As demonstrated by Lawson and Sampson (1996), the dynamic interactions between the competing fisheries can be explored with an individual-based simulation model that monitors the fate of each fish vulnerable to the fisheries.

Recent Pre-season Coho FRAM Exploitation Rates on Unmarked and Marked Cohorts

Before describing the methods of analysis for this report, it is instructive to examine recent projected exploitation rates on the unmarked and marked cohorts during each coho FRAM time step. We can then assess the status of recent pre-season FRAM model runs relative to the SSC guidance. We summarized the "Pop Stat" reports from the final pre-season coho FRAM runs in 2009 and 2010 (Coho0921 and Coho1016, respectively). The PopStat report summarizes FRAM estimates of cohort sizes for each of the 246 coho salmon stocks in FRAM (PFMC 2008b) at each time step. For time steps 1 through 4, the abundance of each stock is reported: (a) at the start of the time step, (b) after natural mortality, and (c) after pre-terminal fisheries. The difference between the abundance reported after pre-terminal fisheries and after natural mortality (b-c) represents fishery mortalities in the time step. Time step 5 reports components a, b, and c, and has a reported abundance for the (d) mature cohort and for the (e) escapement. The difference between the abundance reported for the mature cohort and for escapement (d-e) represents fishery mortalities in time step 5.

We can combine these stock abundances by time step (after natural mortality) with the FRAM report that summarizes exploitation rates by stock, in each time step, for each of the 198 fisheries represented in Coho FRAM (PFMC 2008b). This provides an estimate of the number of mortalities for each stock that occurred in each fishery during the time step. These can be summed separately for the unmarked and marked stocks by mark-selective and non-selective fisheries to estimate total exploitation rates on the unmarked and marked cohorts in mark-selective and non-selective fisheries in each time step. These exploitation rates can then be compared to the SSC guidance.

In 2009 there were 148 stocks with non-zero cohort abundance in the final FRAM pre-season model run and in 2010 there were 150 stocks with non-zero cohort abundance. Table 1 summarizes the FRAM estimates of exploitation rates for the unmarked and marked cohorts in mark-selective and non-selective fisheries by FRAM time step for 2009. In this assessment, the exploitation rates for the marked cohort in the mark-selective fisheries for each time step, and in total, all fall within the SSC guidelines.

The summary in Table 1 includes all stocks including coho stocks in Canada and Alaska. Pre-season estimates of abundance for these stocks are qualitatively much poorer than for southern US-origin stocks. To better examine the effects on southern US-origin stocks, Table 2 summarizes estimated exploitation rates for all Washington and Columbia River stocks combined (no stocks from Alaska, Canada, the Oregon coast, and California were included). For the 2009 assessment, the pre-season projections of exploitation rates for the marked cohort in mark-selective fisheries in time steps 2, 3, and 4 (July, August, and September) exceed the guideline of 0.10 in any time step. The total exploitation rate of the marked cohort in mark-selective fisheries also exceeds the guideline of 0.30. In 2010, the exploitation rates for the marked cohort in the mark-selective fisheries for each time step, and in total, all fall within the SSC guidelines.

Based on this cursory analysis of pre-season FRAM estimates, it appears that in some years we should be concerned about bias given the exploitation rates recently projected. However, the FRAM estimated exploitation rates in Tables 1 and 2 include fishery-specific adjustments for mark recognition error in mark-selective fisheries, drop-off mortality calculations, and catch non-retention (CNR) mortalities (which are added outside the model). It is not clear how these adjustments affect the SSC guidance on the level of exploitation rates for the marked cohort. We will re-visit this assessment at the end of this report.

Table 1. Summary of coho FRAM pre-season estimates of exploitation rates for the total unmarked and marked cohorts in mark-selective (MSF) and non-selective (NSF) fisheries in each FRAM time step. Summary is for all FRAM stocks in 2009 and 2010 pre-season FRAM runs.

Time Step	Fishery Type	2009 Pre-season Run Cohorts (n = 148)		2010 Pre-season Run Cohort (n = 150)	
		Unmarked	Marked	Unmarked	Marked
1	**MSF**	0.001	0.006	0.000	0.004
	NSF	0.004	0.001	0.008	0.009
2	**MSF**	0.007	0.062	0.001	0.042
	NSF	0.045	0.011	0.149	0.036
3	**MSF**	0.010	0.084	0.002	0.073
	NSF	0.051	0.019	0.230	0.060
4	**MSF**	0.009	0.072	0.002	0.041
	NSF	0.045	0.060	0.129	0.131
5	**MSF**	0.000	0.000	0.000	0.001
	NSF	0.079	0.148	0.035	0.212
All	**MSF**	0.026	0.224	0.006	0.159
	NSF	0.224	0.239	0.550	0.447
	Grand Total	0.250	0.463	0.556	0.607

Table 2. Summary of coho FRAM pre-season estimates of exploitation rates for the total unmarked and marked cohorts in mark-selective (MSF) and non-selective (NSF) fisheries in each FRAM time step. Summary is for Washington and Columbia River stocks only from 2009 and 2010 pre-season FRAM runs.

Time Step	Fishery Type	2009 Pre-season Run Cohorts (n = 100)		2010 Pre-season Run Cohort (n = 102)	
		Unmarked	Marked	Unmarked	Marked
1	**MSF**	0.001	0.009	0.001	0.005
	NSF	0.002	0.002	0.008	0.010
2	**MSF**	0.016	0.102	0.007	0.054
	NSF	0.012	0.009	0.013	0.013
3	**MSF**	0.025	0.139	0.014	0.093
	NSF	0.019	0.014	0.020	0.020
4	**MSF**	0.026	0.119	0.016	0.051
	NSF	0.091	0.076	0.121	0.135
5	**MSF**	0.000	0.000	0.000	0.000
	NSF	0.275	0.247	0.252	0.281
All	**MSF**	0.068	0.369	0.039	0.203
	NSF	0.399	0.348	0.413	0.458
	Grand Total	0.468	0.717	0.451	0.662

Methods

Model Set-up and Specification

The simulation model used in this study was an extension of the individual-based model used by Lawson and Sampson (1996). One difference in model parameters is that Lawson and Sampson used a single parameter, γ, to specify the probability of a fisher correctly identifying an unmarked or a marked salmon. We used two parameters, one to specify the probability of a fisher correctly identifying and keeping a marked salmon (γ), and one to specify the probability of a fisher correctly identifying and releasing an unmarked salmon (ζ) because the two often have different values. Parameters and their values used in the simulations are summarized in Table 3. Another major difference was that our model simulated four separate fisheries, two non-selective fisheries (NSF) and two mark-selective fisheries (MSF) operating concurrently on the pool of fish. The release mortality rate for one MSF was 0.14, a value used for ocean recreational fisheries for coho, and 0.26 for the other MSF, a value used for commercial troll fisheries for coho (PFMC 2008a). Because there are multiple MSF and NSF, we use the following notation to differentiate fisheries and types of fisheries:

- subscript i is used to denote MSF i and subscript I denotes the total for all MSF in a time step,
- subscript j is used to denote NSF j and subscript J denotes the total for all NSF in a time step, and
- subscript k is used to denote fishery k (either MSF or NSF) and subscript K denotes the total for all fisheries in a time step.

The model process begins with an initial pool of U unmarked and M marked fish subject to all fisheries operating during the modeled time step. For our simulations, the initial population always consisted of 400,000 total fish. Simulations were run using three different unmarked-to-marked fish ratios (R) to divide the initial pool into unmarked and marked fish cohorts: 1:3, 1:1, and 3:1. The fishing process is simulated as a random selection of a fish from the pool of salmon available. Based on relative probabilities of encounter in each fishery[1], a caught fish is then randomly assigned to one of the four fisheries modeled.

For our parameterization of the model, after a fish has been randomly selected from the pool and randomly assigned to a fishery one of the following occurs:

(1) a marked fish assigned to a NSF is removed from the pool and tallied as a mortality,
(2) an unmarked fish assigned to a NSF is removed from the pool and tallied as a mortality,
(3) a marked fish assigned to a MSF is removed from the pool and tallied as a mortality, or
(4) an unmarked fish assigned to a MSF is returned to the pool with probability $(1 - \delta)$ or removed from the pool and tallied as a mortality with probability δ.

For the single-pool model, it is assumed that an unmarked fish that is released in a MSF and survives is immediately available for harvest in the same fishery or another fishery in the time step.

Target exploitation rates for the marked cohort are specified for each fishery prior to running the model. We examined total (across all four modeled fisheries) target exploitation rates for the marked cohort from 0.10 to 0.60 in increments of 0.10. For each MSF, the target exploitation rate is multiplied by the marked cohort size (M) to specify a marked-fish quota for the fishery. For each NSF, a total fish quota is specified as the product of the target exploitation rate for the marked cohort and the sum of M and U.

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[1] An approximate probability that a fish is encountered in each fishery was calculated as, $\hat{Y}_k = \frac{\mu_k^M}{\sum_{k=1}^{4} \mu_k^M}$ where μ_k^M = the target exploitation rate for the marked cohort in fishery k.

Table 3. Simulation model parameters and their values used in the simulations.

Parameter	Definition and value(s)
U	Initial number of unmarked fish.
M	Initial number of marked fish.
b	Multiple encounter parameter that determines the increase in the release-mortality rate with successive releases. Set to 1.0 for all simulations (i.e., no increase).
λ	Instantaneous encounter rate of a fish with the gear.
α	Drop-off probability: the probability that a hooked fish escapes before being brought to the boat. Set to 0.0 for all simulations (i.e., no drop-off and, hence, no drop-off mortality).
β	Drop-off mortality rate: the probability that a fish which drops off dies due to the encounter with the gear. Set to 0.0 for all simulations.
δ	Release-mortality rate: probability that a fish that is brought to the boat and released dies after release due to the encounter. Values of 0.14 and 0.26 were used for the two mark-selective fisheries modeled.
γ	Mark-recognition rate: the probability that a marked fish that is brought to the boat is properly identified as a marked fish and retained. Set to 1.0 for all simulations and assumed that all marked fish caught are kept.
ζ	Recognition rate for unmarked fish: the probability that an unmarked fish brought to the boat is recognized as unmarked and released in a MSF. Set to 1.0 for all simulations.
μ_k^U	Exploitation rate for the unmarked cohort: the total number of unmarked fish mortalities occurring in fishery k divided by the unmarked fish cohort size at the beginning of the time step. Subscripts i and j are used to differentiate MSF and NSF, respectively.
μ_k^M	Exploitation rate for the marked cohort: the total number of marked fish mortalities occurring in fishery k divided by the marked fish cohort size at the beginning of the time step. Subscripts i and j are used to differentiate MSF and NSF, respectively.

Because the marked cohort is used as an indicator stock for the unmarked cohort, any target exploitation rate specified for the marked cohort in a NSF is also the target for the unmarked cohort.

Finally, the model is run until the quota in each fishery is met. This is analogous to the process used in FRAM of setting a quota for a MSF based on a desired exploitation rate estimated from a projection of landed marked fish only and setting a quota for a NSF using the projected combined landed catch of marked and unmarked fish based on a target exploitation rate for either the marked cohort or the unmarked cohort (using the marked cohort as its indicator). Both methods are commonly used in FRAM to specify seasons for proposed fisheries during the pre-season modeling process. Similarly to FRAM, we assumed perfect in-season management so that all quotas are exactly met.

We also examined three different scenarios for the division of the total exploitation rate for the marked cohort among mark-selective and non-selective fisheries. The three scenarios were:

#1. total exploitation rate in MSF = half the total exploitation rate in NSF,
#2. total exploitation rate in MSF = total exploitation rate in NSF, and
#3. total exploitation rate in MSF = two times the total exploitation rate in NSF.

For each scenario:*R* combination assessed, we used the mean of 25 simulation model runs as a standard for comparison (i.e., it is assumed to represent the "true" estimate). Bias-corrected and FRAM estimates of exploitation rates and unmarked-to-marked ratios are compared to this standard from the simulations. Relative bias is calculated as:

$$\theta = \frac{\text{estimate - simulation mean}}{\text{simulation mean}} \cdot 100\%,$$

therefore, negative θ indicates that a method underestimates a quantity relative to the simulation means, while positive θ indicates that a method overestimates a quantity relative to the simulation means. We also compared methods using the ratio (Ω) of either the FRAM or bias-corrected estimate to the simulation mean exploitation rate, totaled across all mark-selective fisheries, all non-selective fisheries, or all fisheries; this was done separately for the unmarked and marked cohorts. This ratio can be interpreted as the number of unmarked or marked mortalities estimated by either FRAM or the bias-corrected method for each mortality observed in the simulation. A value of 1.0 indicates the methods produce identical estimates.

Formulation of Bias-Corrected Estimators for a Single Mark-selective Fishery

We adapted Equation 3 of Lawson and Sampson (1996), using similar notation and a new parameter, and define the probability of a marked fish dying in a MSF during time span t:

$$p_M(t) = 1 - \exp(-\lambda \cdot t \cdot \{ (1-\alpha) \cdot [\gamma + (1-\gamma) \cdot \delta] + \alpha \cdot \beta \}) \tag{1}$$

and define the probability of an unmarked fish dying in a MSF during time span t (their Equation 4) as,

$$p_U(t) = 1 - \exp(-\lambda \cdot t \cdot \{ (1-\alpha) \cdot [\delta \cdot \zeta + (1-\zeta)] + \alpha \cdot \beta \}). \tag{2}$$

During a single, discrete time step, if the drop-off rate (α) is 0, the mark-recognition rate (γ) is 100%, and the unmarked-recognition rate (ζ) is 100%, equation 1 simplifies to:

$$p_M = \mu^M = 1 - \exp(-\lambda) \tag{3a}$$

or

$$\exp(-\lambda) = 1 - \mu^M. \tag{3b}$$

p_M is equivalent to an exploitation rate for the marked cohort (μ^M) in the fishery during the time step. If p_M is multiplied by the number of marked fish (M) present at the beginning of the time step (but after natural mortality) it provides an estimate of the number of marked fish encountered by the gear and landed in the MSF.

Similarly, equation 2 simplifies to

$$p_U = 1 - \exp(-\lambda \cdot \delta). \tag{4}$$

Substituting the right side of equation 3b into equation 4 for exp(-λ), the exploitation rate for the unmarked cohort (μ^U) becomes:

$$\mu^U = 1 - (1 - \mu^M)^{\delta}. \tag{5}$$

Equation 5 provides an unbiased estimate of the exploitation rate[2] for an unmarked cohort when the only fishery in the time step is a mark-selective fishery.

A problem arises when there are multiple mark-selective fisheries that have impact on an unmarked cohort during a time step in a single-pool model (i.e., all fisheries occurring during the time step have impact on a cohort simultaneously). The sum of the bias-corrected estimates of unmarked mortalities from each of the individual mark-selective fisheries in the time step will be less than the actual unmarked mortalities that occurred in all MSF in the time step. This is demonstrated in Table 4 which compares the bias-corrected exploitation rates for the unmarked cohort (using equation 5) to the biased calculation ($\tilde{\mu}_i^U$) for two different release-mortality rates over a range of μ_i^M. For example, when there are two mark-selective fisheries in a time step each with μ_i^M = 10% (for a total μ_I^M = 20%) and with δ = 0.14, FRAM calculates $\tilde{\mu}_I^U$ = 2.80% which is twice the biased estimate of $\tilde{\mu}_i^U$ when μ_i^M = 10%. However for the bias-corrected $\hat{\mu}_I^U$, twice the bias-corrected $\hat{\mu}_i^U$ when μ_i^M = 10% (2 · 1.464% = 2.928%) is less than the bias-corrected $\hat{\mu}_I^U$ when μ_I^M = 20% (3.076%). This inequality is described in equation 6. If we assume a constant δ in each MSF:

$$\left[\sum_i \left(1 - \left(1 - \mu_i^M\right)^{\delta}\right)\right] < 1 - \left[1 - (\mu_1^M + \mu_2^M + \ldots \mu_i^M)^{\delta}\right] \tag{6}$$

where μ_i^M is the exploitation rate on the marked cohort in MSF i during the time step. The sum of the individual fishery bias-corrected μ_i^U (the left side of the equation) will always be less than the right side of equation 6 because of the non-linearity resulting from the quantities inside the parentheses being raised to the δ power. Our simulation model duplicates these bias-corrected estimates of $\hat{\mu}_i^U$ and $\hat{\mu}_I^U$ when there is one or more mark-selective fisheries being modeled in the time step but no non-selective fisheries.

Table 4. Relative bias in the estimates of unmarked cohort exploitation rate (μ_i^U) for a range of marked cohort exploitation rates (μ_i^M).

	Release-mortality Rate = 0.14			**Release-mortality Rate = 0.26**		
Marked Cohort μ_i^M	Bias-corrected $\hat{\mu}_i^U$	Biased $\tilde{\mu}_i^U$	Relative Bias[a]	Bias-corrected $\hat{\mu}_i^U$	Biased $\tilde{\mu}_i^U$	Relative Bias[a]
1%	0.141%	0.140%	-0.43%	0.261%	0.260%	-0.37%
5%	0.716%	0.700%	-2.17%	1.325%	1.300%	-1.87%
10%	1.464%	1.400%	-4.39%	2.702%	2.600%	-3.78%
15%	2.250%	2.100%	-6.65%	4.137%	3.900%	-5.74%
20%	3.076%	2.800%	-8.96%	5.637%	5.200%	-7.75%
25%	3.948%	3.500%	-11.34%	7.207%	6.500%	-9.81%
30%	4.871%	4.200%	-13.77%	8.857%	7.800%	-11.93%
40%	6.902%	5.600%	-18.86%	12.437%	10.400%	-16.38%
50%	9.248%	7.000%	-24.31%	16.491%	13.000%	-21.17%
60%	12.039%	8.400%	-30.23%	21.198%	15.600%	-26.41%

[a] Relative bias = ([$\tilde{\mu}_i^U$ – $\hat{\mu}_i^U$] / bias-corrected $\hat{\mu}_i^U$) · 100%.

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[2] The exploitation rate accounts for all sources of fishery-related mortality.

Table 5 defines the variables used in the bias-correction equations developed in the following section of this report. The right side of equation 6 correctly estimates the total exploitation rate on the unmarked cohort for a single-pool model when δ is the same for all MSF in the time step:

$$\hat{\mu}_I^U = 1 - (1 - \textstyle\sum_i \mu_i^M)^{\delta}. \qquad (7)$$

The simulation model verifies this relationship when there are multiple mark-selective fisheries with the same δ being modeled in the time step.

A further complication is introduced when the mark-selective fisheries that have impact on an unmarked cohort during the time step have different release-mortality rates. The question is then, what is the proper δ to use in Equation 7? We calculated a weighted release-mortality rate (δ_w) estimated as:

$$\delta_w = \delta_1 \cdot w_1 + \delta_2 \cdot w_2 + \ldots \delta_i \cdot w_i \qquad (8)$$

where δ_i is the release-mortality rate in mark-selective fishery i and the w_i are the weights for each MSF with the $\Sigma w_i = 1$. The weights in equation 8 are calculated using the proportional contribution of the marked cohort's exploitation rate for mark-selective fishery i to the sum of the individual exploitation rates for the marked cohort in all mark-selective fisheries during the time step:

$$w_i = \frac{\mu_i^M}{\sum_i \mu_i^M}. \qquad (9)$$

The total exploitation rate for the unmarked cohort across all mark-selective fisheries in a time step being modeled can be estimated by substituting δ_W for δ in equation 7.

It is interesting to note that the weighted release mortality rate also can be used in the FRAM calculations. FRAM estimates the total exploitation rate for the unmarked cohort in all mark-selective fisheries during a time step as:

$$\tilde{\mu}_I^U = \sum_i^I \mu_i^M \cdot \delta_i$$

which is equivalent to:

$$\tilde{\mu}_I^U = \delta_W \cdot \textstyle\sum_i^I \mu_i^M. \qquad (10)$$

For management purposes, the estimate of the total number of unmarked mortalities that occurred in all mark-selective fisheries (estimated by $U \cdot \hat{\mu}_I^U$) must be apportioned to each MSF occurring in the modeled time step. One method is to estimate the proportions (π_i) using the proportional contribution of the unmarked cohort's simple (biased) exploitation rate ($\tilde{\mu}_i^U = \mu_i^M \cdot \delta_i$) for a mark-selective fishery to the sum of the individual unmarked cohort simple exploitation rates for all mark-selective fisheries in the time step. This method was confirmed to be appropriate by simulation model results:

$$D_i^U = \left(U \cdot \hat{\mu}_I^U\right) \cdot \pi_i \ \ with \ \ \pi_i = \frac{\mu_i^M \cdot \delta_i}{\sum_i (\mu_i^M \cdot \delta_i)} = \frac{\tilde{\mu}_i^U}{\sum_i \tilde{\mu}_i^U}. \qquad (11)$$

D_i^U is the total number of unmarked mortalities occurring in mark-selective fishery i and the $\Sigma\pi_i = 1$. This is equivalent to the bias-corrected exploitation rate for mark-selective fishery i being:

$$\hat{\mu}_i^U = \hat{\mu}_I^U \cdot \pi_i. \qquad (12)$$

Table 5. Definition of variables used in the bias-correction equations.

Variable	Definition
$\tilde{\mu}_k^U$	Simple, biased estimate of exploitation rate for the unmarked cohort in fishery *k*. Subscripts *i* and *j* are used to differentiate MSF and NSF, respectively.
$\tilde{\mu}_k^M$	Simple, biased estimate of exploitation rate for the marked cohort in fishery *k*. Subscripts *i* and *j* are used to differentiate MSF and NSF, respectively.
$\hat{\mu}_k^U$	Bias-corrected estimate of exploitation rate for the unmarked cohort in fishery *k*. Subscripts *i* and *j* are used to differentiate MSF and NSF, respectively.
$\hat{\mu}_k^M$	Bias-corrected estimate of exploitation rate for the marked cohort in fishery *k*. Subscripts *i* and *j* are used to differentiate MSF and NSF, respectively.
R	Ratio of unmarked fish to marked fish.
w_i	Weight used to calculate a weighted release mortality rate using μ_i^M from each MSF in the time step.
π_i	Proportion of total unmarked fish mortalities in all MSF during a time step that occurred in MSF *i*, calculated using $\tilde{\mu}_i^U$.
D_i^X	Total number of mortalities for unmarked fish (D_i^U), marked fish (D_i^M), or marked and unmarked fish combined (D_i^C) in MSF fishery *i*.
D_j^X	Total number of mortalities for unmarked fish (D_j^U), marked fish (D_j^M), or marked and unmarked fish combined (D_j^C) in NSF fishery *j*.
Z_I^X	Total number of encounters for unmarked fish (Z_I^U) or marked fish (Z_I^M) in all MSF in the time step.

As a final note, observe the effect of increasing δ in Table 4. For a given exploitation rate for the marked cohort, increasing δ decreases the relative bias between the bias-corrected $\hat{\mu}_i^U$ and the simple (biased) $\tilde{\mu}_i^U$. Also note that for a given μ_i^M, when δ is nearly doubled (from 0.14 to 0.26) $\tilde{\mu}_i^U$increases linearly by the same relative amount as δ. However, the increase in the bias-corrected $\hat{\mu}_i^U$ is slightly less than the linear increase in δ for all values of μ_i^M and the relative increase get smaller as μ_i^M increases.

Formulation of Bias-Corrected Estimators for Concurrent Mark-selective and Non-selective Fisheries in the Time Step

A further complication is introduced when there are both mark-selective and non-selective fisheries operating during a modeled time step. Mark-selective fisheries in the time step are removing marked fish at a higher rate than unmarked fish which changes the ratio of unmarked-to-marked fish in the pool of fish being exploited. As the mark-selective fisheries progress the unmarked-to-marked ratio (*R*) increases. When a non-selective fishery operates on this pool of fish more unmarked fish (and fewer marked fish) are being harvested than calculated by FRAM because the initial *R*, upon which FRAM-based estimates of both marked and unmarked mortalities are based, is changing. Specifically, the change in *R* causes the following biases in the FRAM estimates of exploitation rates:

- the FRAM estimate of the exploitation rate for the unmarked cohort in mark-selective fisheries is underestimated,
- the FRAM estimate of the exploitation rate for the unmarked cohort in non-selective fisheries is underestimated, and
- the FRAM estimate of the exploitation rate for the marked cohort in non-selective fisheries is overestimated.

The bias-corrected estimates of unmarked mortalities and the estimated mortalities for the marked fish in the mark-selective fisheries can be used to produce a bias-corrected estimate of the unmarked mortalities in the non-selective fisheries that accounts for the change in *R*. Using the bias-corrected results from the mark-selective fisheries we can approximate the number of unmarked fish encountered for each marked fish encountered in the mark-selective fisheries. For the single-pool model, we then expect this encounter rate of unmarked fish per marked fish to be approximately the same in the non-selective fisheries.

The bias-corrected number of unmarked fish encounters in all mark-selective fisheries (Z_I^U) can be estimated using the bias-corrected estimate of the unmarked exploitation rate (equation 7) and the weighted release mortality rate (equation 8):

$$Z_I^U \approx \frac{U \cdot \hat{\mu}_I^U}{\delta_W}. \tag{13}$$

The number of marked fish encountered (Z_I^M) in the mark-selective fisheries is simply estimated by:

$$Z_I^M = M \cdot \sum_i \mu_i^M \tag{14}$$

(which is also an estimate of the total number of marked fish landed in MSF with the model parameters used). The estimate of the number of unmarked fish encountered for each marked fish encountered in all mark-selective fisheries (R_{MSF}) is:

$$\hat{R}_{MSF} \approx \frac{Z_I^U}{Z_I^M} \approx R \cdot \frac{\hat{\mu}_I^U}{\delta_W \cdot \mu_I^M}. \tag{15}$$

If the harvest targets for the non-selective fisheries are based on a total number of mortalities, i.e., the fishery ends when a specified number of fish (marked and unmarked combined) have been harvested in the fishery, FRAM exploitation rates for both unmarked and marked cohorts are incorrectly estimated. The simple exploitation rates for the marked cohort are biased because the ratio of unmarked-to-marked fish increases throughout the time step (due to the selective removal of marked fish in the mark-selective fisheries) and more of the total fish quota is being filled by unmarked fish than is estimated by FRAM. The total number of mortalities (both unmarked and marked) expected in NSF fishery *j* (D_j^C) is:

$$D_j^U + D_j^M = D_j^C\ . \tag{16}$$

Because no fish are being released in the NSF, we expect the ratio of unmarked-to-marked fish in the landed catch from NSF *j* to be approximately the same, on average, as was estimated from the encounters in all mark-selective fisheries,

$$\frac{D_j^U}{D_j^M} \approx \hat{R}_{MSF}\ . \tag{17}$$

Note that this is an approximation because we are using the bias-corrected estimate of unmarked fish *mortalities* to estimate the number of unmarked fish *encounters*. There is not always a one-to-one correspondence between an unmarked fish mortality and an unmarked fish encounter as some unmarked fish are encountered more than once by the fishery. For example, an unmarked fish could survive its first capture and release, be caught again, and then die on its second release; this would be estimated as a single encounter by Equation 13. Because some unmarked fish are encountered more than once in mark-selective fisheries, $\hat{R}_{MSF}$ is biased and underestimates the true ratio of unmarked-to-marked fish encounters in the pool of fish available to the fishery. This introduces a small amount of bias into the following estimates that only becomes evident at higher rates of exploitation on the marked cohort.

Re-arranging equation 17 to isolate D_j^U and then substituting into equation 16:

$$\left(D_j^M \cdot \hat{R}_{MSF}\right) + D_j^M \approx D_j^C, \quad (18)$$

$$D_j^M \cdot \left(\hat{R}_{MSF} + 1\right) \approx D_j^C, \text{ and}$$

$$\hat{D}_j^M \approx \frac{D_j^C}{\left(\hat{R}_{MSF} + 1\right)}, \text{ which can be expressed as}$$

$$\hat{D}_j^M \approx \frac{(U + M) \cdot \mu_j^M}{\left(\hat{R}_{MSF} + 1\right)}. \quad (19)$$

Given the bias-corrected estimate of marked fish mortalities in NSF *j* (equation 19), then the estimated number of unmarked mortalities in NSF *j* is simply:

$$\hat{D}_j^U \approx \left[(U + M) \cdot \mu_j^M\right] - \hat{D}_j^M. \quad (20)$$

Bias-corrected estimates of exploitation rates for NSF can then be estimated for the unmarked and marked cohorts, respectively, by dividing either $\hat{D}_j^U$ or $\hat{D}_j^M$ by their respective cohort sizes. These bias-corrected estimates for the non-selective fishery account for the bias introduced by the change in the unmarked-to-marked fish ratio in the pool of fish subject to harvest but do not account for the bias resulting from multiple encounters with unmarked fish in the fisheries. This results in $\hat{\mu}_j^U$ being slightly underestimated and $\hat{\mu}_j^M$ being slightly overestimated.

Propagation of Bias

The previous discussion focuses on evaluating the bias in unmarked and marked fish mortalities estimated to occur within a single modeled time step. Coho FRAM is a linear model with five time steps in the modeled year. Initial stock abundances are set prior to the first time step. In subsequent time steps, the ending stock abundance from one time step becomes the input stock abundance for the next time step (after accounting for natural mortality). Therefore, any bias in the estimates of mortalities during one time step is incorporated into the next time step. This results in the bias in each time step accumulating over the model year. To demonstrate this we ran a series of three simulations where the unmarked and marked cohorts remaining after one simulation became the starting cohort sizes for the next simulation. This was done to represent the coho FRAM model for the July, August, and September time steps. The model parameters used in this series of simulations are specified in Table 6. These values were chosen to be representative of those seen in FRAM model use. The initial cohort sizes for the first time step were 200,000 for the unmarked and marked cohorts.

Table 6. Model parameters for the three consecutive time step simulation analysis used to examine the propagation of bias.

Model Parameter	Time Step July	August	September
Natural Mortality	NA	0.020618	0.020618
μ_1^M in Mark-selective Fishery #1	0.060	0.085	0.110
μ_2^M in Mark-selective Fishery #2	0.060	0.085	0.110
δ for Mark-selective Fishery #1	0.14	0.14	0.14
δ for Mark-selective Fishery #2	0.26	0.26	0.26
δ_W =	0.20	0.20	0.20
$\tilde{\mu}_k^U =$	0.024	0.034	0.044
μ_1^M in Non-selective Fishery #1	0.010	0.020	0.030
μ_2^M in Non-selective Fishery #2	0.010	0.020	0.030

Results

Factors Affecting Bias

A number of factors could affect the relative differences between the single-pool estimates produced by FRAM, the bias-corrected estimates, and the simulation results, and some factors may be more influential than others. Four factors that we examined as influencing the relative differences between the methods of estimation are:

- total exploitation rate for the marked cohort in the time step,
- unmarked-to-marked ratio for the initial cohorts being modeled,
- proportional distribution of total exploitation rate between mark-selective and non-selective fisheries, and
- release mortality rates.

Other factors we did not explore in this paper are: drop-off rate and drop-off mortality rate, recognition error rates for unmarked and marked fish, and the possible increase in the release-mortality rate with multiple gear encounters.

In the following sections we compare the FRAM estimates and the proposed bias-corrected estimates of exploitation rates to the simulation results. We use the mean of 25 simulation model runs for the comparisons; therefore, it is important that the variability in the model runs is relatively small to provide a good standard for comparison. We calculated the coefficient of variation (CV) for the mean μ_K^U and μ_K^M to examine this variability. For all the different scenarios we conducted with different exploitation rates, initial *R*, and the distribution of total μ_K^M between MSF and NSF, the CVs for mean μ_K^U and μ_K^M were all less than 1.5%, indicating very little variation in simulation results over 25 model runs. The weighted release-mortality rate (δ_W) for the majority of these runs was 0.22.

Target Exploitation Rate for the Marked Cohort:

The intensity of the fishing pressure on the unmarked and marked cohorts is defined by the total exploitation rate target for the marked cohort. Figure 1 compares the bias-corrected and FRAM estimates of total exploitation rates to the simulation means for the: (A) unmarked cohort across both mark-selective fisheries; (B) unmarked cohort across both non-selective fisheries; and (C) marked cohort across both non-selective fisheries. All three methods produce identical estimates for the marked cohort in the mark-selective fisheries because the harvest of that group determines when each mark-selective fishery ends; therefore, those results are not shown. The results in Figure 1 are for the scenario (#2) when the total exploitation rate for the marked cohort is split equally between the MSF and NSF.

Unmarked cohort in mark-selective fisheries: Both methods underestimate μ_I^U compared to the simulation mean (Figure 1A). However, the bias-corrected estimates correspond so closely to the simulation means at all three initial *R* over the range of target μ_K^M that the differences are not noticeable in the figure. All differences in μ_I^U between the two are within -0.002. In comparison, differences between the FRAM estimates and the simulation means are greater than the bias-corrected differences and increase with target exploitation rate. Initial *R* for these estimates has no effect on the results so only a single line is visible for each method in Figure 1A.

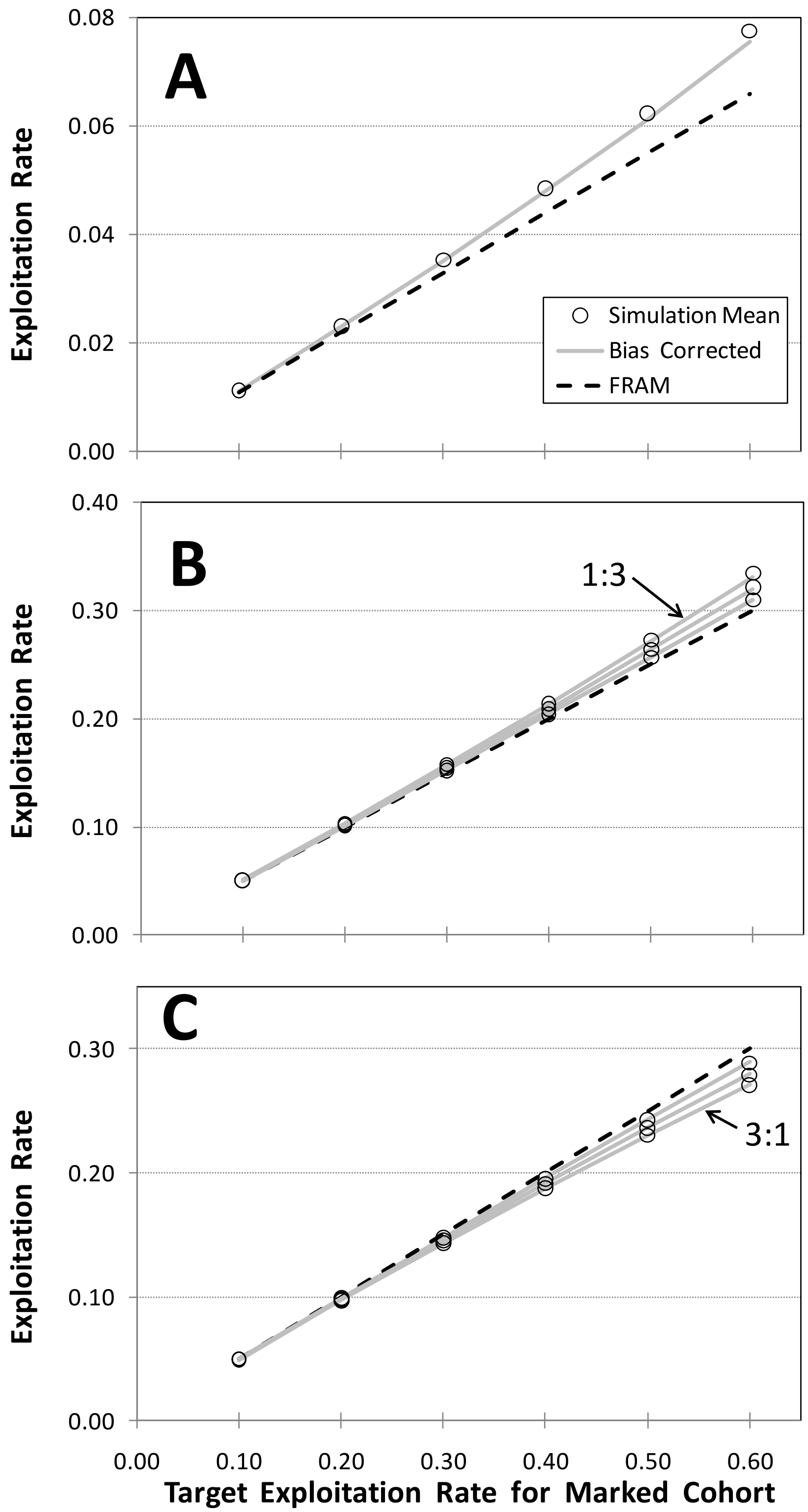

Figure 1. Comparison of bias-corrected and FRAM estimates of exploitation rates to the simulation means for each initial unmarked-to-marked ratio (*R*) for: (A) the unmarked cohort in all mark-selective fisheries, (B) the unmarked cohort in all non-selective fisheries and (C) the marked cohort in all non-selective fisheries. Scenario shown is when there is equal division of the total exploitation rate for the marked cohort between mark-selective and non-selective fisheries (scenario #2).

Unmarked cohort in non-selective fisheries: Both methods underestimate μ_J^U compared to the simulation mean (Figure 1B). FRAM estimates of μ_J^U are not sensitive to *R* (hence the single line for FRAM in Figure 1B), while the simulation and bias-corrected results depend on *R*. Again, the bias-corrected estimates correspond so closely to the simulation means that the differences are not noticeable in the figure. All differences in μ_J^M between the two are within 0.005. Differences between the FRAM estimates and the simulation means are greater than the bias-corrected differences for all values of *R*. Differences between the FRAM estimate of μ_J^U and the simulation mean increase as the unmarked-to-marked ratio decreases.

Marked cohort in non-selective fisheries: FRAM consistently overestimates μ_J^M compared to the simulation mean (Figure 1C). Similarly to the unmarked cohort, FRAM estimates of μ_J^M are not sensitive to *R*, while the simulation and bias-corrected results depend on *R*. The bias-corrected estimates correspond very closely to the simulations at all three initial *R* over the range of target μ_K^M. The bias-corrected estimates correspond so closely to the simulation means that the differences are not noticeable in the figure. All differences in μ_J^M between the two are within 0.001. Differences between the FRAM estimates and the simulation means are greater than the bias-corrected differences for all values of *R*. Differences between the FRAM estimate of $\mu_J^M$and the simulation mean increase as the unmarked-to-marked ratio increases.

Initial Cohort Unmarked-to-Marked Fish Ratio:

As was evident in Figure 1, the effect of initial *R* on estimated exploitation rates is different for the unmarked and marked cohorts and depends on the fishery type, mark-selective or non-selective. Figure 2 compares the ratio of estimated exploitation rates to the simulation means (*Ω*) for the bias-corrected method and FRAM. The results shown are for the simulations with the total exploitation rates equal in the mark-selective and non-selective fisheries (scenario #2). The comparison of methods is not shown for the marked cohort in the mark-selective fisheries since under the model formulation and assumptions the target exploitation rate is always exactly achieved by both methods (i.e., Ω = 1.0). Figure 2A shows that in the mark-selective fisheries, *Ω* for the FRAM estimates does not depend on the initial *R* and the differences from the simulation means range from about 2% at the lowest value of μ_K^M to about 15% when μ_K^M = 0.60. The bias-corrected estimates perform similarly for all three *R*, also, and all *Ω* are > 0.97. However, in the non-selective fisheries (Figures 2B and 2C) *Ωs* for the FRAM estimates are different depending upon *R*. For the unmarked cohort (Figure 2B), the greatest differences occur when *R* = 1:3. Conversely, for the marked cohort (Figure 2C), the greatest differences occur when *R* = 3:1. In the non-selective fisheries, the bias-corrected estimates are relatively constant and only noticeably deviate from 1.0 at the highest levels of μ_K^M (≥ 0.40). The relative bias of the FRAM estimates is greater than the relative bias of the bias-corrected estimates in all comparisons.

Proportional Distribution of Total Exploitation:

Sets of simulations were conducted with three different distributions of the total exploitation rate between mark-selective and non-selective fisheries. Otherwise, each set of simulations explored the same three values for initial *R*, had the same release-mortality rates in the two mark-selective fisheries, and the same total target exploitation rates for the marked cohort. Therefore, a comparison of the distributions of the resulting total exploitation rates for the (A) unmarked cohort in mark-selective fisheries, (B) unmarked

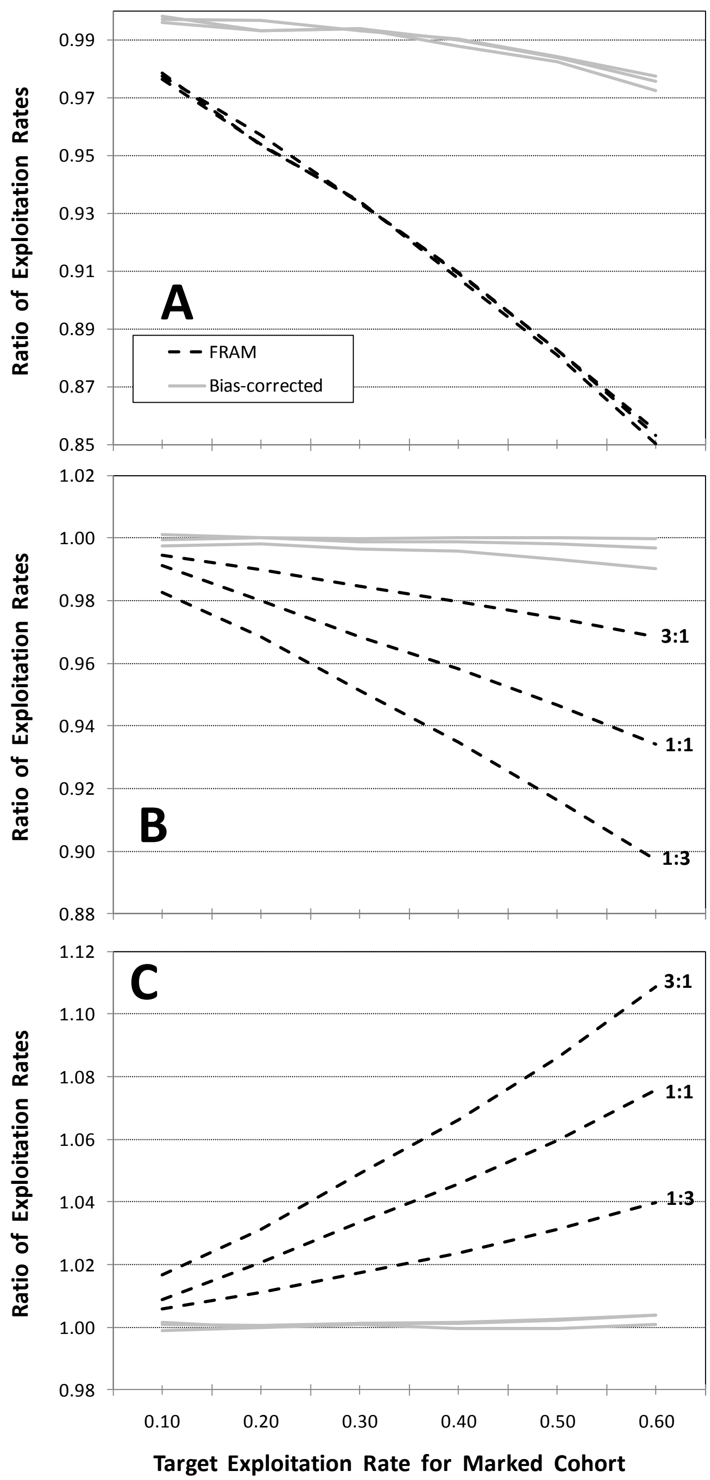

Figure 2. Ratio of exploitation rates (Ω) estimated by the bias-corrected methods and FRAM to simulation mean exploitation rates for: (A) the unmarked cohort in all mark-selective fisheries, (B) the unmarked cohort in all non-selective fisheries and (C) the marked cohort in all non-selective fisheries. Results are shown for the three initial unmarked-to-marked ratios (R) used in the simulations and equal division of the total exploitation rate for the marked cohort between mark-selective and non-selective fisheries (scenario #2).

cohort in non-selective fisheries, and (C) marked cohort in non-selective fisheries, across the complete range of target μ_K^M illustrates the effects of the different proportional distributions of total exploitation between MSF and NSF. Figure 3 uses box-and-whiskers plots to illustrate how bias varies depending upon *R* and the MSF:NSF exploitation rate distribution scenarios. Each box encompasses the central 50% of the six relative bias estimates (one for each target exploitation rate for the marked cohort) for each *R*:scenario combination and shows the median. The full range of the bias is indicated by the whiskers. Note that the scales of the box-and-whiskers plots are different for the FRAM and bias-corrected estimates in each comparison.

Unmarked cohort in mark-selective fisheries: For a given initial *R*, relative bias for the FRAM estimates increases as the proportion of the total exploitation occurring in mark-selective fisheries increases (Figure 3A). Median relative bias increases from about -5% when the majority of the total exploitation on the marked cohort occurs in NSF, to about -7.5% when total exploitation is equally split between MSF and NSF, and is slightly greater than -10% when the majority of the total exploitation on the marked cohort occurs in MSF. Median relative bias for the bias-corrected estimates is not clearly related to the exploitation rate scenario. For the bias-corrected method, median bias is less than -1.5% across all comparisons.

Unmarked cohort in non-selective fisheries: For a given initial *R*, relative bias for the FRAM estimates follows the same pattern as in mark-selective fisheries for the three exploitation rate scenarios. As the proportion of total exploitation of the marked cohort in mark-selective fisheries increases so does the median relative bias. Median relative bias ranges from -1.5% to almost -8%. Relative bias decreases as *R* increases. Median relative bias for the bias-corrected estimates is approximately the same for scenarios #1 and #2. The distribution of relative bias for scenario #3 is consistently more positive than for the other two scenarios. Median bias for the bias-corrected estimates is less than ±0.5% across all comparisons.

Marked cohort in non-selective fisheries: For a given initial *R*, median relative bias for the FRAM estimates increases as the proportion of total exploitation of the marked cohort in mark-selective fisheries increases. Median relative bias ranges from about +1% to +8%. Relative bias increases as *R* increases. Relative bias for the bias-corrected estimates is again similar for scenarios #1 and #2. However, the relative bias for scenario #3 tends to be consistently below the other scenarios. Median bias for the bias-corrected estimates is less than ±0.5% across all comparisons.

Release-Mortality Rates:

Lawson and Sampson (1996) illustrated that the mortality rate of unmarked fish is an increasing function of the apparent harvest rate and the release-mortality rate. Table 4 demonstrates how the bias in the FRAM estimates of the unmarked exploitation rate in mark-selective fisheries ($\tilde{\mu}_I^U$) decreases as the release-mortality rate increases. Our previous illustrations of FRAM bias showed bias relative to the target total exploitation rate for the marked cohort in all fisheries (both MSF and NSF). An alternative illustration of bias is to compare $\tilde{\mu}_I^U$ to the difference between $\tilde{\mu}_I^U$ and the bias-corrected estimate $\hat{\mu}_I^U$ as a function of the release-mortality rate. We calculated $\tilde{\mu}_I^U$ (Equation 10) and $\hat{\mu}_I^U$ (Equation 7) over a range of δ_W and $\sum_i^I \mu_i^M$. The difference ($\tilde{\mu}_I^U$ - $\hat{\mu}_I^U$) was then plotted versus $\tilde{\mu}_I^U$ (Figure 4). Using Figure 4, we can determine the bias-adjustment for the FRAM exploitation rate needed for a given FRAM estimate of the exploitation rate for the unmarked cohort and weighted release-mortality rate.

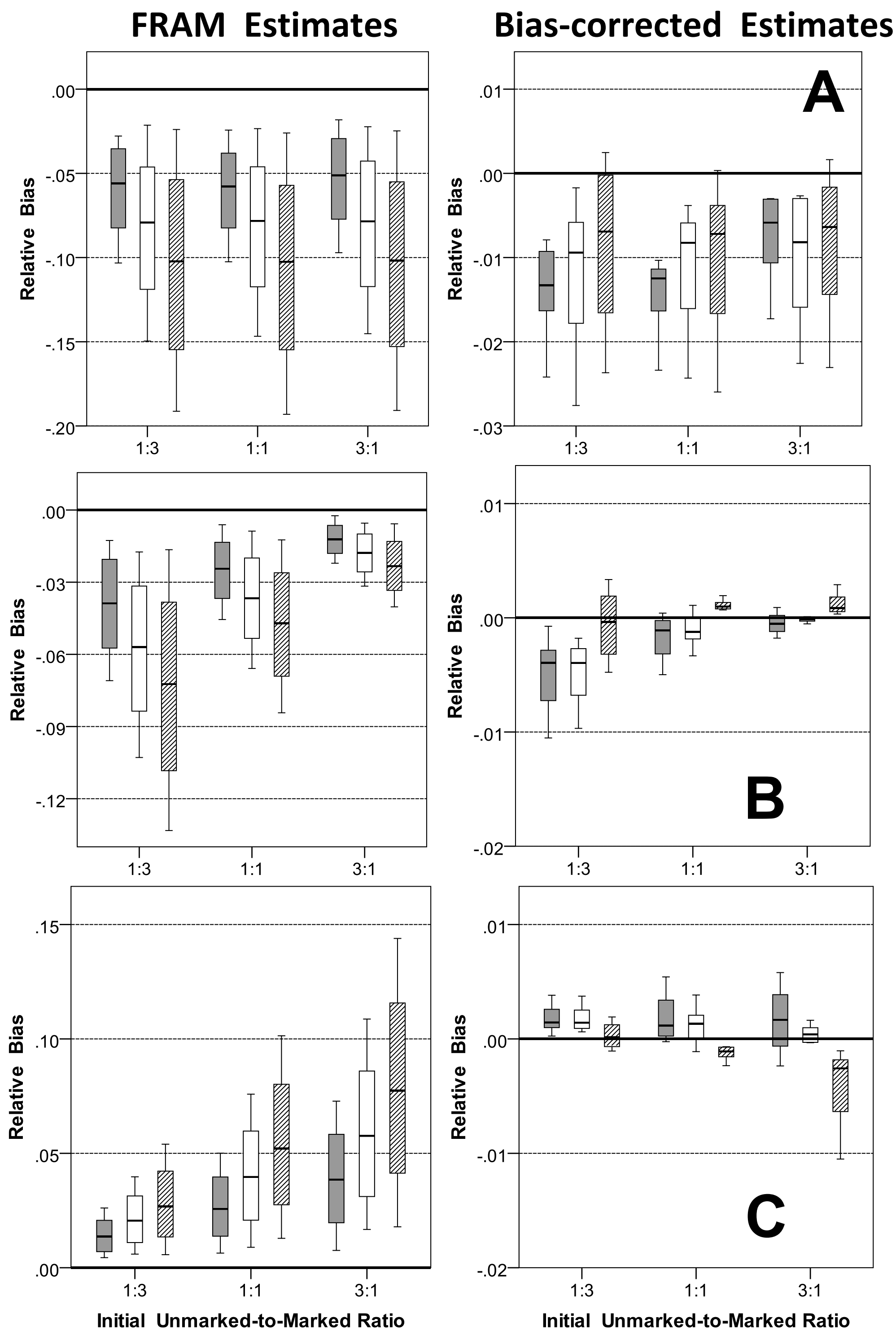

Figure 3. Box-and-whiskers plots comparing the bias of exploitation rates estimated by the FRAM and bias-corrected methods relative to the simulation mean exploitation rates for each exploitation rate distribution scenario [solid box = scenario #1, open box = scenario #2, and striped box = scenario #3] by: (A) the unmarked cohort in all mark-selective fisheries, (B) the unmarked cohort in all non-selective fisheries and (C) the marked cohort in all non-selective fisheries.

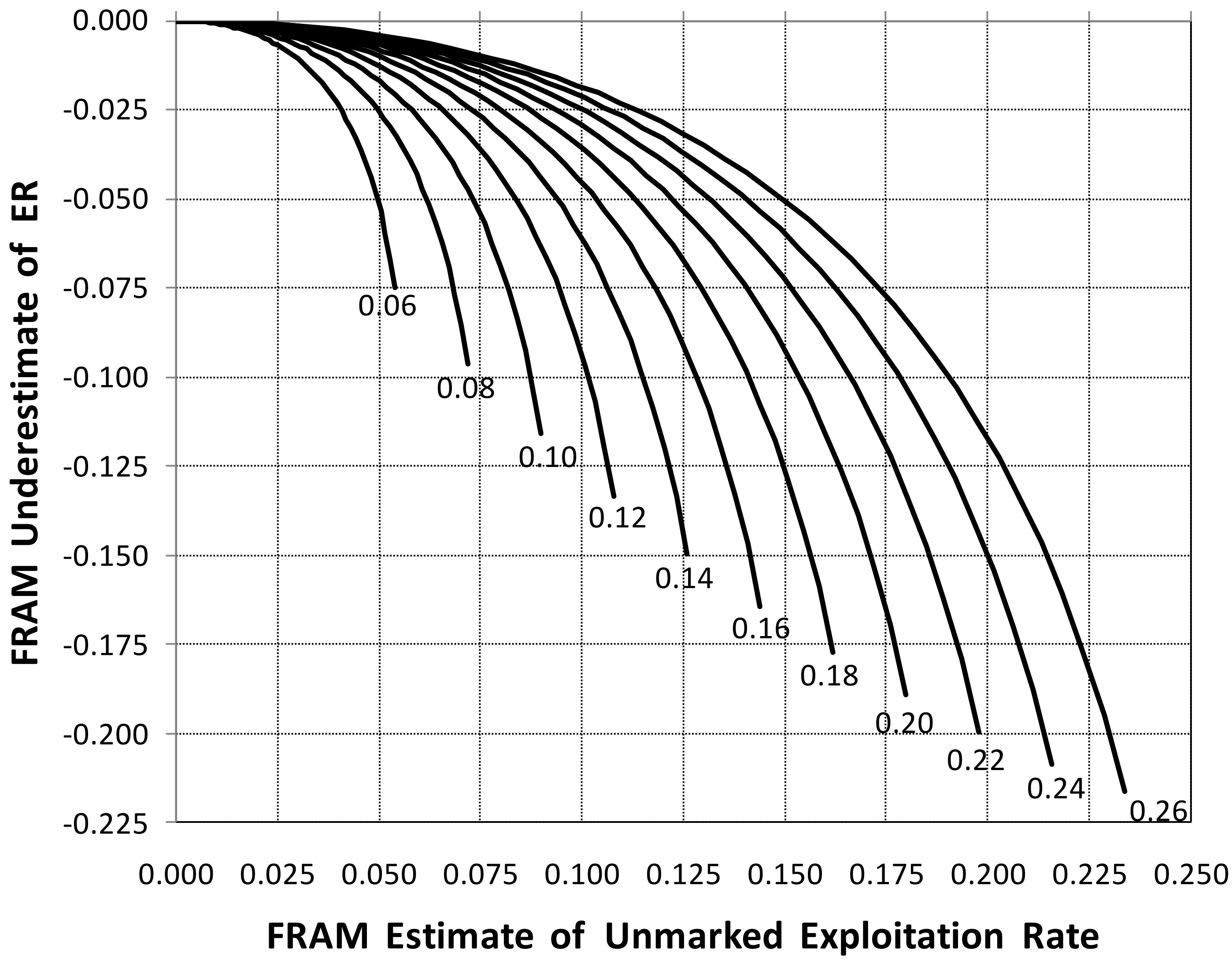

Figure 4. Amount of the FRAM underestimate of the exploitation rate (ER) of the unmarked cohort in mark-selective fisheries for given a FRAM estimate of the exploitation rate of the unmarked cohort across all mark-selective fisheries in a time step; shown for different values of the weighted release-mortality rate (value at the end of each contour).

For example, if the FRAM estimate of exploitation rate for the unmarked cohort in all mark-selective fisheries in a time step is 0.050 (i.e., $\sum_i^I \tilde{\mu}_i^U$ = 0.050) and the weighted release-mortality rate for the mark-selective fisheries is 0.08, then FRAM underestimates the true exploitation rate on the unmarked cohort by about -0.027; the true exploitation rate for the unmarked cohort is about 0.075. Similarly, if the FRAM estimate of exploitation rate for the unmarked cohort in all mark-selective fisheries in a time step is 0.150 and the weighted release-mortality rate for the mark-selective fisheries is 0.26, then FRAM underestimates the true exploitation rate on the unmarked cohort by about -0.05 and the true exploitation rate for the unmarked cohort is about 0.200. The end of each contour in Figure 4 corresponds to an exploitation rate of 0.90 on the marked cohort in the mark-selective fisheries during the time step.

Bias in Concurrent Non-selective Fisheries:

Figures similar to Figure 4 cannot be constructed for the bias in the FRAM estimates of the unmarked and marked exploitation rates in the non-selective fisheries ($\tilde{\mu}_J^U$ and $\tilde{\mu}_J^M$, respectively). This bias is a function of the release-mortality rate (δ_W), total exploitation rate for the marked cohort in concurrent mark-selective fisheries (μ_I^M), total exploitation rate for the marked cohort in the non-selective fisheries (μ_J^M), and the ratio of the starting cohort sizes (R). Figure 5 compares the differences between the FRAM and bias-corrected estimates of the exploitation rate ($\tilde{\mu}_J^U - \hat{\mu}_J^U$) for the unmarked cohort in the non-selective fisheries for two different δ_W (0.14 and 0.26) and for two different initial R (1:1 and 3:1). Figure 6 makes the same comparisons for the marked cohort in the non-selective fisheries.

Figure 5 demonstrates FRAM consistently underestimates the exploitation rate for the unmarked cohort in non-selective fisheries, relative to the bias-corrected estimates, when there are concurrent mark-selective fisheries in the time step and that:

- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the unmarked cohort in non-selective fisheries increases as the exploitation rate of the marked cohort in the non-selective fisheries increases,
- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the unmarked cohort in non-selective fisheries increases as the exploitation rate of the marked cohort in concurrent mark-selective fisheries increases,
- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the unmarked cohort in non-selective fisheries decreases as the release-mortality rate increases, and
- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the unmarked cohort in non-selective fisheries decreases as initial unmarked-to-marked ratio increases.

Figure 6 demonstrates FRAM consistently overestimates the exploitation rate for the marked cohort in non-selective fisheries, relative to the bias-corrected estimates, when there are concurrent mark-selective fisheries in the time step and that:

- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the marked cohort in non-selective fisheries increases as the exploitation rate of the marked cohort in the non-selective fisheries increases,
- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the marked cohort in non-selective fisheries increases as the exploitation rate of the marked cohort in concurrent mark-selective fisheries increases,
- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the marked cohort in non-selective fisheries decreases as the release-mortality rate increases, and
- the difference between the FRAM and bias-corrected estimates of the exploitation rate for the marked cohort in non-selective fisheries increases as initial unmarked-to-marked ratio increases.

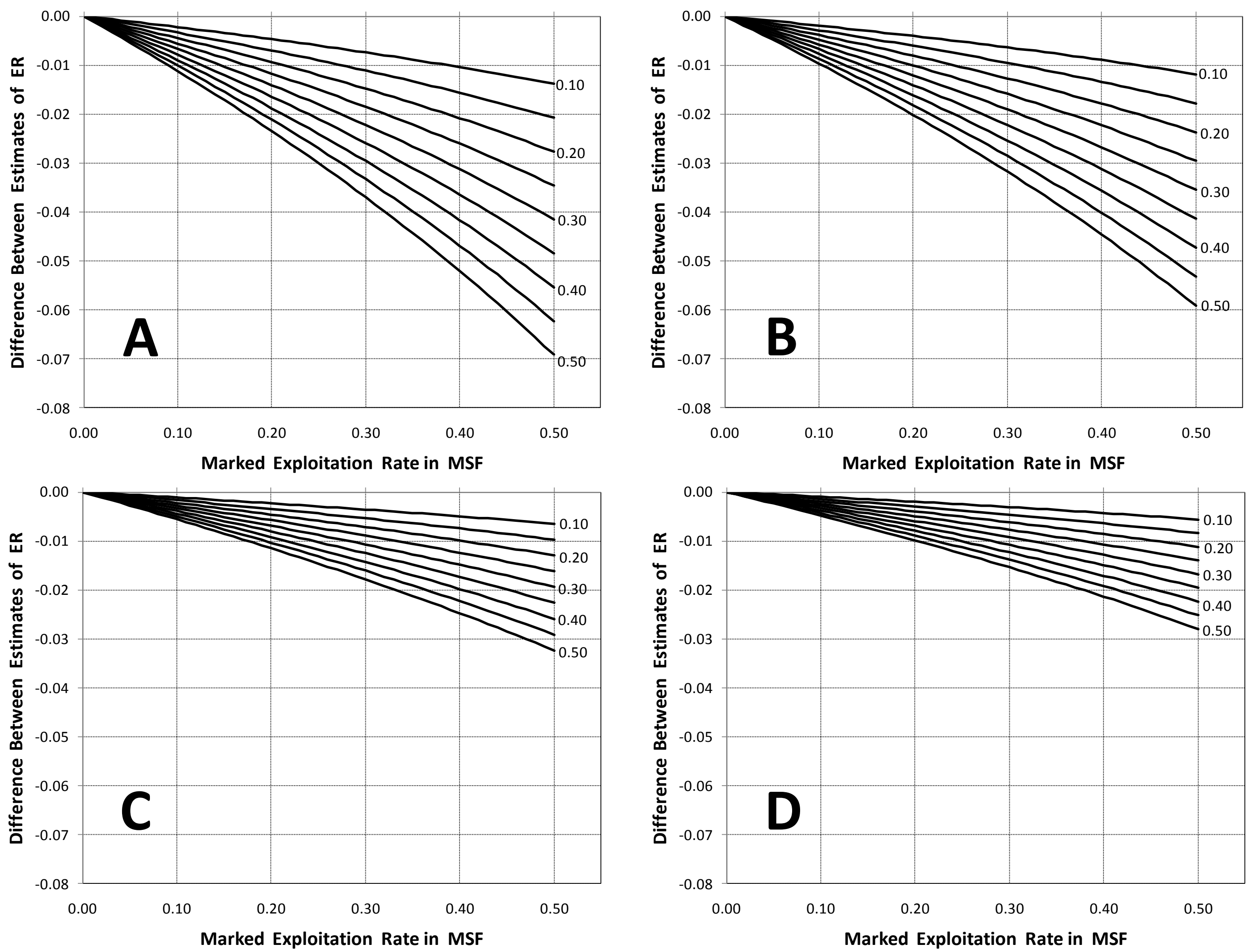

Figure 5. Difference between the FRAM and bias-corrected estimates of the exploitation rate (ER) of the unmarked cohort in non-selective fisheries ($\tilde{\mu}_J^U - \hat{\mu}_J^U$) as a function of the exploitation rate of the marked cohort in concurrent mark-selective fisheries (MSF) and the exploitation rate of the marked cohort in non-selective fisheries (value at the end of each contour). Examples shown are for: (A) R = 1:1 and δ_W = 0.14, (B) R = 1:1 and δ_W = 0.26, (C) R = 3:1 and δ_W = 0.14, and (D) R = 3:1 and δ_W = 0.26.

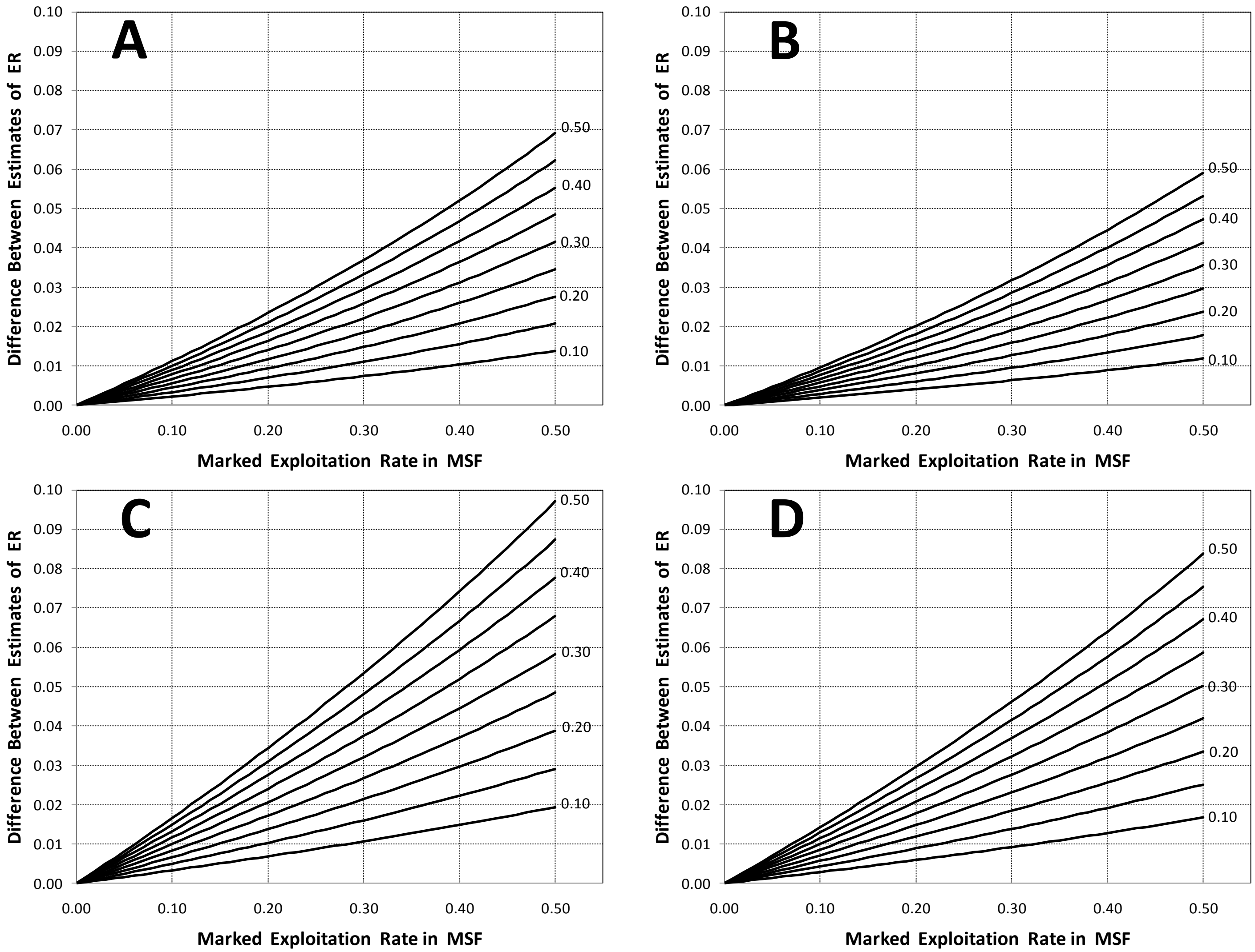

Figure 6. Difference between the FRAM and bias-corrected estimates of the exploitation rate (ER) of the marked cohort in non-selective fisheries ($\tilde{\mu}_J^M - \hat{\mu}_J^M$) as a function of the exploitation rate of the marked cohort in concurrent mark-selective fisheries (MSF) and the exploitation rate of the marked cohort in non-selective fisheries (value at the end of each contour). Examples shown are for: (A) R = 1:1 and δ_W = 0.14, (B) R = 1:1 and δ_W = 0.26, (C) R = 3:1 and δ_W = 0.14, and (D) R = 3:1 and δ_W = 0.26.

Figures 4 and 5 demonstrate that bias in the FRAM estimates of the exploitation rate of the unmarked cohort in concurrent non-selective fisheries is at least as important as the bias in the mark-selective fisheries. Table 7 shows the mean percentage of the total bias in the FRAM estimate of the exploitation rate for the unmarked cohort that can be attributed to mark-selective fisheries (the difference of this percentage from 100% is the percentage that can be attributed to non-selective fisheries). For this analysis, the overall target exploitation rate for the marked cohort across all fisheries (μ_K^M) has very little effect so the mean percentage contribution is shown for each combination of initial *R* and scenario for division of μ_K^M between MSF and NSF. The majority of the bias in the FRAM estimate of the total exploitation rate for the unmarked cohort occurs in the non-selective fisheries in nearly all circumstances. The exception is when *R* = 3:1 and for the scenario where the majority (67%) of the total exploitation rate on the marked cohort occurs in mark-selective fisheries.

Table 7. Proportion of the total bias in the FRAM estimate of the total exploitation rate of the unmarked cohort that occurs in mark-selective fisheries as a function of initial unmarked-to-marked fish ratio and the scenario for the distribution of the total exploitation rate for the marked cohort between mark-selective and non-selective fisheries.

Initial Unmarked-to-Marked Ratio (*R*)	Scenario for Split of Total Exploitation Rate between MSF and NSF		
	#1	#2	#3
1:3	13%	23%	38%
1:1	18%	31%	48%
3:1	31%	48%	66%

Allocation of Unmarked Mortalities between Mark-selective Fisheries

Managers require estimates of the total number of unmarked and marked fish mortalities that occur in each fishery. Equations 11 and 12 propose a method to apportion the bias-corrected estimate of total unmarked mortalities in all mark-selective fisheries during a time step to each MSF and estimate bias-corrected, fishery-specific exploitation rates for the unmarked cohort. In the simulation, the target exploitation rate for the marked cohort in MSF #2 was always twice the target rate in MSF #1. Also, the release mortality rates were always 0.14 for MSF #1 and 0.26 for MSF#2. Figure 7 compares the bias-corrected and FRAM estimates of fishery-specific exploitation rates for the unmarked cohort to the simulation means. The difference from the simulation means is plotted for each method of estimation in each fishery over the range of target total exploitation rates for the marked cohort. The results for this comparison are relatively insensitive to initial *R* so only the results for a initial unmarked-to-marked ratio of 1:1 are shown.

Bias for both methods increases in each fishery as the proportion of the total exploitation rate in MSF increases. This increase is much smaller for the bias-corrected estimates compared to the FRAM estimates. The difference between the bias-corrected estimates and the simulation means is less than the corresponding difference for the FRAM estimates in all comparisons. The difference between the bias-corrected estimates and the simulations means is less than 0.002 in nearly all cases. In comparison, the differences between the FRAM estimates and simulation means are much larger.

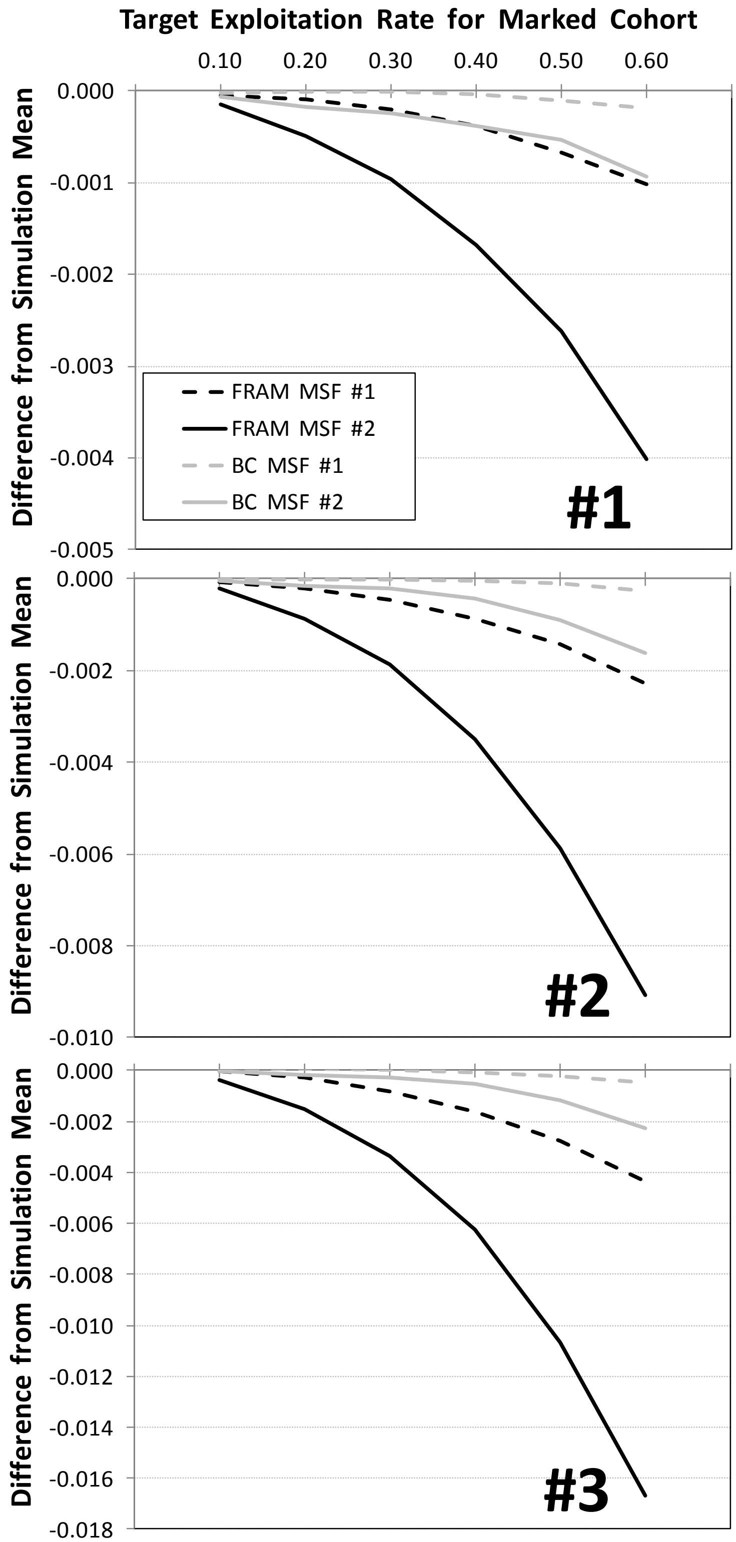

Figure 7. Difference between the FRAM and bias-corrected (BC) methods and the simulation mean estimates of fishery-specific exploitation rates for the unmarked cohort in mark-selective fisheries (MSF) for each different scenario (#1, #2, and #3) for the distribution of total marked exploitation rate between mark-selective and non-selective fisheries (initial *R* = 1:1).

Propagation of Bias

The simulation demonstrating the propagation of bias examined total mortalities across three time steps with the results of one time step used as the inputs to the next step. Figure 8 compares the estimated number of fishery mortalities from each method during each time step for the three major groups of interest: (A) the unmarked cohort in mark-selective fisheries, (B) the unmarked cohort in non-selective fisheries, and (C) the marked cohort in non-selective fisheries. The increase in the bias of the FRAM estimates over time is clearly evident. Compared to the simulations means, relative bias (θ) of the FRAM estimates for the exploitation rate of the unmarked cohort over the three months increases from -3.8% in June to -5.8% in August (Table 8). For the marked cohort, θ for the FRAM estimates of the exploitation rate increases from +0.4% in June to +0.9% in August. For the entire three-month period, θ for the bias-corrected estimates of the total exploitation rate for the unmarked and marked cohorts was ≤ ±0.1%, respectively. In comparison, θ for the FRAM estimates of the total exploitation rate for the unmarked and marked cohorts was -5.1% (μ_K^U was underestimated by 0.011) and +0.7% (μ_K^M was overestimated by 0.003), respectively.

Table 8. Relative bias of the bias-corrected (BC) and FRAM estimates of total exploitation rates for the unmarked and marked cohorts during each time step.

Time		Mark-selective		Non-selective		Total	
Step	Method	Unmarked	Marked	Unmarked	Marked	Unmarked	Marked
July	BC	-0.1%	0.0%	0.1%	-0.1%	0.0%	0.0%
	FRAM	-5.0%	0.0%	-2.4%	2.5%	-3.8%	0.4%
August	BC	-0.2%	0.0%	0.0%	-0.1%	-0.1%	0.0%
	FRAM	-7.1%	-0.1%	-3.1%	3.9%	-5.0%	0.7%
September	BC	-0.3%	0.0%	-0.1%	-0.1%	-0.2%	0.0%
	FRAM	-8.9%	-0.2%	-3.3%	5.3%	-5.8%	0.9%

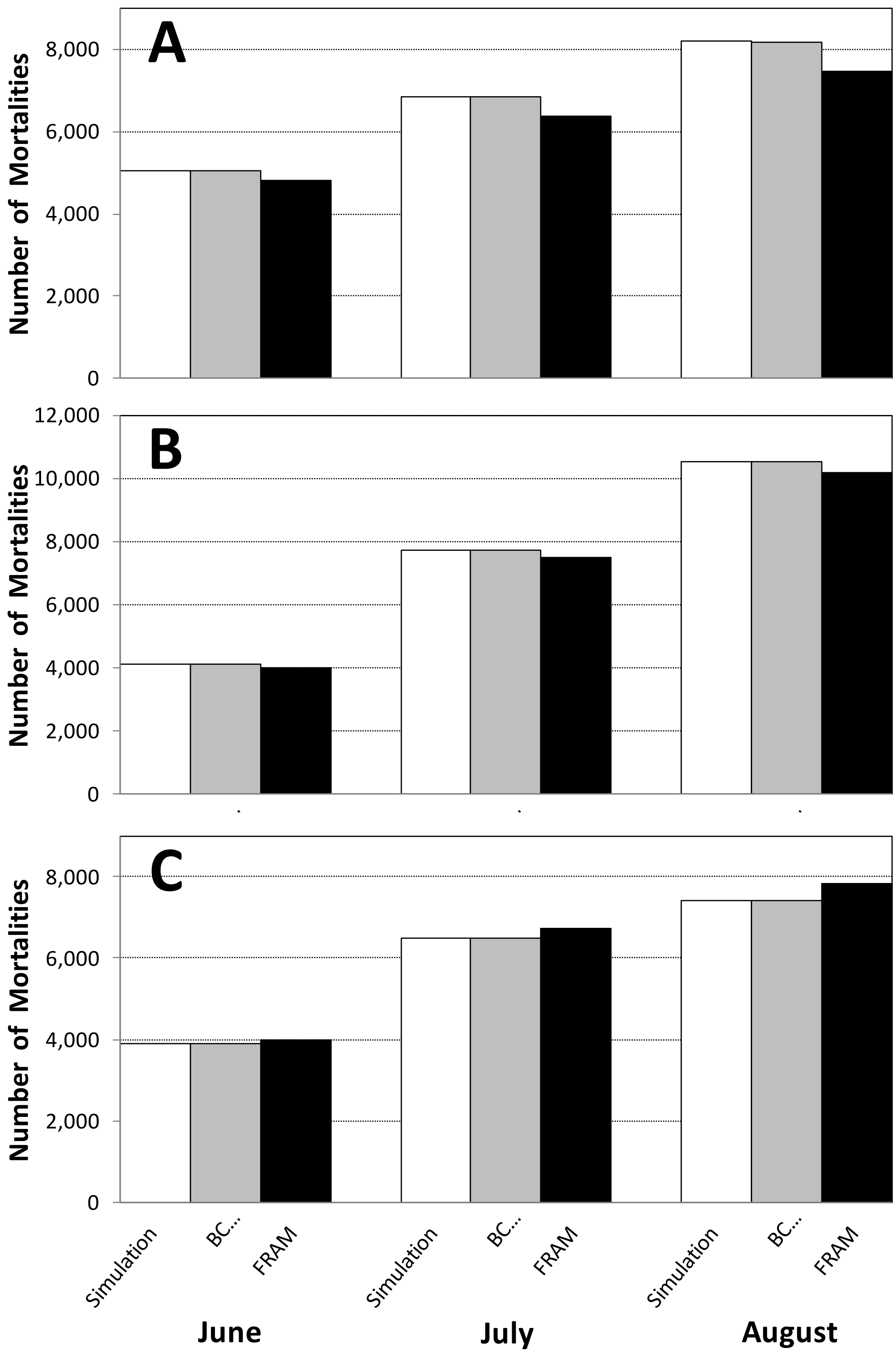

Figure 8. Results from the simulations conducted to illustrate the propagation of bias. Total fishery mortalities for the June, July, and August time steps are shown for: (A) the unmarked cohort in all mark-selective fisheries, (B) the unmarked cohort in all non-selective fisheries and (C) the marked cohort in all non-selective fisheries.

Discussion

The discussion will focus on four issues:

- How well do the bias-corrected methods perform?
- Is the potential bias in the estimates of mortalities and exploitation rates identified in the simulations large enough to be of significance to management?
- How realistic is the single-pool model and what are the alternatives to a single-pool model?
- What is the effect of applying the bias-corrected methods to recent coho FRAM pre-season model runs?

Performance of the Bias-corrected Methods

Most of the bias in the FRAM estimates of unmarked and marked fish mortalities is due to FRAM being unable to capture the change in the unmarked-to-marked fish ratio (*R*) caused by mark-selective fisheries during a time step. Figure 9 compares the projected unmarked-to-marked fish ratio at the end of the time step for the bias-corrected method and FRAM to the simulation means.

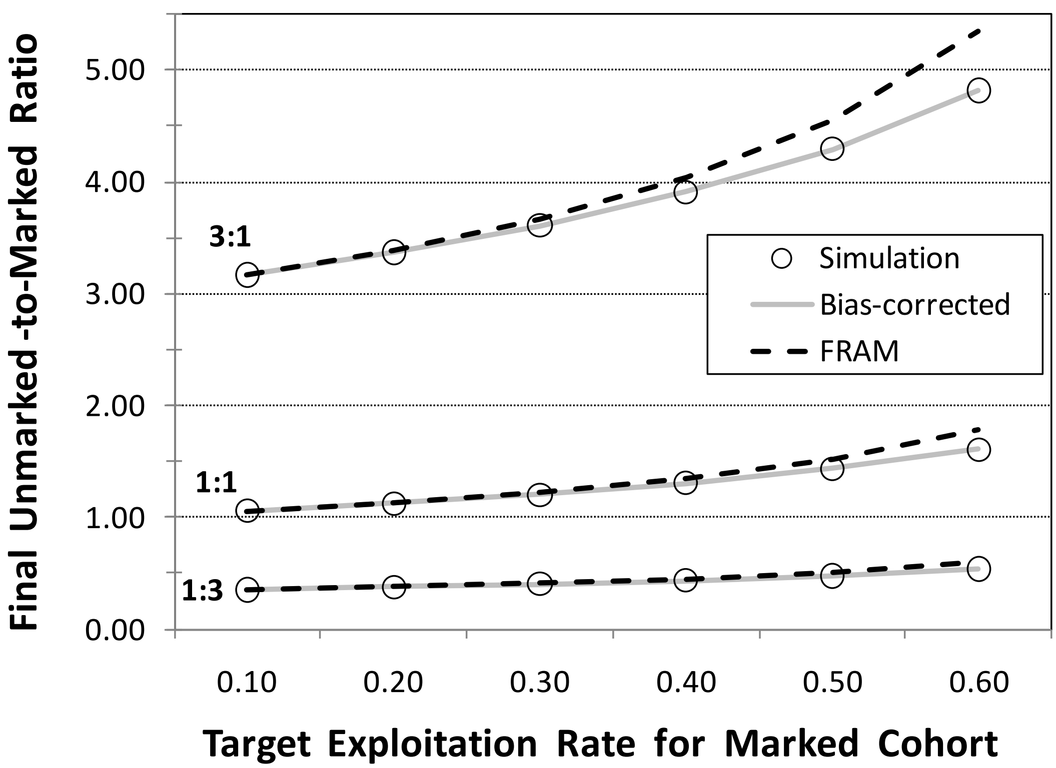

Figure 9. Final (end of time step) ratio of unmarked-to-marked cohort sizes estimated by the bias-corrected method and FRAM compared to simulation means. Results are shown for the three initial unmarked-to-marked ratios (*R*) used in the simulations and 67% of total exploitation rate for the marked cohort in mark-selective fisheries (scenario #3).

Both methods tended to consistently underestimate the exploitation rate on the unmarked cohort thus overestimating the number of unmarked fish alive at the end of any time step. The proposed bias-corrected methods were very similar to the simulation means over the range of initial unmark-to-marked fish ratios, target exploitation rates for the marked cohort, and scenarios for distribution of the exploitation rate for the marked cohort between mark-selective and non-selective fisheries. The bias-corrected estimates of exploitation rates always had less bias than the FRAM estimates for the: (1) unmarked cohort in mark-selective fisheries; (2) unmarked cohort in non-selective fisheries; and (3) marked cohort in non-selective fisheries. In all cases, the bias-corrected estimates were within ±0.005 of the simulation exploitation rate. Although the bias-corrected estimates tended to slightly underestimate the total exploitation rate for the unmarked cohort, this negative bias was very small (≤ -0.003 for exploitation rate targets for the marked cohort less than 0.60). In comparison, the bias in the FRAM estimates was consistently greater than 0.003 except when the target exploitation rate was ≤0.20 and, at target exploitation rates ≥0.30, commonly exceeded 0.010.

For the marked cohort in non-selective fisheries, the bias-corrected methods both underestimated and overestimated the total exploitation rate depending on the scenario and initial *R* (Figure 3C). The differences in total exploitation rate from the simulation means ranged from -0.002 to 0.002. FRAM consistently over-estimated the total exploitation rate for the marked cohort. The differences from the simulation means for the FRAM estimates of the total exploitation rate ranged from <0.005 to 0.029.

Management Significance of Potential Bias

As an example of the size of the bias that might be present in the coho FRAM estimates of exploitation rates for the unmarked and marked cohorts, we use the results from the simulations with an initial *R* of 1:1 and scenario #3 for the distribution of the total exploitation rate for the marked cohort between MSF and NSF (total exploitation rate in MSF = two times the total exploitation rate in NSF). This series of simulation runs encompasses the range of FRAM values that has occurred in recent FRAM model runs. Figure 10 summarizes the differences between the bias-corrected and FRAM estimates of total exploitation rates and the simulation means for the unmarked and marked cohorts. FRAM underestimates the total exploitation rate for the unmarked cohort by less than 0.001 up to nearly 0.040. In comparison, the differences for the bias-corrected estimates range from less than 0.001 to about 0.002. For the marked cohort, FRAM overestimates the total exploitation rate by less than 0.001 up to 0.018. In comparison, the differences for the bias-corrected estimates are all less than 0.001. Although the estimated bias may not seem significant in the lower end of the range (less than 0.01), in the annual management process seasons are being structured to obtain total exploitation rates on specific stocks of concern (e.g., stocks listed under the Federal Endangered Species Act [ESA] and stocks with international treaty obligations) with the total exploitation rate targeted to the tenth of a percent (0.001 for the total exploitation rate). Table 9 presents some examples of these total exploitation rate targets. Commonly, fisheries are structured until the exploitation rate limit on the weakest stock is matched by FRAM estimates. The bias in the FRAM estimates, in most cases, potentially exceeds this level of assumed precision.

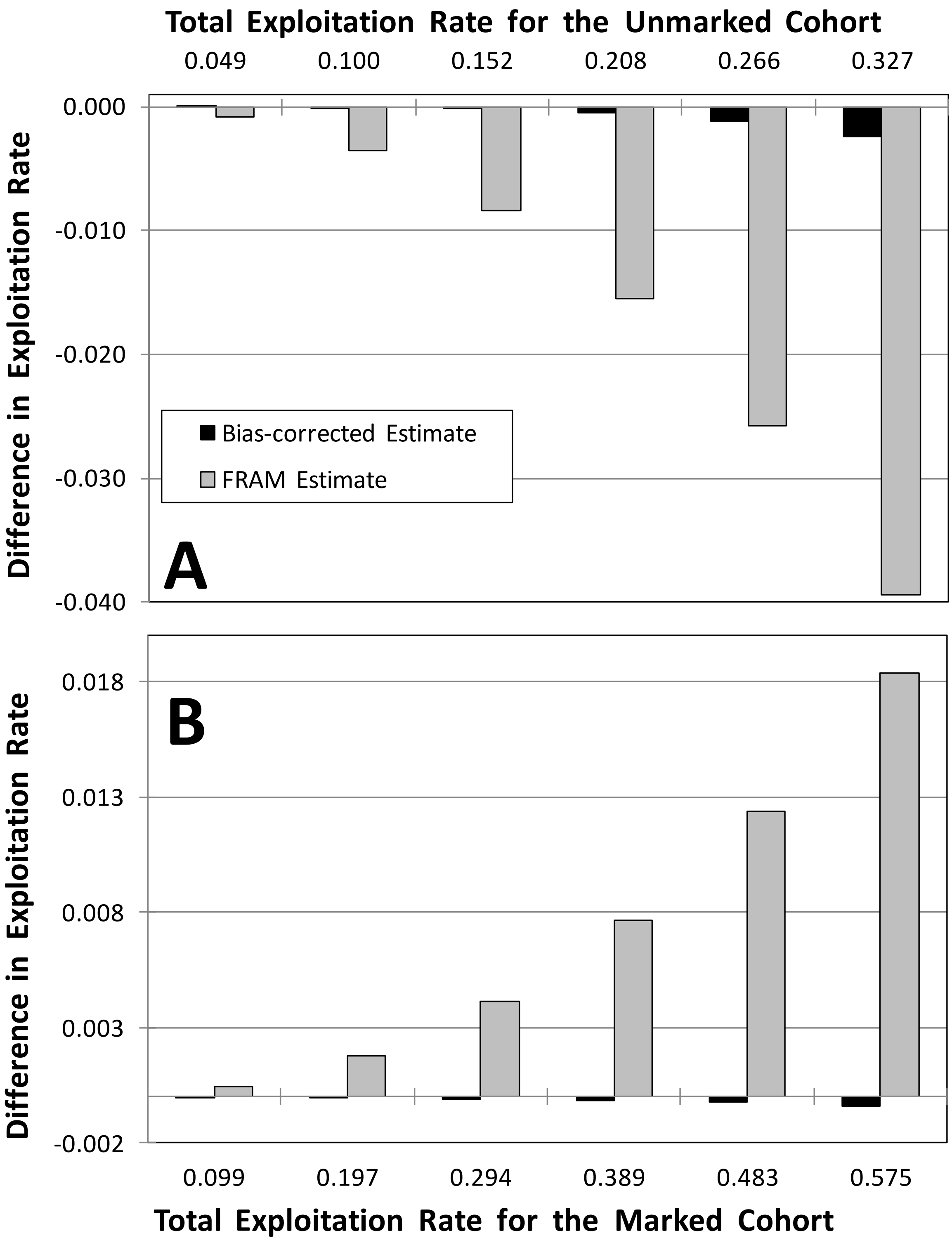

Figure 10. Difference between the FRAM and bias-corrected estimates of total exploitation rates and the simulation means for the (A) unmarked and (B) marked cohorts. Results are shown for an initial unmarked-to-marked ratio (R) of 1:1 and 67% of the total exploitation rate for the marked cohort in mark-selective fisheries (scenario #3).

Table 9. Examples of exploitation rate limits for coho salmon stocks included in the FRAM.

Stock Group	Exploitation Rate Limit	Comment
Rogue | Klamath Hatchery	0.130	Listed as endangered under the Federal Endangered Species Act (ESA).
Lower Columbia R. Natural	0.150 (2006) 0.200 (2007) 0.080 (2008) 0.200 (2009) 0.150 (2010)	Listed as endangered under the Oregon state ESA and threatened under the Federal ESA, the allowable exploitation rate for this stock in ocean and mainstem Columbia R. fisheries has varied annually.
Thompson R. (Canada)	0.100	Under the Pacific Salmon Treaty Coho Agreement this is the exploitation rate allowed in US fisheries south of the US|Canada border.

Assessment of the Single-pool Model and Alternatives

The major assumptions of the single-pool model and its limitations are briefly discussed in PFMC (2008a). Our analysis does not evaluate those assumptions that are related to the accuracy of the FRAM estimates of fishery- and stock-specific stock exploitation rates derived from CWT data, assumed natural mortality rates, and whether a stock's current ocean distribution and migration pattern are accurately represented by averages from a historic base period.

Similarly to FRAM, the bias-corrected estimates of exploitation rates still rely on the assumptions that:

- all fish from stocks modeled in a time step are randomly mixed,
- all fisheries modeled in the time step are fishing on this common pool of mixed fish, and
- an unmarked fish that is released in a MSF and survives is immediately available for harvest in the same fishery or another fishery in the time step.

The bias-corrected methods proposed specifically address the "instantaneous" catch assumption of the coho FRAM. That is, the proposed methods address the assumptions that: (1) all catch during a time step occurs simultaneously on a pool of fish with a <u>fixed</u> unmarked-to-marked fish ratio that does not change during the time step and (2) unmarked fish that are released in a mark-selective fishery and survive are not encountered again during the same time step. The bias-corrected methods account for the increase in the unmarked-to-marked fish ratio that occurs when there are mark-selective fisheries that operate during a time step and for multiple encounters in mark-selective fisheries (but not non-selective fisheries).

The assumption that all fish in the pool are randomly mixed and being simultaneously fished upon by all fisheries represented in the modeled time step is a challenging assumption for both the FRAM and bias-corrected methods. In some modeled time steps, FRAM estimates that stocks are being simultaneously harvested by fisheries off the coast of British Columbia, off the Washington coast, and in Puget Sound. To assume that a stock group is randomly mixed throughout this broad geographic area is unrealistic.

However, no practical alternatives to the single-pool model structure have been found. Zhou (2004) proposed a "pipeline" migration model that passes each stock sequentially through a series of fisheries, i.e., a stock is subject to only a single fishery at a time. He describes methods for estimating unmarked and marked fishery mortalities that capture the change in the unmarked-to-marked fish ratio that occurs in each mark-selective fishery that impacts a stock. However, Zhou's model is based on the assumption that each mark-selective fishery is short enough in time to maintain a constant R and it assumes there are no multiple encounters in the fishery. At lower fishery-specific exploitation rates (≤0.20) this may be a reasonable assumption. This paper shows that at higher rates of exploitation (>0.30) significant bias may be introduced when this assumption is violated. In addition, it would be very difficult to parameterize this model with currently existing data.

Effect of Applying Bias-corrected Methods to Recent Coho FRAM Pre-season Model Runs

Using the estimated exploitation rates from Coho FRAM for the unmarked and marked cohorts in mark-selective and non-selective fisheries by time step, presented in Tables 1 and 2, we can apply the bias-corrected methods and examine the differences in the estimates. However, as was noted in the Introduction, the FRAM estimated exploitation rates include fishery-specific adjustments for mark-recognition error in mark-selective fisheries, drop-off mortality calculations, and catch non-retention (CNR) mortalities. It is not clear how these adjustments affect the bias-corrected methods for estimating exploitation rates. Therefore, this is more of an exercise to examine potential bias than a true assessment of bias.

The parameters needed in addition to the FRAM exploitation rate estimates are:

- R, the unmarked-to-marked fish ratio at the beginning of the time step (after natural mortality) which can be obtained from the "PopStat" report,
- δ_W, the weighted release mortality rate which can be approximated using $\hat{\mu}_I^U$ and μ_I^M and re-arranging Equation 10,
- $\hat{R}_{MSF}$, the average unmarked-to-marked fish ratio for the pool of fish during the time step which can be estimated using Equation 15, and
- U and M, the final unmarked and marked cohort sizes which can also be obtained from the "PopStat" report.

Tables 10 and 11 present a comparison of the FRAM estimates of exploitation rates and the bias-corrected estimates for each time step and across all time steps. What is immediately apparent is that the majority of the bias in the estimate of the exploitation rate for the unmarked cohort is attributable to the bias occurring in the non-selective fisheries. This bias occurs because FRAM uses the initial unmarked-to-marked fish ratio in each time step to estimate the number of unmarked and marked fish mortalities in non-selective fisheries. Because concurrent mark-selective fisheries in the time step are causing this ratio to increase, more unmarked fish mortalities occur than estimated by FRAM. The end result is that in 2009 the difference between the FRAM estimate of the total exploitation rate for the unmarked cohort and the bias-corrected estimate was -0.041 with -0.037 of the difference occurring in non-selective fisheries. In 2010, the difference between the FRAM estimate of the total exploitation rate for the unmarked cohort and the bias-corrected estimate was -0.101 with -0.100 of the difference occurring in non-selective fisheries. It is important to remember that this total difference needs to be apportioned among all stocks in the model and that it will not be equally divided among the stocks because of differences in the relative exploitation rates in the modeled fisheries during the base period.

Table 10. Bias-correction methods applied to coho FRAM final pre-season model run for 2009 with comparison to FRAM estimates for the exploitation rates of the unmarked and marked cohorts in mark-selective (MSF) and non-selective (NSF) fisheries. Shaded boxes indicate values with no expected bias.

Time Step	Fishery Type	FRAM Estimates Cohort Unmarked	FRAM Estimates Cohort Marked	Bias-correction Parameters R	Bias-correction Parameters δ_W	Bias-correction Parameters $\hat{R}_{MSF}$	Bias-Corrected Estimates Unmarked	Bias-Corrected Estimates Marked	Difference Between Estimates Unmarked	Difference Between Estimates Marked
1	**MSF**	0.001	0.009	0.528	0.141		0.001	0.009	0.000	
	NSF	0.002	0.002			0.531	0.002	0.002	0.000	0.000
2	**MSF**	0.016	0.102	0.532	0.155		0.017	0.102	-0.001	
	NSF	0.012	0.009			0.557	0.009	0.009	0.003	0.000
3	**MSF**	0.025	0.139	0.580	0.183		0.027	0.139	-0.002	
	NSF	0.019	0.014			0.616	0.015	0.013	0.003	0.001
4	**MSF**	0.026	0.119	0.667	0.217		0.027	0.119	-0.001	
	NSF	0.091	0.076			0.701	0.091	0.068	0.000	0.008
5	**MSF**	0.000	0.000	0.795	0.392		0.000	0.000	0.000	
	NSF	0.275	0.247			0.795	0.319	0.209	-0.043	0.038
All	**MSF**	0.068	0.369				0.072	0.369	-0.004	
	NSF	0.399	0.348				0.437	0.301	-0.037	0.046
Grand Total		0.468	0.717				0.509	0.670	-0.041	0.046

Table 11. Bias-correction methods applied to coho FRAM final pre-season model run for 2010 with comparison to FRAM estimates for the exploitation rates of the unmarked and marked cohorts in mark-selective (MSF) and non-selective (NSF) fisheries. Shaded boxes indicate values with no expected bias.

Time Step	Fishery Type	FRAM Estimates Cohort Unmarked	FRAM Estimates Cohort Marked	Bias-correction Parameters R	Bias-correction Parameters δ_W	Bias-correction Parameters $\hat{R}_{MSF}$	Bias-Corrected Estimates Unmarked	Bias-Corrected Estimates Marked	Difference Between Estimates Unmarked	Difference Between Estimates Marked
1	MSF	0.001	0.005	0.820	0.119		0.001	0.005	0.000	
	NSF	0.008	0.010			0.822	0.010	0.010	-0.002	0.000
2	MSF	0.007	0.054	0.825	0.138		0.008	0.054	0.000	
	NSF	0.013	0.013			0.845	0.013	0.013	-0.001	0.000
3	MSF	0.014	0.093	0.865	0.151		0.015	0.093	-0.001	
	NSF	0.020	0.020			0.901	0.021	0.019	-0.001	0.001
4	MSF	0.016	0.051	0.949	0.323		0.017	0.051	0.000	
	NSF	0.121	0.135			0.966	0.148	0.125	-0.028	0.010
5	MSF	0.000	0.000	1.052	0.154		0.000	0.000	0.000	
	NSF	0.252	0.281			1.052	0.321	0.248	-0.069	0.033
All	MSF	0.039	0.203				0.040	0.203	-0.001	
	NSF	0.413	0.458				0.513	0.414	-0.100	0.044
Grand Total		0.451	0.662				0.553	0.617	-0.101	0.044

Conclusions

The bias-corrected estimates of exploitation rates correspond very closely to the simulation results in all situations examined except under the highest levels of exploitation (≥0.50) and even then the differences between the two are relatively small compared to FRAM estimates. When operating under the single-pool framework, the proposed bias-correction methods offer improved estimates of unmarked fish mortalities in both mark-selective and non-selective fisheries and marked fish mortalities in non-selective fisheries relative to the current FRAM algorithms.

Recommendations

1. Coho FRAM runs that duplicate the 2009 and 2010 FRAM pre-season runs, but have adjustments (marked recognition error, unmarked retention error, drop-off-mortality, and non-retention mortality) zeroed out, should be run for comparison to the standard runs to examine the effect of these adjustments to the estimated exploitation rates on the unmarked and marked cohorts. The proposed bias-corrections could then be more appropriately applied to these FRAM results and compared with the results in this report.
2. Further examination of the propagation of bias issue should be conducted, possibly using the FRAM runs proposed above.
3. Implementation of the proposed-bias correction methods into the Coho FRAM model should be explored. This could involve some restructuring of the current FRAM model. For example, to address the assumption that stocks are randomly mixed throughout the fisheries operating in a time step, the FRAM analysis could operate on blocks of stocks from similar geographic regions that are mainly impacted by fisheries in those regions. For example, conduct bias-correction methods separately for all Canadian and Alaskan stocks, all Washington and Columbia River stocks, and all Oregon coast and California stocks.
4. The reasons for the decreased performance of the bias-corrected methods at higher levels of exploitation are not clear. This should be further investigated.

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Agenda Item F.5.a
Attachment 3
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Forecast Models for Oregon Coastal Natural Coho Salmon (*Oncorhynchus kisutch*) Adult Recruitment

SUMMARY REPORT

29 September 2010

DAVID E. RUPP[1]
PETER W. LAWSON[2]
THOMAS C. WAINWRIGHT[2]
WILLIAM T. PETERSON[2]

[1]*Cooperative Institute for Marine Resources Studies, Hatfield Marine Science Center, Oregon State University, Newport, OR 97365, USA*
[2]*NOAA/NMFS, Northwest Fisheries Science Center, Hatfield Marine Science Center, Newport, OR 97365, USA*

ABSTRACT

Generalized additive models (GAMs) were used to investigate the relationships between annual recruitment of Oregon coastal natural coho salmon (*Oncorhynchus kisutch*) and indices of physical ocean environment conditions. Nine indices were examined, ranging from indices of large-scale ocean patterns (e.g., Pacific Decadal Oscillation (PDO)) to local ecosystem variables (e.g., coastal water temperature near Charleston, OR). GAMs with 2 and 3 predictor variables were evaluated using a set of performance metrics aimed at quantifying the models' skill at making short-lead (~1 year) forecasts. It was found that high explanatory power and promising forecast skill could be achieved when the spring/summer PDO averaged over the 4-years prior to the return year was used to explain the low-frequency (multi-year) pattern in recruitment while a second (or second and third) variable was used to account for year-to-year deviations from the low-frequency pattern. When averaging the predictions from a set of models (i.e., taking the ensemble mean) a higher skill (in terms of variance explained or a cross-validation score) was achieved than by selecting any single model. Making multiple forecasts from a set of models also provides a range of possible outcomes that reflects, to some degree, the uncertainty we have in our understanding of how salmon productivity is driven by physical ocean conditions.

INTRODUCTION

Past methods for forecasting adult recruitment of Oregon Coastal Natural (OCN) coho salmon have performed, overall, poorly during the previous decade. The last 10 years has seen a dramatic reversal in an approximately 25-year decline in recruitment, followed by yet another decline to previous lows in but 5 years, with the last 2 years showing once again a return to moderately-high abundances (see Fig. 1a). A consequence is that this apparent change in the recruitment pattern has invalidated, or weakened, the empirical relationships that make up the past forecast models.

In order to arrive at an improved forecasting method, we examined a suite of potential predictor variables that includes indices of both large-scale ocean conditions (Multi-variate ENSO index, North Pacific Gyre Oscillation index, North Pacific index, Ocean Niño index, and Pacific Decadal Oscillation index) and local ocean conditions (upwelling wind strength, upwelling spring transition, sea surface temperature and sea surface height). We built generalized additive models (GAMs) using various combinations of indices and evaluated the models in terms of their skill at making forecasts. We chose GAMs because they have the powerful attribute of not imposing *a priori* a given functional relationship between the predictor(s) and the predictand. GAMs have been used previously to explore relationships between environmental variables and marine survival of Oregon Production Index (OPI) hatchery coho (Logerwell *et al*., 2003) and freshwater survival of OCN coho (Lawson *et al*., 2004).

METHODOLOGY

Data

The OCN coho salmon stock is naturally produced in rivers and lakes along the Oregon coast south of the Columbia River. This stock aggregate is a component of the greater OPI area coho stock, which also includes hatchery and natural coho from the Columbia River and hatchery coho from the Oregon coast (though coastal hatchery coho have historically been a minor component of the OPI and are currently inconsequential).

Annual time series of aggregate OCN coho adult recruitment for the period 1970 – 2009 from Oregon coastal rivers (OCNR) and lakes (OCNL) were generated from spawner escapement estimates (Oregon Department of Fish and Wildlife) and fishery exploitation rates (Chapter 3 in Pacific Fishery Management Council, 2010). The river and lake data were kept separate because it is believed that population dynamics differ markedly between river and lake runs (Lawson *et al*., 2004). This report focuses exclusively on the river (OCNR) estimates.

We tested 9 ocean environment indices and parent spawner abundance as predictor variables for ONCR recruitment. The 9 indices are listed in Table 1. A description of each index and a more detailed rationale behind their selection is given in the full report. In general, these indices were chosen because previous studies have found them to be correlated to survival and recruitment of salmon in the Pacific Northwest (PNW).

Three-month running means were calculated for each environmental variable with the exception of MEI which was left as a 2-month running mean (the condition in which it was obtained). The following format was used to label each environmental variable: **VVV.MMM,** where VVV is the 3-character abbreviation of the environmental variable, and MMM are the months over which the mean of variable is calculated.

Table 1. Potential predictor variables

Predictor variable	Short name	Hypothesis
Multivariate ENSO Index	MEI	High value -> low recruitment
North Pacific Gyre Oscillation	NPGO	High value -> high recruitment
North Pacific Index	NPI	High value -> high recruitment
Ocean El Niño Index	ONI	High value -> low recruitment
Pacific Decadal Oscillation	PDO	High value -> low recruitment
Day of Spring Transition of Upwelling Period	SPR	High value -> low recruitment
Sea Surface Height at Newport, OR	SSH	High value -> low recruitment
Sea Surface Temperatures near Charleston, OR	SST	High value -> low recruitment
Coastal Upwelling Index (45^o N)	UWI	High value -> high recruitment
Parent Spawner Abundance	$N_{spawners}$	High value -> high recruitment

General Additive Models (GAMs)

We used generalized additive models (GAMs) to build relationships between environment indices and OCNR recruitment. A GAM with, for example, 3 predictor variables, can be expressed in the following general form:

$$\hat{Y} = f(X_1) + f(X_2) + f(X_3) + \varepsilon \qquad (1)$$

where $\hat{Y}$ is the prediction, X_1 through X_3 are the predictor variables, and ε is the deviation of $\hat{Y}$ from the observation Y. For our study, Y was the log-transformation of annual recruit abundance. A GAM is similar to a standard linear regression model except that the term f here represents a cubic spline, as opposed to a single coefficient in the case of a linear regression model. We limited the maximum number of knots in the spline to 3 to avoid severe wiggliness and thus limit any tendency towards over-fitting.

We chose the PDO index during late spring-early summer (PDO.MJJ) as our primary predictor (X_1) because it was the most highly correlated to adult recruitment (Table 2). Furthermore, we found that by taking the average of PDO.MJJ over the fours years prior to return to freshwater, we could account for apparent lags between shifts in the PDO index and large changes in recruitment during the last decade (compare Figs. 1a and b). From hereon we use PDO.MJJ-4 to refer to the four-year average of PDO.MJJ.

Table 2. Correlation coefficients[1] for log OCNR coho recruits with environmental indices

	Environmental index								
Month[2]	MEI	NPGO	NPI	ONI	PDO	SSH	SST	UWI	SPR[2]
D*JF	-0.14	0.39	0.09	-0.06	-0.22	-0.24	-0.41	0.08	
JFM	-0.16	0.35	0.04	-0.08	-0.27	-0.33	-0.40	0.20	
FMA	-0.24	0.36	0.13	-0.13	-0.33	-0.43	-0.41	0.28	
MAM	-0.26	0.40	0.23	-0.22	-0.46	-0.54	-0.39	0.41	-0.47
AMJ	-0.35	0.43	0.36	-0.26	-0.56	-0.58	-0.34	0.34	
MJJ	-0.45	0.45	-0.04	-0.25	-0.60	-0.58	-0.12	0.02	
JJA	-0.40	0.45	-0.19	-0.20	-0.54	-0.51	-0.01	-0.05	
JAS	-0.35	0.46	-0.11	-0.20	-0.44	-0.41	-0.05	-0.19	
ASO	-0.36	0.48	-0.06	-0.19	-0.30	-0.37	-0.19	-0.16	
SON	-0.33	0.48	-0.13	-0.20	-0.22	-0.31	-0.27	-0.10	
OND	-0.32	0.47	-0.08	-0.20	-0.15	-0.25	-0.35	-0.07	
NDJ**	-0.29	0.40	0.01	-0.21	-0.16	-0.30	-0.43	0.05	
J**	-0.28	0.29	0.11	-0.20	-0.21	-0.36	-0.49	0.13	

[1]Significant correlations are shaded in gray. .
[2]All months are for the calendar year of ocean entry, unless denoted by an asterisk: (*) = year prior to ocean entry, (**) = year of return to freshwater.
[3]Spring transition occurs once per year, so monthly average has no meaning. The SPR value has been placed with MAM because SPR typically occurs during these months.

We tested models which paired PDO.MJJ-4 with every other ocean environment variable during the year of ocean entry. We also tested SST in January of the return year because it has been used in the past to forecast OCNR coho. Furthermore, we examined the logarithmic transformation of the number of parent spawners $N_{spawners}$ (the number of spawners lagged by three years).

We also evaluated 3-variable models by combining PDO.MJJ-4 with every other possible pair of variables. We ranked all models by their generalized cross-validation (GCV) score. GCV is similar to ordinary cross-validation (OCV), but much faster computationally.

From the possible 2-variable models, we selected the highest ranking models with the restriction that no index was selected twice (9 models in total: 8 environmental variables plus log $N_{spawners}$). From the possible 3-variable models, we selected the 9 highest ranking models with the restriction that no environmental index appeared twice within the same model (for example, SST.FMA with SST.SON) and that every index was represented at least once. Furthermore, we did not select sets of variables that we considered to be too similar (for example, SST.JJA with UWI.JAS would be too similar to SST.MJJ with UWI.JAS to be providing any new information). We also limited NPGO to no more than one model because currently the NPGO index is not calculated in time to make actual forecasts (though it may be in the future).

The 18 selected models were further evaluated based on their full OCV score (rather than the approximate GCV used above), the Akaike information criterion (AIC), and what we term the "historical forecast skill" (HFS).

In OCV, one data point is removed from the data set, the model is refit from the remaining data points, and a prediction is made of the extracted data point. This is repeated for each data point, and the OCV score is the mean of the squares of the differences between the predictions $\hat{Y}_i$ and the observations Y_i. Normalizing by the variance and subtracting from 1 gives us another way of expressing the OCV score, which we denote as OCV^*:

$$\mathbf{OCV}^* = 1 - \frac{\sum_{i=1}^{n} (\hat{Y}_i - Y_i)^2}{\sum_{i=1}^{n} (\overline{Y} - Y_i)^2} \qquad (2)$$

where $\overline{Y}$ is the mean of the observations. Note that Eq. (2) is equivalent in form as the equation for calculating R^2; only the methods of determining the $\hat{Y}_i$ are different.

The HFS is similar to the OCV in that the score is evaluated using predictions for observations not included when fitting the model. However, the HFS mimics how a model would be applied "operationally". We began by fitting the model using the first half of the dataset (1970 – 1989) and then making a forecast for the year 1990. Next, we included the year 1990 in the dataset, refitted the model, and made a forecast for 1991. This procedure was repeated until a final forecast was made for 2009. The HFS is calculated the same way as is the OCV^* in Eq. (2), except $\hat{Y}_i$ and Y_i are instead the one-year lead forecasts and observations, respectively, for the period when the forecasts were made (which, in this specific case, is 1990 – 2009). Note that the HFS of a perfect forecast is 1, while an HFS of 0 would arise from forecasting (correctly) the mean $\overline{Y}$, which can be poorly known, particularly for small datasets; there is no theoretically lower bound to the HFS.

RESULTS

Among the selected 2-variable models, PDO.MJJ-4 coupled with date of spring transition (SPR) scored best across all skill measures (GCV, AIC, R^2, OCV*, and HFS) (Table 3). After SPR, the PDO index performed similarly coupled with three of the other large-scale indices (MEI, NPGO, and ONI); interestingly, all were in late fall/early winter. The next two best models included late spring-early summer SSH and winter return SST, in order.

Log spawners and NPI were the weakest second variables. Furthermore, the relationship between NPI and log recruits was contrary to our hypothesis: the model assumed lower recruitment with higher values of NPI.

Table 3. Selected models

Predictor variables[1]			Performance statistics					
1[2]	2	3	GCV	AIC	R^2	OCV^*	HFS	Fore-cast[3]
PDO.MJJ	UWI.JAS	NPGO.OND	0.126	31.4	0.81	0.73	0.53	NA
PDO.MJJ	SPR	log $N_{spawners}$	0.136	35.1	0.77	0.70	0.67	206
PDO.MJJ	MEI.OND	UWI.JAS	0.140	36.1	0.78	0.69	0.50	180
PDO.MJJ	SPR	NPI.JFM	0.141	36.6	0.77	0.67	0.67	179
PDO.MJJ	SPR	MEI.OND	0.142	36.7	0.77	0.69	0.63	189
PDO.MJJ	UWI.JAS	SST.AMJ	0.144	37.1	0.77	0.68	0.42	246
PDO.MJJ	SPR	ONI.OND	0.144	37.3	0.76	0.67	0.62	187
PDO.MJJ	SSH.AMJ	UWI.JAS	0.145	37.4	0.77	0.67	0.49	208
PDO.MJJ	UWI.SON	SST.J	0.145	37.7	0.76	0.66	0.58	215
Ensemble mean[4]					*0.81*	*0.74*	*0.60*	*206*
PDO.MJJ	SPR		0.149	38.9	0.74	0.67	0.64	213
PDO.MJJ	MEI.OND		0.158	41.2	0.72	0.65	0.56	170
PDO.MJJ	NPGO.OND		0.160	41.6	0.73	0.64	0.57	–
PDO.MJJ	ONI.OND		0.161	41.9	0.73	0.62	0.55	168
PDO.MJJ	UWI.JAS		0.162	42.2	0.73	0.64	0.42	206
PDO.MJJ	SSH.AMJ		0.166	43.2	0.71	0.63	0.56	199
PDO.MJJ	SST.J		0.172	44.8	0.70	0.61	0.50	169
PDO.MJJ	log $N_{spawners}$		0.180	46.3	0.70	0.59	0.49	212
PDO.MJJ	NPI.JFM		0.180	46.6	0.68	0.59	0.52	165
Ensemble mean[4]					*0.75*	*0.67*	*0.56*	*194*

[1]Predictor variables in column-order of explanatory power and models in row order by GCV. Note that better fit is indicated by lower values of GCV and AIC, and by higher values of R^2, OCV*, and HFS.
[2]Average of prior 4 years of mean of PDO.MJJ.
[3]Forecast of 2010 OCN coho adult recruits (in thousands). The NPGO index for Oct. 2009 through Jan. 2010 was not available in time to use in forecast models.
[4]Models shaded in gray were used to calculate the ensemble mean scores.

Of the 2-variable models selected, the one with summer UWI provided the worst forecast skill (HFS) over the last two decades. UWI.JAS also showed the most striking non-monotonic relationship with log recruits. The trend between recruitment and upwelling wind strength was positive (as hypothesized) only up to a UWI of about 50 m^3 s^{-1} 100 m^{-1}, after which recruitment decreased with increasing UWI.

The addition of a third variable resulted in marked improvements in the standard performance metrics (GCV, AIC, R^2, and OCV^*) for all indices (Table 3). The 3-variable model with the best scores (excepting HSF) included summer UWI and NPGO.OND. In fact, UWI.JAS was included in four models; however, these five models had the lowest historical forecast skill. In fact, the HFS scores of the 3-variable models that included

UWI.JAS were actually lower than many of the HFS scores of the 2-variable models. In contrast, the 3-variable models with the highest HFS scores all included SPR.

Time series of the predictions by the fitted 3-variable models using the full time period 1970 – 2009 are shown in Fig. 2, while the time series of the models' forecasts in "operational" mode are shown in Fig. 3.

DISCUSSION

While any one of the models in Table 3 could be selected to serve as the forecast model for OCNR coho recruitment, we believe the forecasts from a selection of models could be taken into consideration when reporting a recruitment forecast. This would provide a range of possible outcomes that reflects, to some degree, the uncertainty we have in our understanding of how salmon productivity is driven by ocean conditions. However, there will always be a desire within the management community and the public to be supplied a single value (for one, it is simpler to design decision making rules based on a single value).

An alternative to selecting a single model with which to make a forecast is to take the mean of the forecasts from a set of models, or an *ensemble* of model forecasts, as it is commonly called in the climate modeling literature. We evaluated the ensemble mean forecast using three performance metrics: R^2, OCV*, and HFS (Note that the R^2 here is not precisely the coefficient of determination of a regression, but is calculated similarly). We chose a subset of the previously selected models, focusing on the 3-variable models as an example. We excluded models that contained NPI, ONI and NPGO. NPI was excluded because it was the weakest explanatory variable and the modeled relationship between NPI and log recruits was contrary to our hypothesis (the model assumed lower recruitment with higher values of NPI). ONI was excluded because it provided a very similar response as that of MEI but scored slightly lower; we did not want two variables that were essentially providing the same information. Lastly, NPGO was excluded because it currently is not calculated with sufficient lead time to be used as a forecast variable. This left us with six 3-variable models, which are shaded in gray in Table 3. The additive effects (as partial regression plots) of the variables in the 6 models are shown in Figs. 4 and 5.

The ensemble means scored as high or higher with respect to R^2 and OCV* than any of the individual forecasts in the ensemble (see Table 3). The HFS scores for the ensemble means were not as high as the highest-scoring individual models, but were still higher than most (Table 3).

Compared to the past methods of forecasting OCNR coho recruit abundance, the ensemble mean forecast of the six proposed 3-variable GAMs does very well. As shown in Fig. 6, had the method proposed here been used to make the forecasts for the period from 1996 to the present, the historical forecast skill score would have been 0.72 as compared to -0.17 using past methods.

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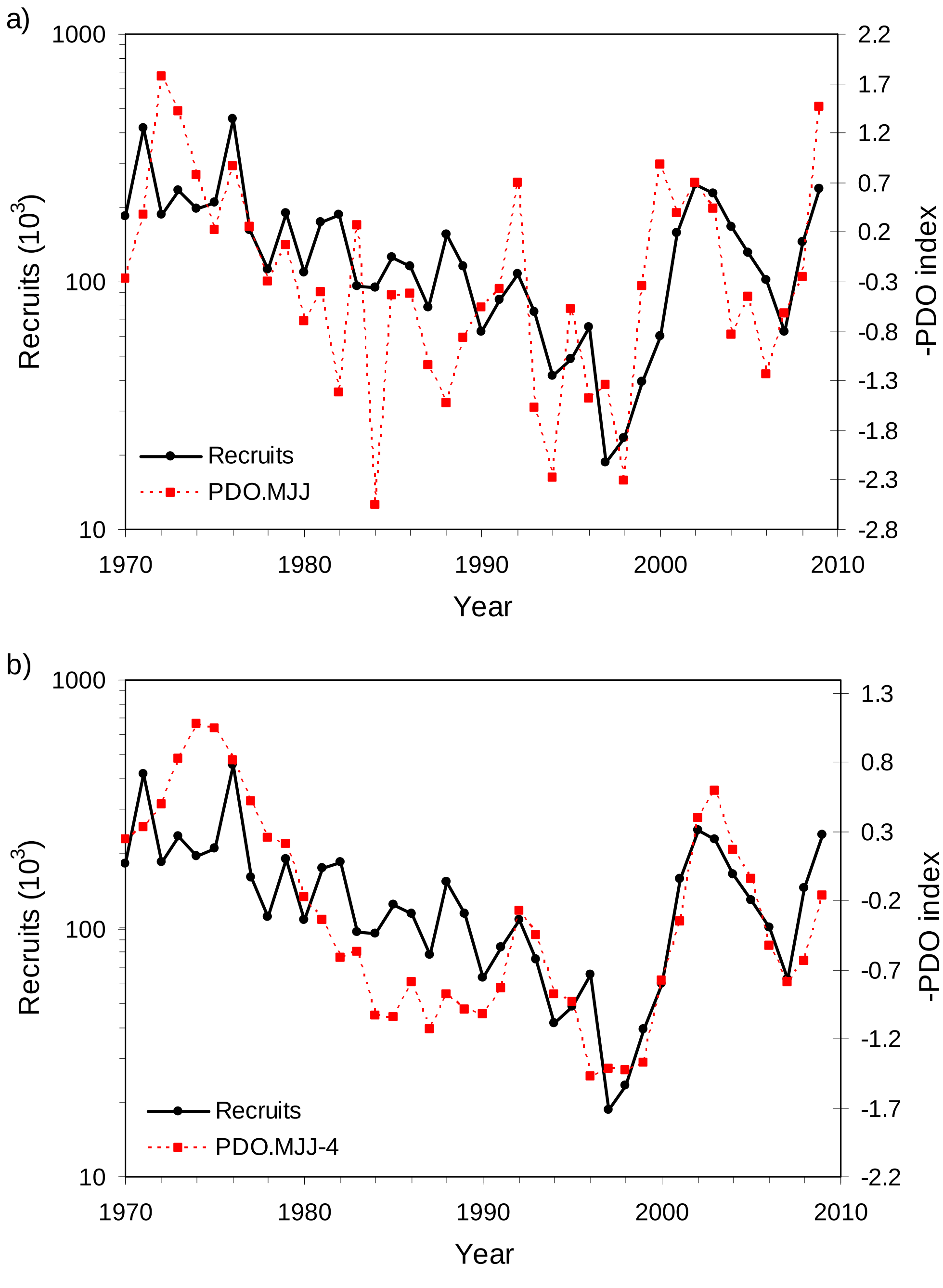

Figure 1. Time series of OCN river coho recruits during year of return to freshwater with the mean May-June-July PDO index of the ocean entry year (PDO.MJJ) (a), and with the mean of the 4 years of PDO.MJJ up to, and including, the ocean entry year (b). Note the sign of the PDO index has been reversed so that changes in recruits are in the same direction as changes in the PDO index.

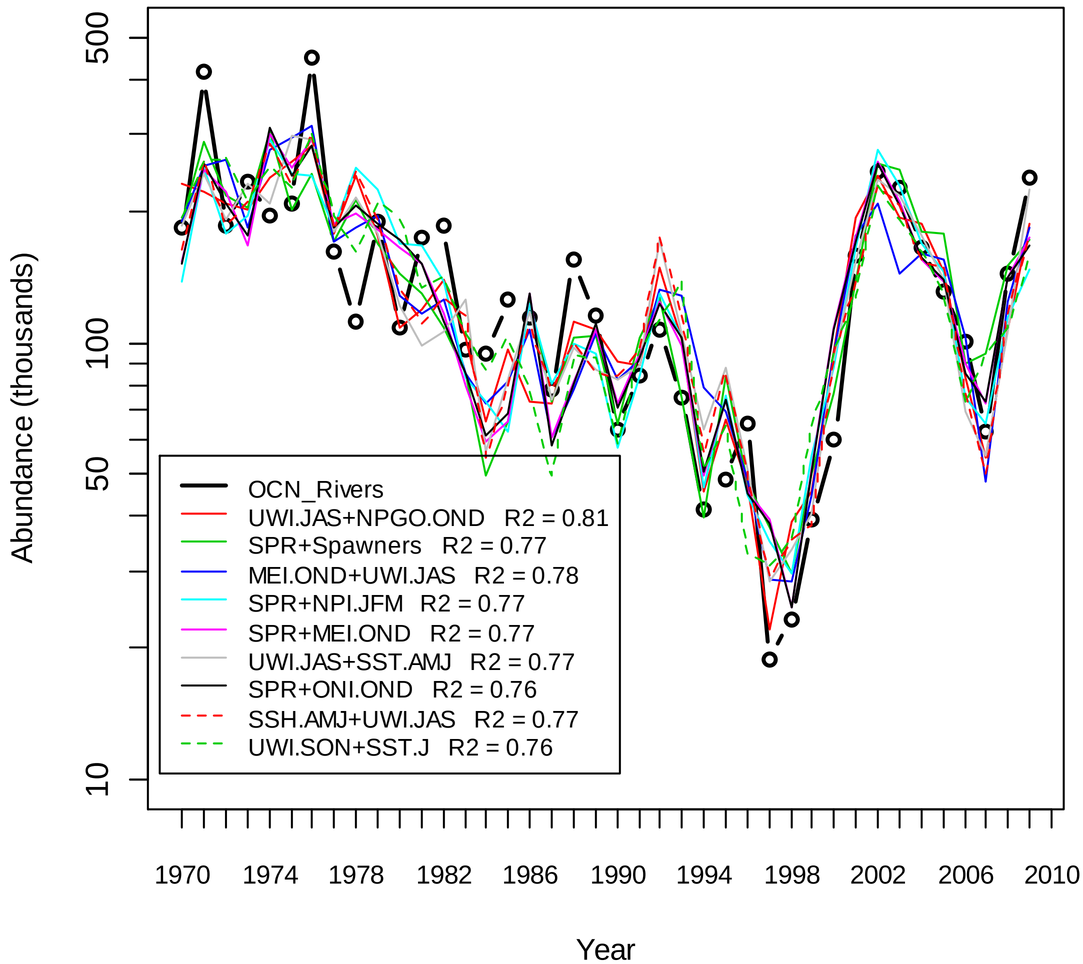

Figure 2. Time series of observed and modeled Oregon coastal natural river coho salmon adult recruits. The open circles with the thick line are the observations and the colored lines represent the predicted values from selected models using PDO.MJJ-4 combined with two additional predictor variables (as given in the legend).

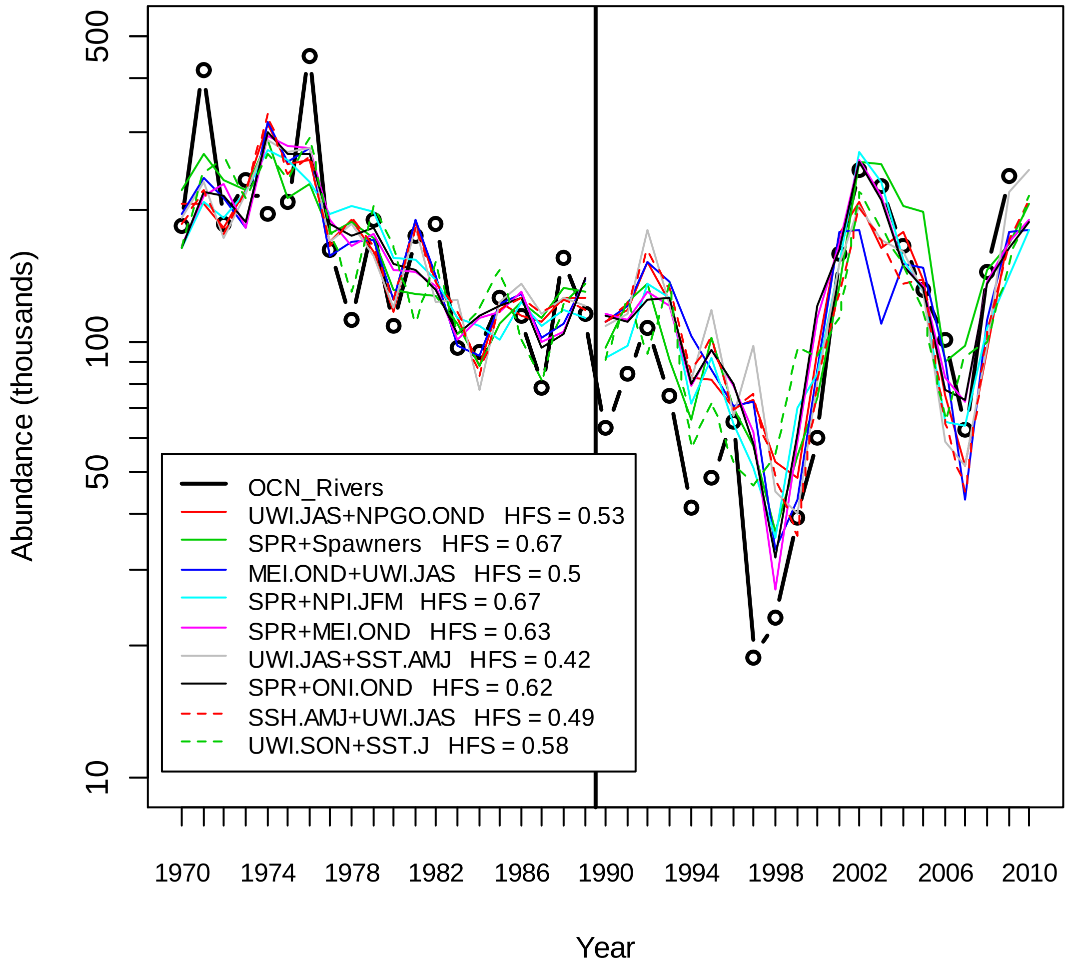

Figure 3. Time series of observed Oregon coastal natural river coho salmon adult recruits with forecasts from selected 3-variable models. The open circles with the thick line are the observations, the dashed/solid colored lines represent predictions/forecasts. The predictions shown prior to 1990 are from the models fitted to the 1970 – 1989 period, while the values for 1990 and after are 1-year lead forecasts from the models fitted to the data for all years prior to the forecast year (i.e., the models are refitted with the additional year of data prior to each forecast). Also shown is the "historical forecast skill" (HFS) for the period 1990 – 2009 (see text for details).

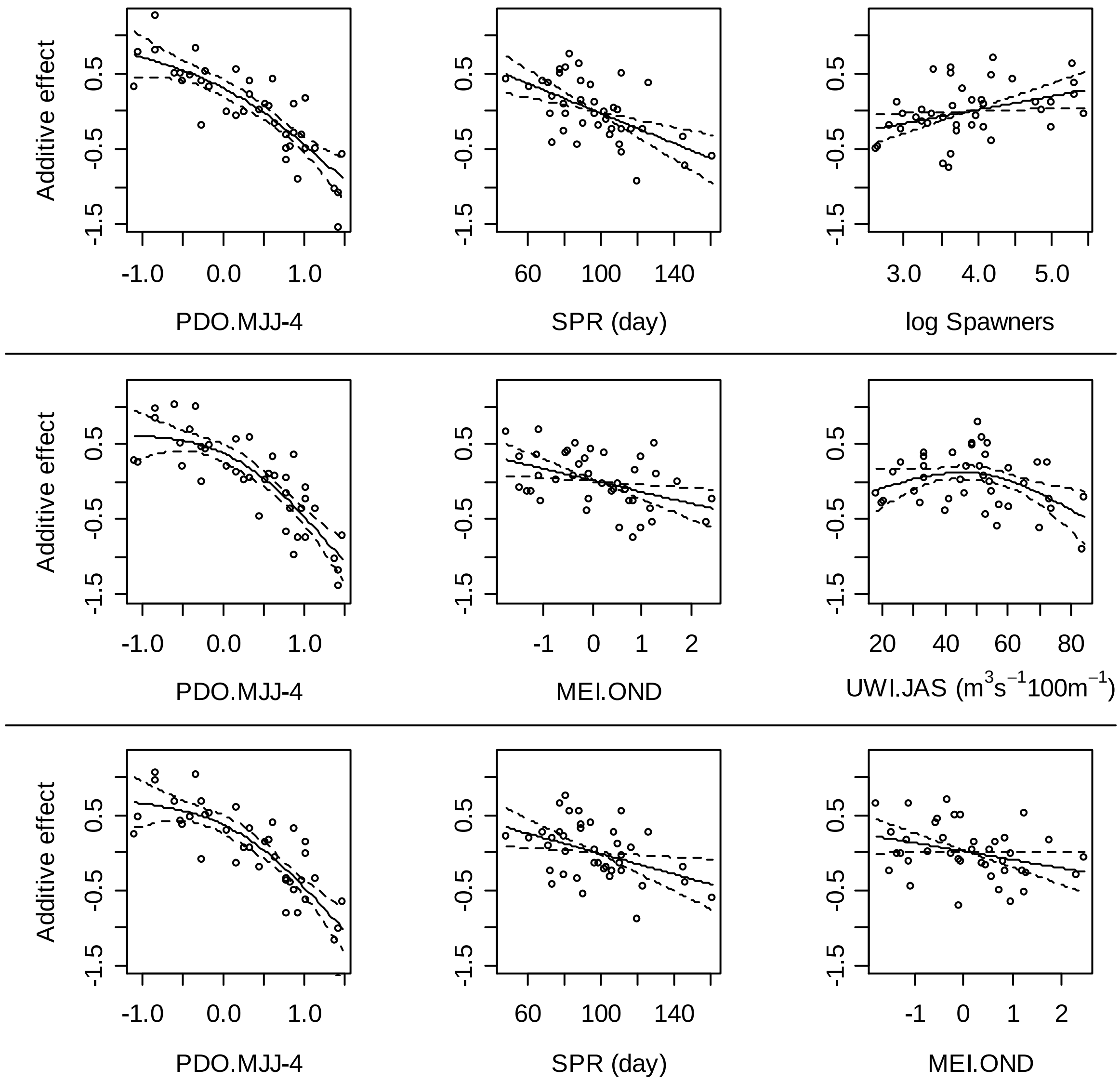

Figure 4. Partial regression plots for three of the selected three-variable GAMs listed in Table 4. Partial regression plots give the additive effect, or contribution, of each variable to the predicted log recruitment. Model variables are grouped by row and given in column order by explanatory power. Confidence limits (95%; dashed lines) and partial residuals (open circles) around the fitted lines are shown.

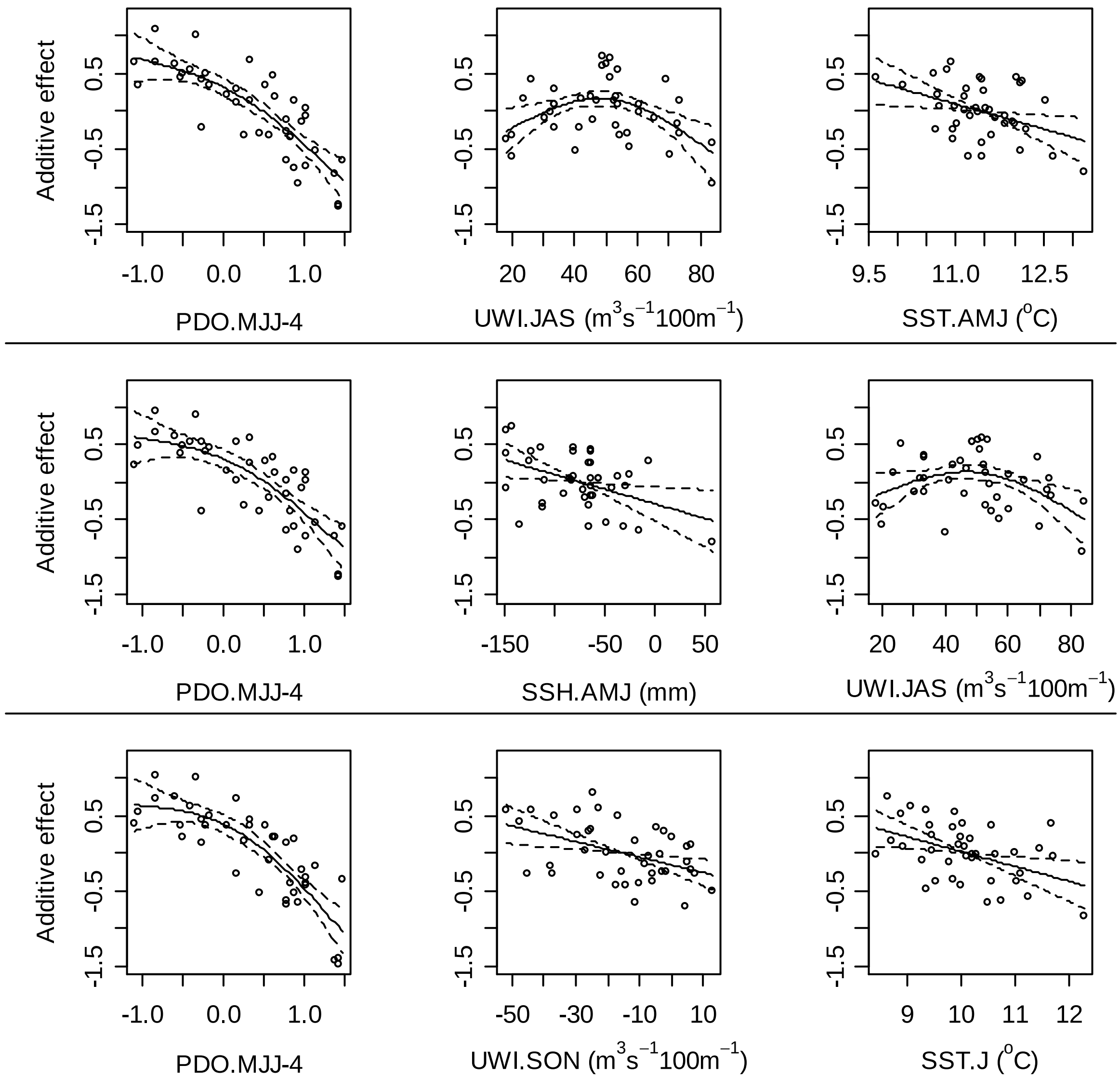

Figure 5. Partial regression plots for three of the selected three-variable GAMs listed in Table 4. Partial regression plots give the additive effect, or contribution, of each variable to the predicted log recruitment. Model variables are grouped by row and given in column order by explanatory power. Confidence limits (95%; dashed lines) and partial residuals (open circles) around the fitted lines are shown.

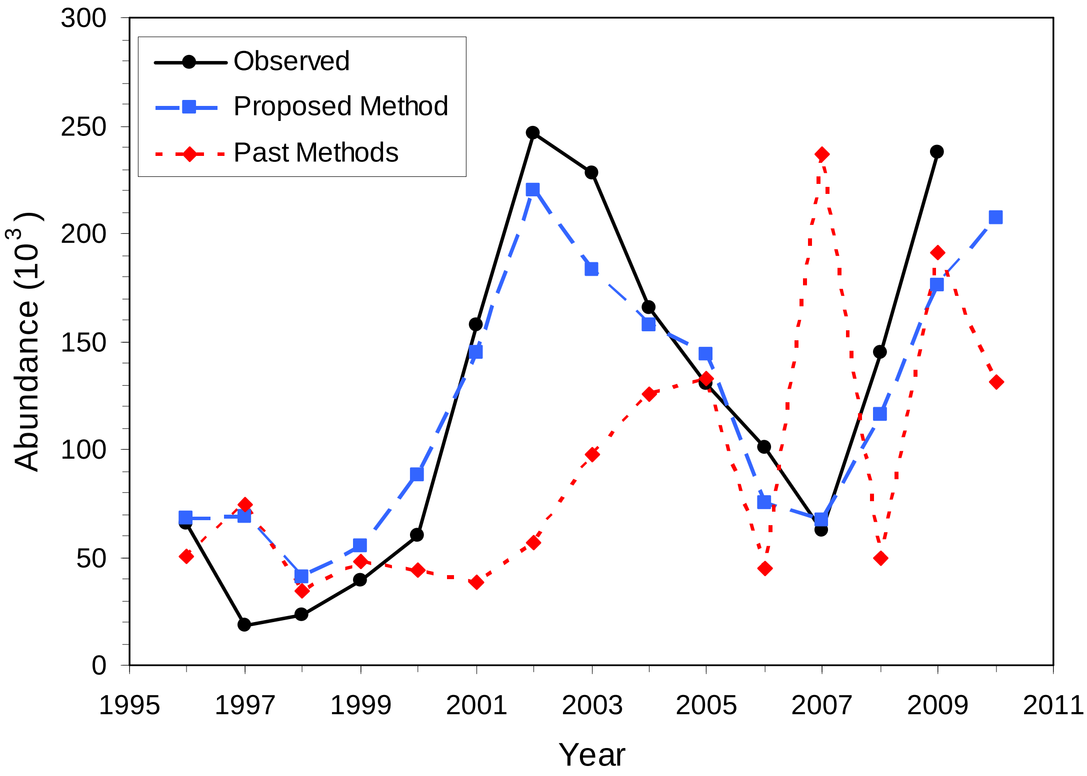

Figure 6. Observed and forecasted Oregon coastal natural river coho salmon adult recruits for the period 1996 – 2010. The blue dashed line shows the forecasts that would have been made using the method proposed in this report and the red dotted line show the actual forecasts that were made using past methods.

Forecast Models for Oregon Coast Natural Coho Salmon (*Oncorhynchus kisutch*) Adult Recruitment

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David E. Rupp[1]
Peter W. Lawson[2]
Thomas C. Wainwright[2]
William T. Peterson[2]

[1]Cooperative Institute for Marine Resources Studies, Oregon State University, Newport, Oregon
[2]Northwest Fisheries Science Center, National Oceanic and Atmospheric Administration, Newport, Oregon

Abstract

Generalized additive models (GAMs) were used to investigate the relationships between annual recruitment of Oregon coast natural (OCN) coho salmon and indices of physical ocean environment conditions. Nine indices were examined, ranging from indices of large-scale ocean patterns (e.g., Pacific Decadal Oscillation (PDO)) to local ecosystem variables (e.g., sea surface temperature at Charleston, OR). GAMs with 2 and 3 predictor variables were evaluated using a set of performance metrics aimed at quantifying the models' skill at making short-lead (~1 year) forecasts. It was found that high explanatory power and promising forecast skill could be achieved when the spring/summer PDO averaged over the 4-years prior to the return year was used to explain the low-frequency (multi-year) pattern in recruitment while a second (or second and third) variable was used to account for year-to-year deviations from the low-frequency pattern. When averaging the predictions from a set of models (the ensemble mean) a higher skill (in terms of variance explained or cross-validation) was achieved than by selecting any single model. Making multiple forecasts from a set of models also provides a range of possible outcomes that reflects, to some degree, the uncertainty we have in our understanding of how salmon productivity is driven by ocean conditions.

1. Introduction

Short-lead (1-year) forecasts of abundance are used to set allowable harvest for West Coast salmon stocks (Pacific Fishery Management Council, 2003). Forecasts typically are based on stock-recruit relationships and/or regressions of older age returns against younger-age returns within cohorts ("sibling regressions"), such as against precocious males that return after only a few months at sea (i.e., jacks). These techniques work well for many stocks, but fail when stock accounting is inaccurate (or simply lacking for a given age, such as no jack accounting) or there are strong environmental effects on either maturation rates or mortality rates. To date, only one of these management forecasts provided to the Pacific Fishery Management Council, that for Oregon Coast Natural (OCN) coho salmon (*Oncorhynchus kisutch*), incorporates climate indicators. This is despite several efforts at developing climate-related predictors. For example, Koslow et al. (2002), Logerwell et al. (2003), Lawson et al. (2004), Scheuerell and Williams (2005) and Greene et al. (2005) provide physical descriptive models that can be used to forecast future returns for coho salmon, Snake River Spring chinook (*O. tshawytscha*), and Skagit River fall chinook salmon.

The model used to forecast annual recruits of OCN coho from rivers (coho originating in Oregon coastal lakes are treated separately) has undergone several modifications since forecasts of OCN coho recruits were first made in 1988 by the Oregon Production Index Technical Team (OPITT).

Initially (1988-1993), the forecast model was the standard Ricker spawner-recruit function (Ricker, 1954) with an ocean survival index included as an additional predictor variable (Table 1). This ocean survival index was calculated as the ratio of returns of hatchery jacks to hatchery smolts of the Oregon Production Index (OPI). There were three issues raised with this modified Ricker model:

1) The number of parent spawners within the standard density-dependent Ricker model explained little of the year-to-year variability in the number of recruits.

2) Predictions in the years this model was used were all biased high.

3) The OPI hatchery-based marine survival index was not believed to adequately incorporate environmental variability for OCN coho.

The latter concern can be seen to arise from two sources. One is that OPI (OPIH) hatchery coho survival and wild coho survival may not always align given their different life histories, ancestry, and geography (unlike OCN coho, OPI hatchery coho come predominately from the Columbia River system). A second is the fact that ocean survival accounts for only part of total survival; total coho salmon survival is believed to be roughly equally divided between the freshwater and marine life phases (Holtby and Scrivener, 1989; Bradford, 1995).

These concerns led to a review of environmental variables that could be used as predictors of OCN coho recruitment. Spring upwelling in the year of ocean entry had already been linked to coho recruitment (Nickelson, 1986; Pearcy, 1992; Lawson, 1993) while sea surface temperature of the following winter was found to be equally correlated to OCN coho recruits (Lawson, 1997). Together, spring upwelling winds and winter sea surface temperature (SST) could explain 73% of the variability in recruitment (Lawson, 1997). The selected model was a linear regression of log-transformed recruits against the spring Bakun upwelling wind index (UWI) and winter sea surface temperatures (SST) and against year (Table 1). The use of year as a predictor reflected the overall steady and approximately linear (on log-scale) decline of recruit abundance during the preceding 2.5 decades (Fig 1).

Year was removed as a predictor during the years 1996 – 1998 but reinstated in 1999. However, the dramatic increase in recruitment in 2001 and 2002 (Fig. 1) meant that year could no longer be used as a reliable predictor; hence year was again dropped from the model in 2003. Lacking this variable which (at least to up about the year 2000) helped explain a strong low-frequency pattern in annual recruitment, the model could only explain about 32% of the variability in abundance (compared to 78% with year as a variable using data from 1970 to 2000). Whereas one decade prior when UWI and SST could account for a large amount (R^2 =73%) of the variability in annual recruitment, these two environmental indices were no longer strong predictors.

In 2008, the model forecasted abundances higher than what OPITT believed were reasonable. After examining alternative models, all of which tended to forecast unusually high abundances, the official forecast was made that the 2008 abundance would be equal to the 2007 abundance.

In 2009, a variable called the “regime index” (RI) was introduced to account for the period 1990 – 2000 when recruitment was at its lowest (Table 1). The RI was set equal to 1 for the years 1990 – 2000, and to 0 for all other years. The RI along with UWI and SST explained 71% of the variability in recruitment from 1970 to 2009.

Though the RI proved to be a powerful explanatory variable, it can only be applied in retrospect once a regime has been identified (or, more appropriately, “designated”). This poses a problem for forecasting, unless we have a means of knowing (or predicting) if a regime transition is occurring.

This need for a variable that explains low-frequency patterns in the OCN recruitment time series is the motivation for this study. Though changes in freshwater habitat (e.g., terrestrial climate change, and habitat degradation and restoration) will certainly affect productivity, our focus is on the marine environment and indices of ocean conditions that are likely to influence coho production. It has been shown that ocean environment indices could explain 83% of the variability on OCN coho recruitment between 1970 and 2000 (Koslow et al., 2002), though whether this is due to positive correlation between factors promoting both freshwater and marine survival (Lawson et al., 2004) and/or to model over-fitting is debatable. In the latter case, the reliability of the model as a forecast tool needs to be considered beyond simply reporting the R^2 of the fit (Koslow et al., 2002).

We examined a suite of potential predictor variables that includes indices of both large-scale ocean conditions (Multi-variate ENSO index, North Pacific Gyre Oscillation index, North Pacific index, Ocean Niño index, and Pacific Decadal Oscillation index) and local ocean conditions (upwelling wind strength, upwelling spring transition, sea surface temperature and sea surface height). We first examined each index individually to see how well it correlated with OCN recruitment. Secondly, we built generalized additive models (GAMs) using various combinations of indices and evaluated the models in terms of their ability to make accurate forecasts. We chose GAMs because they have the powerful attribute of not imposing *a priori* a given functional relationship between the predictor(s) and the predictand. GAMs have been used previously to explore relationships between environmental variables and marine survival of OPI hatchery coho (Logerwell et al., 2003) and freshwater survival of OCN coho (Lawson et al., 2004).

2. Data and Methods

2.1. Data

2.1.1. Oregon Coast Natural (OCN) Coho salmon

The Oregon Coast Natural (OCN) coho salmon stock is naturally produced in rivers and lakes along the Oregon coast south of the Columbia River. This stock aggregate is a component of the greater Oregon Production Index (OPI) area coho stock, which also includes hatchery and natural coho from the Columbia River and hatchery coho from the Oregon coast (though coast hatchery coho have historically been a minor component of the OPI and are currently inconsequential).

Annual time series of aggregate OCN coho adult recruitment for the period 1970 – 2009 from Oregon coast rivers (OCNR) and lakes (OCNL) were generated from spawner escapement estimates (Oregon Department of Fish and Wildlife) and fishery exploitation rates (Chapter 3 in Pacific Fishery Management Council, 2010). The river and lake data were kept separate because it is believed that population dynamics differ markedly between river and lake runs (Lawson et al., 2004). This report focuses exclusively on the river (OCNR) estimates.

2.1.2. Multi-variate ENSO Index (MEI)

The Multi-variate ENSO Index (MEI) is the first principal component of six variables over the tropical Pacific: sea-level pressure (SLP), zonal and meridional components of the surface wind, sea surface temperature (SST), surface air temperature, and total cloudiness fraction of the sky (Wolter and Timlin, 1993). High values of the MEI indicate El Niño events. The unexpectedly low survival of OPI hatchery coho in the years from 1983 to 1985 has been attributed to the very strong El Niño event of 1982-83 (Pearcy, 1992). Others have pointed out that the extended El Niño period from 1990 to

1998 (with a brief La Niña in from mid-1995 through 1996) coincides the period of lowest-recorded OPI hatchery survival and OCN adult returns (Peterson et al., 2006).

2.1.3. North Pacific Gyre Oscillation (NPGO)

The North Pacific Gyre Oscillation (NPGO) index is defined as the second principal component of sea surface height (SSH) anomalies over the region 25º N-62º N, 180º W-110º W (Lorenzo et al., 2008). The NPGO index has recently been shown to be correlated with nutrient concentrations and salinity in both the Alaskan Gyre along Line P and in Southern California Current System (Lorenzo et al., 2008; 2009), which bound the northern and southern extremes of the OPI area. It is hypothesized, therefore, that the monthly mean NPGO index serves as an index of productivity, and therefore marine survival, in the greater California Current System, including the OPI area.

2.1.4. North Pacific Index (NPI)

The North Pacific Index (NPI) is an index of the strength of Aleutian Low and is calculated as the area-weighted SLP over the region 30ºN-65ºN, 160ºE-140ºW. A higher NPI signifies a weaker low with cooler air being advected to the western coast of the US and weaker winter downwelling. It has been suggested that winter ocean environment affects water column stratification, and thus productivity, the following spring (Polovina et al., 1995; Gargett, 1997; Logerwell et al., 2003). It is hypothesized, therefore, that high values of the NPI imply more productivity and increased survival. However, Ryding (1998) and Logerwell et al. (2003) did not find NPI to be a significant predictor of coho marine survival of either Washington State hatchery or OPI hatchery coho, respectively. Still, we have included monthly mean NPI as a potential large-scale regime index because it represents a region geographically closer to the OPI area than either the MEI or ONI.

2.1.5. Ocean Niño Index (ONI)

The Ocean Niño Index (ONI) is the monthly mean SST anomaly for the Niño 3.4 region (5ºN-5ºS, 120º-170ºW). Like the MEI, high values of the ONI indicate El Niño events. We use the same rationale for investigating ONI as we do for MEI (see Section 2.1.2 above)

2.1.6. Pacific Decadal Oscillation (PDO)

The Pacific Decadal Oscillation (PDO) index is defined as the first principal component of SST anomalies over the region 25ºN-62ºN, 180ºW-110ºW (Lorenzo et al., 2008). Variability in the PDO has been associated with variability in NE Pacific salmon catch (Mantua et al., 1997; Hare et al. 1999) and the PDO index has been shown to be correlated to marine survival of OPI hatchery coho (Peterson and Schwing, 2003) and survival of Alaska/British Columbia pink (*O. gorbuscha*) and sockeye (*O. nerka*) salmon (Mueter et al., 2005). Negative values of the PDO index (which imply cooler sea surface temperatures in the California current) have been associated with higher survival of salmon stocks south of Alaska; therefore we hypothesize that the same will be true for OCN coho.

2.1.7. Spring Transition Date (SPR)

The date of spring transition (SPR) marks the shift between the winter period dominated by downwelling to the summer period dominated by upwelling. The SPR generally varies from March to May. Because coho smolts migrate to the ocean from March to June, the timing of the spring transition determines the upwelling conditions that most smolts first encounter when entering the marine environment. It is therefore hypothesized that a late spring transition negatively affects early marine survival. Negative correlation has been observed between SPR and survival of Washington State and Columbia River hatchery coho smolts (Ryding and Skalski, 1999; Logerwell et al., 2003). We relied on the method of Logerwell et al. (2003), based on an analysis of daily upwelling winds and sea level, to define the date for the spring transition.

2.1.8. Sea Surface Height (SSH)

It has long been known that sea surface height (SSH) is highly correlated with current structure and wind stress over the Oregon continental shelf (Huyer and Smith, 1978; Strub et al., 1987). We therefore examined monthly SSH as an index of ocean conditions influencing OCN coho production. Between WA and northern CA, long-term and continuously updated records of SSH are available for Neah Bay, WA, South Beach, OR, and Crescent City, CA. The data from South Beach, OR (44º 37.5′ N, 124 º 02.6′ W) were chosen for this study because of the station's central location. However, data from Neah Bay and Crescent City were used to fill gaps in the South Beach data by means of linear regression relationships after the following steps were taken to process the data.

Monthly SSH was adjusted for the inverse barometric effect (e.g., Strub et al., 1987). The adjustment consisted of adding the atmospheric sea level pressure SLP anomaly to the unadjusted, or "raw", SSH:

$$\mathbf{SSH}_{adj} = \mathbf{SSH}_{raw} + 9.948(\mathbf{SLP} - 1013.3) \qquad (1)$$

where SSH_{adj} is the adjusted sea level height in units of mm and SLP has units of mb. Monthly SLP was obtained from 2.5 degree latitude x 2.5 degree longitude gridded surfaces of monthly SLP generated by the National Centers for Environmental Protection/National Center for Atmospheric Research (NCEP/NCAR) Reanalysis I Project (Kalnay et al., 1996). The SLP values at the grid cells corresponding to the station locations were extracted from the gridded data sets.

Long-term temporal trends in SSH exist for many stations along the coast. For example, at South Beach, sea level has increased by an average of 2.37 mm a^{-1} between 1969 and 2009, inclusive, for a total of nearly 100 mm during that 41-year period. This sea level increase amounts to nearly 20% of the total variability in SSH during the same period (data not shown). We removed this trend in SSH by regressing SSH linearly against time and then taking the residuals of the fitted equation to be the final values of SSH. From hereon, it is assumed that SSH has been adjusted for the inverse barometric affect and for the long-term temporal trend.

2.1.9. Sea Surface Temperature (SST)

Several studies have found sea surface temperature (SST) to be negatively correlated to Pacific Northwest (PNW) coho survival (Lawson, 1997; Cole, 2000; Koslow et al., 2002; Logerwell et al., 2003). Furthermore, as stated previously, the mean SST for January of the adult return year has been used as a variable in linear models for practical short-lead (~1-year) forecasting of OCNR recruits since 1994 (Table 1; PFMC, 2010).

The SST series used began with a historical data set collected at the Oregon Institute of Marine Biology (OIMB) dock in Charleston, OR. This data was collected from 1966 until 1997, and was obtained from www.sccoos.org. More recent temperature data is available for the Charleston tide gauge (available at www.opendap.co-ops.nos.noaa.gov) from 1993 to the present. The OIMB data was calibrated against the tide gauge data based on monthly regressions for the overlapping years 1993-1997, and was used for 1966 to 1993. Unfortunately, the tide gauge series has gaps in 2002-2003. The nearest comparable data we could obtain for these years was SST data from the NOAA Stonewall Banks Buoy (Buoy 46050), and we used this data to fill missing values, again calibrated via linear monthly regressions for the overlapping period.

2.1.10. Upwelling Wind Index (UWI)

Many studies have linked the strength of coastal upwelling winds to favorable conditions for marine survival of PNW coho (Scarnecchia, 1981; Nickelson, 1986; Fisher and Pearcy, 1988; Holtby et al., 1990). The coastal upwelling is arguably the key process driving plankton production, and therefore the food source for coho, in the California current system (Peterson et al., 2006). As an index of coastal upwelling, we used monthly mean values of Bakun's coastal upwelling index (Bakun, 1973) for 45º N, 125º W.

2.1.11. Data Preparation

The data for each environmental variable were downloaded from the internet (see Table 2 for the URL of each data source). Three-month running means were calculated for each environmental variable with the exception of MEI which was left as a two-month running mean (the condition in which it was obtained). The following format was used to label each environmental variable:

VVV.MMM

where VVV is the three-character abbreviation of the environmental variable, MMM are the months over which the mean of variable is calculated.

12 annual time series were created for each variable using each but one of the 12 three-month running means within the calendar year. In addition, for each variable annual time series of December means and January means were generated (except for MEI).

2.2. Methods

2.2.1. Correlation Analysis

Pearson's correlation coefficient ρ was calculated for the logarithmic transformation of OCNR recruits against each environmental variable during the year of ocean entry at each of 12 monthly lags. Furthermore, ρ of log recruits against each variable for January of the return year was calculated. (Because forecasts of OCN coho salmon are made during February of the return year, January is the latest month for which data potentially can be used in a forecast.) A test was conducted to determine if ρ for a given environmental index was significantly different from zero (see Appendix A for details).

2.2.2. General Additive Models (GAMs)

We used generalized additive models (GAMs) to build relationships between ocean environment indices and OCNR recruitment. A GAM with, for example, 3 predictor variables, can be expressed in the following general form:

$$\hat{Y} = f(X_1) + f(X_2) + f(X_3) + \varepsilon \quad (2)$$

where $\hat{Y}$ is the prediction, X_1 through X_3 are the predictor variables, and ε is the deviation of $\hat{Y}$ from the observation Y. For our study, Y was the log-transformation of annual recruit abundance. The term f represents a smooth function, which in this case is a cubic spline. We limited the maximum number of knots in the spline to 3 to avoid severe wiggliness and thus reduce the degree of over-fitting. The GAMs were fit using the *mgcv* package in R.

We first tested all possible combinations of two-variable models. Given there are 14 lags per environmental index (except for SPR for which there is only one time series), this amounted to 6,441 models. The models were ranked by their generalized cross-validation (GCV) score. GCV is similar to ordinary cross-validation (OCV), but much faster computationally (Wood, 2006).

We noticed while testing all possible 2-variable combinations that those that included PDO, particularly for MJJ, consistently scored highest in terms of the GCV, no matter with which index PDO was paired. The highest R^2 achieved was 0.51 (when PDO.MJJ was paired with UWI.JJA). However, there was a notable lag between a large shift in the PDO index between 1998 and 1999 from positive to negative values (warm ocean temperatures to cool ocean temperatures) and the strong rebound of coho recruits in 2001 (Fig. 1a). This resulted in disappointing performance of the models for the period 1999 – 2004 (data not shown), which coincides with the dramatic increase to numbers in abundance not seen since 1976, and then the beginning of a nearly equally large decline (albeit more gradual).

The apparent lag in the time series between the recruit pattern and PDO pattern led us to speculate that coho production was linked not only to the ocean conditions of the ocean entry year, but that multi-year persistence of good (or poor) ocean conditions also drove recruit numbers up (or down). In other words, in took more than one "good" PDO year to cause a strong response in coho productivity.

Therefore, we examined how the PDO index average over multiple years was correlated to coho abundance and selected the average PDO.MJJ over the four years prior to the adult return year as a potential predictor variable (see section 3.1 for discussion and rationale). PDO.MJJ, therefore, served as our variable that described the low-frequency (multi-year) changes in ocean conditions (Fig 1b) and replaced those variables (i.e., year and RI) that had been used previously to achieve a similar result. From hereon, it is assumed that PDO.MJJ-4 refers to the mean PDO.MJJ of the 4 calendar years prior to the return to freshwater.

We tested models which paired PDO.MJJ-4 with every other environmental variable (excluding PDO for other months) including the logarithmic transformation of the number of parent spawners $N_{spawners}$ (the number of spawners lagged by three years). This amounted to 100 different models. We also tested models which combined PDO.MJJ-4 with every other possible pair of environmental variables (again excluding PDO) for a total of 4,950 models.

In order to limit the affects of multi-collinearity, we rejected any models for which any pair of variables had $\rho \geq 0.6$ (personal communication, Lorenzo Ciannelli, Oregon State University).

Again, we ranked the models by their GCV score. From the 2-variable models, we selected the highest ranking models with the restriction that no index was selected twice (9 models in total: 8 environmental variables plus log $N_{spawners}$). From the 3-variable models, we selected the 9 highest ranking models with the restriction that no environmental index appeared twice within the same model (for example, SST.FMA with SST.SON) and that every index was represented at least once. Furthermore, we did not select sets of variables that we considered to be too similar (for example, SST.JJA with UWI.JAS would be too similar to SST.MJJ with UWI.JAS to be providing any new information). We also limited NPGO to no more than one model because currently the NPGO index is not calculated in time to make actual forecasts (though it may be in the future). Lastly, we excluded, with one exception, all variables that included January of the return year because January data is typically not available in time for the forecasts made in February. The one exception was January SST, which has been used for forecasting OCNR coho abundance since 1994.

The 18 selected models were further evaluated based on their full OCV score (rather than the approximate GCV used above), the Akaike information criterion (AIC), and what we term the "historical forecast skill" (HFS).

In OCV, one data point is removed from the data set, the model is refit from the remaining data points, and a prediction is made of the extracted data point. This is repeated for each data point, and the OCV score is the mean of the squares of the differences between the predictions $\hat{Y}_i$ and the observations Y_i. Normalizing by the variance and subtracting from 1 gives us another way of expressing the OCV score, which we denote as OCV*:

$$\mathbf{OCV}^* = 1 - \frac{\sum_{i=1}^{n} (\hat{Y}_i - Y_i)^2}{\sum_{i=1}^{n} (\bar{Y} - Y_i)^2} \qquad (3)$$

Note that Eq. (4) is equivalent in form as the equation for calculating R^2; only the methods of determining the $\hat{Y}_i$ are different.

The HFS is similar to the OCV in that the score is evaluated using predictions for observations not included when fitting the model. However, the HFS mimics how a model would be applied in practice. We began by first fitting the model using the years 1970-1989 and then making a forecast for the year 1990. Next, we included the year 1990 into the fitting data and made a forecast for 1991. This procedure was repeated until a final forecast was made for 2009. The HFS is calculated as

$$\mathbf{HFS} = 1 - \frac{\sum_{i=1}^{n} (\hat{Y}_i - Y_i)^2}{\sum_{i=1}^{n} (\bar{Y} - Y_i)^2} \qquad (3)$$

where $\hat{Y}_i$ and Y_i are the one-year lead forecasts and observations, respectively, for the period 1990 – 2009. Note that Eq. (4) is identical to Eq. (3). The difference between HFS and OCV* (and, for that matter, R^2) is in how the $\hat{Y}_i$ are generated.

3. Results

3.1. Correlation Analysis

Of the nine environmental indices examined, PDO was found to be the most highly correlated to OCNR coho recruits, followed by SSH (Table 3). The highest correlations for these two indices occurred during the spring and early summer months of the ocean entry year (AMJ or MJJ) and were of negative sign. Other variables that showed significant correlation in spring were SST, UWI and SPR. Consistent with Lawson (1997), SST during the winter of the return year, was also significantly correlated with adult returns.

Interestingly, MEI was significantly correlated with recruits during late-spring and summer, but ONI showed no correlation with recruitment. NPI was also uncorrelated with recruits. The only significant correlation during autumn was with NPGO (SON).

As discussed in Section 2.2.2, we evaluated *N*-year averages of the PDO for each month of the year (by "monthly" we mean also the three month-running averages) as potential variables for explaining low-frequency (more than 1 year) patterns in recruitment. Through taking progressively longer averages up to $N = 4$ years, ρ between PDO.MJJ and log recruits increased from 0.60 ($N = 1$) to 0.79 ($N = 4$), while ρ decreased when N was increased from 4 to 5 years (Table 4). It is important to note that taking the *N*-year average of the environmental time series increased the degree of autocorrelation and thus increased the critical ρ needed for rejection of the null hypothesis. Even so, the correlations remained significant for PDO.MJJ up to at least $N = 5$.

3.2. General Additive Models (GAMs)

The GAM fitting showed a clear non-linear relationship between annual log recruits and PDO.MJJ-4 for all the models selected (Figs. B1-B18). The equivalent degrees of freedom (e.d.f.) for PDO ranged from 1.74 to 1.94. (To provide a reference, e.d.f. = 1 signifies a linear relationship while e.d.f. = 2 signifies a quadratic-type relationship). When coupled with PDO, NPGO and UWI were also non-linearly related to log recruits, while MEI, SPR, SSH and SST showed linear relationships (Table 5; Appendix B). NPI and ONI were either linearly or weakly non-linearly related to log recruits, depending on the model (Table 5).

Among the selected 2-variable models, PDO.MJJ-4 coupled with date of spring transition (SPR) scored best across all skill measures (GCV, AIC, R^2, OCV*, and HFS). After SPR, the PDO index performed similarly coupled with three of the other large-scale indices (MEI, NPGO, and ONI); interestingly, all were in late fall/early winter. The next two best models included late spring-early summer SSH and winter return SST, in order.

Log spawners and NPI were the weakest second variables. Furthermore, the relationship between NPI and log recruits was contrary to our hypothesis: the model assumed lower recruitment with higher values of NPI (Fig. B9).

Of the 2-variable models selected, the one with summer UWI provided the worst forecast skill (HFS) over the last two decades. UWI.JAS also showed the most striking non-monotonic relationship with log recruits (see Fig. B5). The trend between recruitment and upwelling wind strength was positive (as hypothesized) only up to a UWI of about 50, after which recruitment decreased with increasing UWI.

Time series of the predictions by the fitted 2-variable models using the full time period 1970 – 2009 are shown in Fig. 2. Time series of the models' forecasts in "operational" model are shown in Fig. 3.

The addition of a third variable resulted in marked improvements in the standard performance metrics (GCV, AIC, R^2, and OCV^*) for all indices. The 3-variable model with the best scores (excepting HSF) included UWI and NPGO. In fact, UWI was included in five models; however, these five models provided the lowest historical forecast skill. In fact, the HFS scores of the 3-variable models that included UWI were actually lower than many of the HFS scores of the 2-variable models. The 3-variable models with the highest HFS scores all included SPR.

Time series of the predictions by the fitted 3-variable models using the full time period 1970 – 2009 are shown in Fig. 4. Time series of the models' forecasts in "operational" model are shown in Fig. 5.

The restriction we imposed of eliminating from consideration those variables with January of the return year meant we excluded several models that would have scored higher than many of the models we have selected here. SSH.J in particular, stood out as a strong variable (data not show) and would have scored only below SPR among the 2-variable models. Among the 3-variable models, three models would have included variables that used January values (SSH, MEI, and ONI).

4. Discussion

We have given special attention to estimating the forecast skill of the models with the aim of avoiding *artificial skill*. A model may have artificial skill for one, or a combination, of three reasons: 1) model complexity, 2) the number of models considered, and 3) screening of predictors prior to model building (e.g., DelSole and Shukla, 2009). Model complexity may lead to over-fitting to the sample data, which itself contains error. As a model becomes more complex (e.g., as it has more fitting parameters), the parameter values begin to reflect more of the error in the data and less of the true underlying relationship. While this increases the quality of fit, it can decrease the confidence we have in a forecast.

Because the GAMs we applied here are based on cubic splines, they can be allowed to fit very complex patterns if given enough degrees of freedom. However, we limited the number of degrees by restricting the number of knots to a maximum of 3. The fitting procedure assumed many relationships to be linear, while some were roughly quadratic (Figs. B1-B18). The lack of wiggliness in the fitted relationships suggests that over-fitting is minor with the selected models.

With regards to the number of models considered, the more models that are tested, the more likely one will be found that appears to have high skill when in fact predictors and the predictand are purely independent. In order to avoid the probabilistic problem of considering very many models, or to simply reduce the computational burden, predictor screening is often carried out prior to model building/testing. Predictor screening is the practice of selecting, from a large pool of variables, those variables that are strongly correlated to the predictand. It has been show that predictor screening, however, results in over-estimation of forecast skill even when cross-validation method are used (DelSole and Shukla, 2009).

Though we examined the correlation between all possible predictor variables and log recruits, we only used the correlation coefficients to screen for the low-frequency variable (i.e., PDO.MJJ-4). Moreover, we took into consideration multiplicity when testing for significance in PDO among all months of the year. We then tested all possible combinations of 2-variable and 3-variable GAMs with PDO.MJJ-4 as the first variable, irrespective of the correlations of each predictor to the predictand. This made sense not only to avoid bias introduced by screening; the correlation strength of a predictor variable and log recruits is not indicative of how well it, as a second and/or third variable in a model, would explain the residuals of log recruits regressed against PDO.MJJ-4 only.

We are still faced with the issue of having tested a large number of models. However, we ranked them based on their generalized cross-validation score, which, unlike the R^2, is a measure of the error of the predictions of data points left out of the fitting process. This, in itself, should reduce the probability of artificial skill in the selected models. Furthermore, for the selected models we calculated two additional measures meant to help us estimate the forecast skill of the model (the ordinary cross-validation and historical forecast skill score). We would have like to have calculated the OCV* and HFS scores for every model tested, but this was computationally prohibitive.

We have avoided recommending any one particular model to serve as the forecast model for OCNR coho recruitment. We believe the forecasts from all the selected models (or a subset of the models) could be taken into consideration when reporting a recruitment forecast. This would provide a range of possible outcomes that reflects, to some degree, the uncertainty we have in our understanding of how salmon productivity is driven by ocean conditions. However, there will always be a desire within the management community and the public to be supplied a single value (for one, as single value is easier to plug into a decision making rule). An alternative to selecting a single model with which to make a forecast is to take the ensemble mean of the forecasts. We evaluated the ensemble mean against the observations using three performance metrics: R^2, OCV*, and HFS (Note that the R^2 here is not precisely the coefficient of determination of a regression, but is calculated similarly). We calculated ensemble means separately for the 2- and 3-variable models. We also excluded the models that contained NPI, ONI and NPGO. NPI was excluded because it was the weakest explanatory variable and the modeled relationship between NPI and log recruits was contrary to our hypothesis (the model assumed lower recruitment with higher values of NPI). ONI was excluded because it provided a very similar response as that of MEI but scored slightly lower; we did not want two variables that were essentially providing the same information. Lastly, NPGO was excluded because it currently is not calculated with sufficient lead time to be used as a forecast variable. This left us with six 2-variable models six 3-variable models. The ensemble means scored as high or higher with respect to R^2 and OCV* than any of the individual models (see Table 5). The HFS scores for the ensemble means were not as high as the highest-scoring individual models, but were still higher than most of the individual models (Table 5).

Compared to the past methods of forecasting OCNR coho recruit abundance, the ensemble mean of the six proposed 3-variable GAMs (which are summarized in Table 6) does very well. As shown in Table 7 and Fig. 6, had the method proposed here been used to make the forecasts for the period from 1996 to the present, the historical forecast skill score would have been 0.72 as compared to -0.17 using past methods. Note that simply forecasting the mean abundance each year (assuming the mean was accurately known) would result in a score of 0.

Notation

AIC	Akaike information criterion
GAM	Generalized additive model
GCV	Generalized cross-validation
HFS	Historical forecast skill
MEI	Multi-variate ENSO index
$N_{spawners}$	Number of OCNR coho parent spawners
$N_{jacks.OPIH}$	Number of OPIH jack returns
$N_{smolts.OPIH}$	Number of OPIH smolts
NPGO	North Pacific Gyre Oscillation
NPI	North Pacific index
OCN	Oregon Coast Natural
OCNL	OCN lakes component
OCNR	OCN riverine component
OCV	Ordinary cross-validation
ONI	Ocean Niño index
OPI	Oregon Production Index
OPIH	Oregon Production Index hatchery
PDO	Pacific Decadal Oscillation
R	Number of OCN coho adult recruits
R^2	Coefficient of determination
RI	Regime index (RI = 1 from 1990 to 2000, else RI = 0)
SLP	Sea level pressure
SPR	Spring transition date
SSH	Sea surface height
SST	Sea surface temperature
UWI	Upwelling wind index
α	Level of significance for an individual test
α_0	Level of significance for multiple tests
ρ	Pearson's correlation coefficient

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Appendix A: Testing for significant correlation

Both the OCN recruit time series and the time series of environmental variables show strong to moderate autocorrelation (data not shown). When testing for significant cross-correlation between pairs of variables, autocorrelation has the effect of increasing the probability of erroneously rejecting the null hypothesis at a given level of significance α under the assumption of serial independence. In other words, autocorrelation has the effect of reducing the number of degrees of freedom. To calculate the effective degrees of freedom under autocorrelation, we used the method of Pyper and Peterman (1998).

Moreover, when testing for significant correlation between recruits and a given environmental index, we are actually making 13 individual comparisons. This multiple testing is known as "multiplicity" and has the effect of increasing the probability of erroneously rejecting at least one null hypothesis (e.g. Katz and Brown, 1991). Various methods have been developed to account for multiple comparisons (Miller, 1981), but a very simple one is to make the following calculation for the significance level of an individual test α necessary to achieve an overall level α_0 for all K comparisons:

$$\alpha = 1 - (1 - \alpha_0)^{1/K} \qquad \text{(A1)}$$

Eq. (A1) assumes the K comparisons are independent. However, the lags of the monthly means are moderately to strongly correlated (particularly given we have calculated 3-month running means). This means the effective number of comparisons is actually smaller than K.

There have been investigations into the question of coping with multiplicity given autocorrelation in the individual time series and dependency among the individual tests (e.g., correlation between lags) (Katz and Brown, 1991; Olden and Neff, 2001). However, we still lack an analytical adjustment to account for multiplicity under arbitrary autocorrelation and lag-correlation structures. Therefore, we took the simple approach of Mueter et al. (2005), which was to apply a significance level of $\alpha = 0.01$ in place of the more standard $\alpha = 0.05$, assuming that the effective number of tests ranged from $K = 5$ to 10 (out of 13) for strong to moderate correlation among lags. This meant that α_0 would range between approximately 0.05 and 0.1 for each environmental variable.

Table 1. Chronology of forecast models for OCN river coho recruits R	
Years used	Model[1]
1988-1993	$\log R = \log N_{spawners} + b_0 + b_1 N_{spawners} + b_2 N_{jacks.OPIH} / N_{smolts.OPIH}$
1994-1995	$\log R = b_0 + b_1 \mathbf{UWI.AMJ} + b_1 \mathbf{SST.J} + b_3 \mathbf{Year}$
1996-1998	$\log R = b_0 + b_1 \mathbf{UWI.AMJ} + b_1 \mathbf{SST.J}$
1999-2002	$\log R = b_0 + b_1 \mathbf{UWI.AMJ} + b_1 \mathbf{SST.J} + b_3 \mathbf{Year}$
2003-2007	$\log R = b_0 + b_1 \mathbf{UWI.AMJ} + b_1 \mathbf{SST.J}$
2008	$R_{2008} = R_{2007}$
2009-2010	$\log R = b_0 + b_1 \mathbf{UWI.AMJ} + b_1 \mathbf{SST.J} + b_3 \mathbf{RI}$

UWI.AMJ = mean upwelling winds index in April-June of ocean migration year @ 42º N 125º W
SST.J = mean sea surface temperature in January of return year @ Charleston, OR.
RI = regime index
[1]See Notation section and Section 2.1.11 for further description of terms.

Table 2. Sources for ocean indices	
Name	URL
MEI	http://www.esrl.noaa.gov/psd//people/klaus.wolter/MEI/table.html
NPGO	http://www.o3d.org/npgo/data/NPGO.txt
NPI	http://www.cgd.ucar.edu/cas/jhurrell/indices.data.html#npmon
ONI	ftp://ftp.cpc.ncep.noaa.gov/wd52dg/data/indices/sstoi.indices
PDO	http://jisao.washington.edu/pdo/PDO.latest
SLP	http://www.esrl.noaa.gov/psd/data/gridded/data.ncep.reanalysis.derived.surface.html
SPR[1]	http://www.cbr.washington.edu/data/trans_data.html
SSH	http://ilikai.soest.hawaii.edu/uhslc/datai.html
SST[2]	http://opendap.co-ops.nos.noaa.gov/dods/IOOS/Water_Temperature.html
UWI	ftp://orpheus.pfeg.noaa.gov/outgoing/upwell/monthly/upindex.mon

[1]SPR at site listed above is still only current through 2008. This needs to be kept up-to-date or we need to provide another source for this information.

[2]SST was compiled from various sources. See text for details.

Table 3. Correlation coefficients[1] for log OCNR coho recruits with environmental indices

	Environmental index								
Month[2]	MEI	NPGO	NPI	ONI	PDO	SSH	SST	UWI	SPR[2]
D*JF	-0.14	0.39	0.09	-0.06	-0.22	-0.24	-0.41	0.08	
JFM	-0.16	0.35	0.04	-0.08	-0.27	-0.33	-0.40	0.20	
FMA	-0.24	0.36	0.13	-0.13	-0.33	-0.43	-0.41	0.28	
MAM	-0.26	0.40	0.23	-0.22	-0.46	-0.54	-0.39	0.41	-0.47
AMJ	-0.35	0.43	0.36	-0.26	-0.56	-0.58	-0.34	0.34	
MJJ	-0.45	0.45	-0.04	-0.25	-0.60	-0.58	-0.12	0.02	
JJA	-0.40	0.45	-0.19	-0.20	-0.54	-0.51	-0.01	-0.05	
JAS	-0.35	0.46	-0.11	-0.20	-0.44	-0.41	-0.05	-0.19	
ASO	-0.36	0.48	-0.06	-0.19	-0.30	-0.37	-0.19	-0.16	
SON	-0.33	0.48	-0.13	-0.20	-0.22	-0.31	-0.27	-0.10	
OND	-0.32	0.47	-0.08	-0.20	-0.15	-0.25	-0.35	-0.07	
NDJ**	-0.29	0.40	0.01	-0.21	-0.16	-0.30	-0.43	0.05	
D	-0.29	0.41	0.06	-0.21	-0.11	-0.15	-0.38	0.05	
J**	-0.28	0.29	0.11	-0.20	-0.21	-0.36	-0.49	0.13	

[1]Significant correlations are shaded in gray. See text for explanation.
[2]All months are for the calendar year of ocean entry, unless denoted by an asterisk: (*) = year prior to ocean entry, (**) = year of return to freshwater.
[3]Spring transition occurs once per year, so monthly average has no meaning. The SPR value has been placed with MAM because SPR typically occurs during these months.

Table 4. Correlation coefficients[1] for log OCNR coho recruits with PDO					
	Years[3]				
Month[2]	1	2	3	4	5
D*JF	-0.22	-0.31	-0.36	-0.37	-0.36
JFM	-0.27	-0.38	-0.42	-0.42	-0.41
FMA	-0.33	-0.44	-0.48	-0.49	-0.47
MAM	-0.46	-0.55	-0.61	-0.63	-0.60
AMJ	-0.56	-0.65	-0.70	-0.73	-0.70
MJJ	-0.60	-0.70	-0.74	-0.79	-0.76
JJA	-0.54	-0.66	-0.72	-0.79	-0.77
JAS	-0.44	-0.58	-0.65	-0.74	-0.73
ASO	-0.30	-0.42	-0.52	-0.63	-0.64
SON	-0.22	-0.31	-0.40	-0.51	-0.54
OND	-0.15	-0.21	-0.28	-0.38	-0.42
NDJ**	-0.16	-0.23	-0.29	-0.36	-0.39
D	-0.11	-0.16	-0.19	-0.24	-0.28
J**	-0.21	-0.27	-0.33	-0.38	-0.40

[1]Significant correlations are shaded in gray. See text for explanation.
[2]All months are for the calendar year of ocean entry, unless denoted by an asterisk: (*) = year prior to ocean entry, (**) = year of return to freshwater.
[3]Number of years prior to return over which PDO was averaged.

Table 5. Selected models								
Predictor variables[1]			Performance statistics					
1[2]	2	3	GCV	AIC	R^2	OCV^*	HFS	Fore-cast[3]
PDO.MJJ	UWI.JAS	NPGO.OND	0.126	31.4	0.81	0.73	0.53	NA
PDO.MJJ	SPR†	log $N_{spawners}$†	0.136	35.1	0.77	0.70	0.67	206
PDO.MJJ	MEI.OND†	UWI.JAS	0.140	36.1	0.78	0.69	0.50	180
PDO.MJJ	SPR†	NPI.JFM	0.141	36.6	0.77	0.67	0.67	179
PDO.MJJ	SPR†	MEI.OND†	0.142	36.7	0.77	0.69	0.63	189
PDO.MJJ	UWI.JAS	SST.AMJ†	0.144	37.1	0.77	0.68	0.42	246
PDO.MJJ	SPR†	ONI.OND	0.144	37.3	0.76	0.67	0.62	187
PDO.MJJ	SSH.AMJ†	UWI.JAS	0.145	37.4	0.77	0.67	0.49	208
PDO.MJJ	UWI.SON†	SST.J†	0.145	37.7	0.76	0.66	0.58	215
Ensemble mean[4]					*0.81*	*0.74*	*0.60*	*206*
PDO.MJJ	SPR†		0.149	38.9	0.74	0.67	0.64	213
PDO.MJJ	MEI.OND†		0.158	41.2	0.72	0.65	0.56	170
PDO.MJJ	NPGO.OND		0.160	41.6	0.73	0.64	0.57	–
PDO.MJJ	ONI.OND		0.161	41.9	0.73	0.62	0.55	168
PDO.MJJ	UWI.JAS		0.162	42.2	0.73	0.64	0.42	206
PDO.MJJ	SSH.AMJ†		0.166	43.2	0.71	0.63	0.56	199
PDO.MJJ	SST.J†		0.172	44.8	0.70	0.61	0.50	169
PDO.MJJ	log $N_{spawners}$		0.180	46.3	0.70	0.59	0.49	212
PDO.MJJ	NPI.JFM†		0.180	46.6	0.68	0.59	0.52	165
Ensemble mean[5]					*0.75*	*0.67*	*0.56*	*194*

[1]Predictor variables in column-order of explanatory power and models in row order by GCV. Note that better fit is indicated by lower values of GCV and AIC, and by higher values of R^2, OCV*, and HFS.
[2]Average of prior 4 years of mean of PDO.MJJ.
[3]Forecast of 2010 OCN coho adult recruits (in thousands). The NPGO index for Oct. 2009 through Jan. 2010 was not available in time to use in forecast models.
[4]Excludes models that contain NPGO, ONI and NPI.
†Linearly related to predictand.

Table 6. Final selected forecast models of OCNR coho recruitment

Predictor variables[1]			Performance statistics					
1[2]	2	3	GCV	AIC	R^2	OCV*	HFS	Forecast[3]
PDO.MJJ	SPR	log $N_{spawners}$	0.136	35.1	0.77	0.70	0.67	206
PDO.MJJ	MEI.OND	UWI.JAS	0.140	36.1	0.78	0.69	0.50	180
PDO.MJJ	SPR	MEI.OND	0.142	36.7	0.77	0.69	0.63	189
PDO.MJJ	UWI.JAS	SST.AMJ	0.144	37.1	0.77	0.68	0.42	246
PDO.MJJ	SSH.AMJ	UWI.JAS	0.145	37.4	0.77	0.67	0.49	208
PDO.MJJ	UWI.SON	SST.J	0.145	37.7	0.76	0.66	0.58	215
Ensemble mean					*0.81*	*0.74*	*0.60*	*206*

[1]Predictor variables in column-order of explanatory power.
[2]Average of prior 4 years of mean of PDO.MJJ.
[3]Forecast of 2010 OCNR coho adult recruits (in thousands).

Table 7. Actual OCN river coho recruitment and forecasted recruitment using past and proposed method for the years 1996 – 2010

Year	Actual recruits (thousands)	Forecasted recruits (thousands)	
		Past Model[1]	Proposed Model[2]
1996	65.4	50.1	68.2
1997	18.7	74.3	68.7
1998	23.2	34.4	40.8
1999	39.2	48.1	54.9
2000	60.2	43.9	88.1
2001	157.6	38.1	145.0
2002	246.8	57.2	220.4
2003	227.8	97.8	183.2
2004	165.9	125.4	157.5
2005	130.5	133.1	143.6
2006	101.1	44.6	75.1
2007	62.8	236.9	67.0
2008	144.7	50.0	115.8
2009	237.8	191.4	175.8
2010	NA	131.4	207.2
HFS [3]		*-0.17*	*0.72*

[1]Actual forecast made using models given in Table 1.
[2] Mean forecast from proposed models in operational mode, i.e., 1-year lead forecasts are made from the GAMs fitted to the data for all years prior to the forecast year (i.e., the models are refitted with the additional year of data prior to each forecast).
[3]Historical forecast skill score for 1996 – 2009.

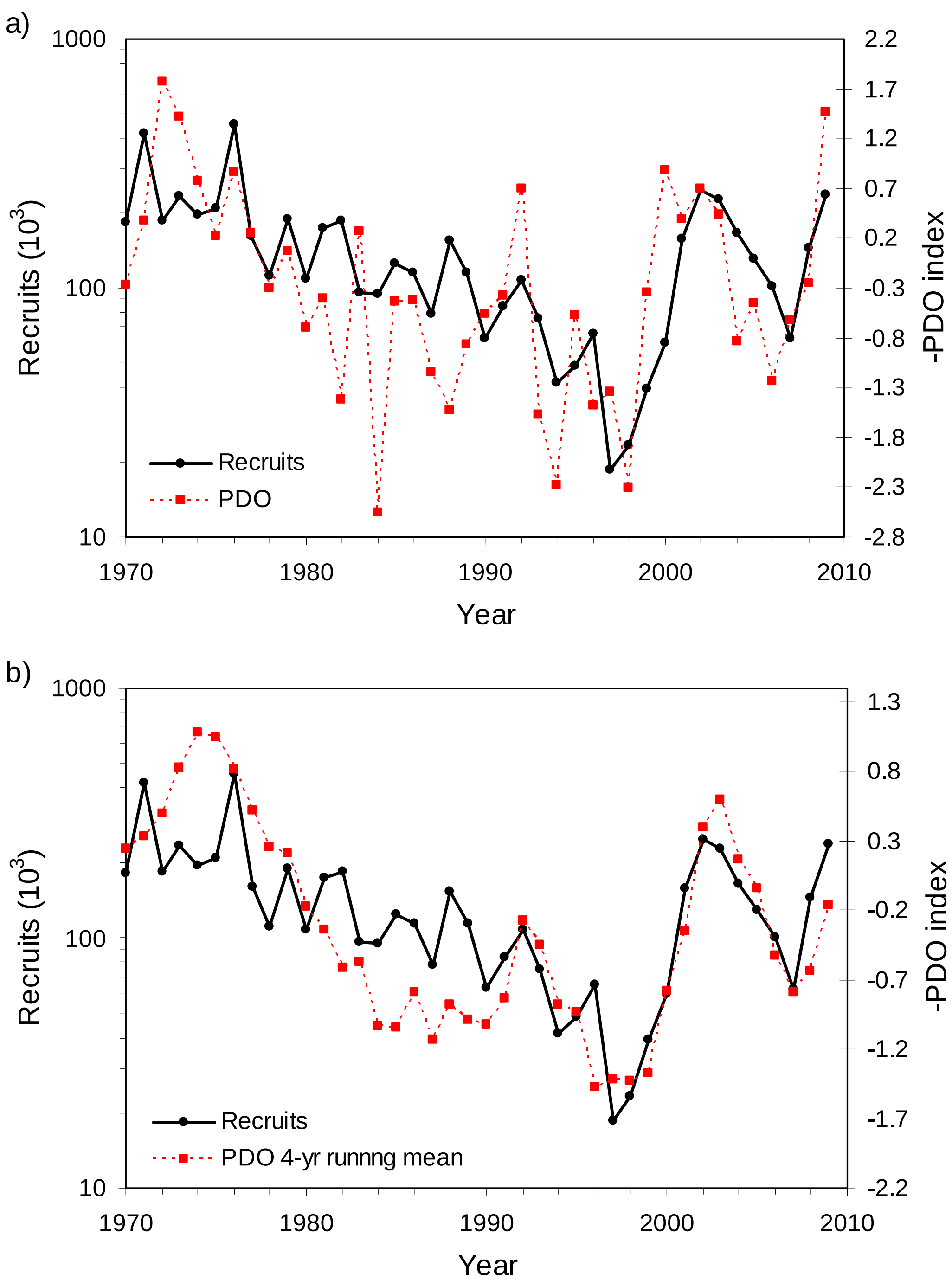

Fig. 1. Time series of OCN coho river recruits during year of return to freshwater with the mean May-June-July PDO index of the ocean entry year (PDO.MJJ.t1) (a), and with the mean of the 4 years of PDO.MJJ.t1 up to the ocean entry year (b). Note the sign of the PDO index has been reversed so that changes in recruits are in the same direction as changes in the PDO index.

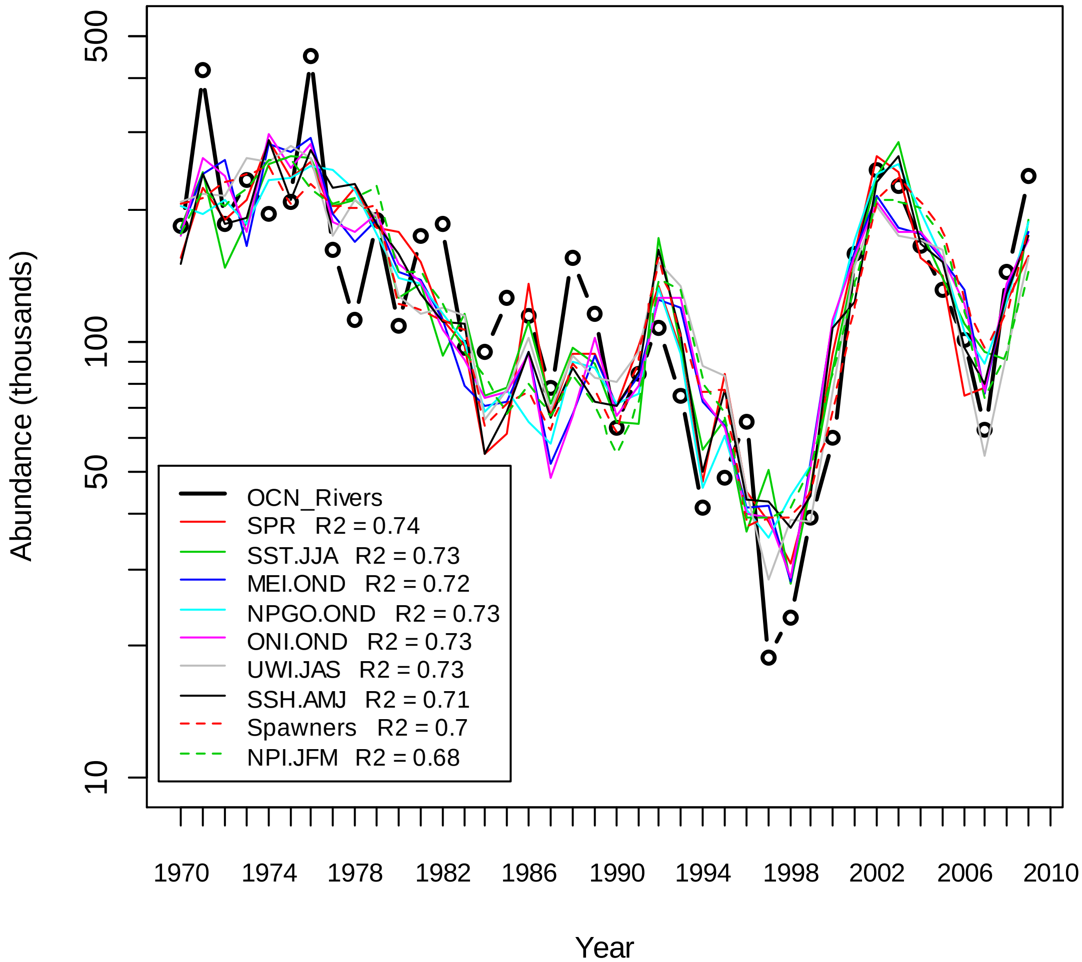

Fig. 2. Time series of observed and modeled Oregon coast natural river coho salmon adult recruits. The open circles with the thick line are the observations and the colored lines represent the predicted values from selected models using PDO.MJJ-4 combined with a second predictor variable (as given in the legend).

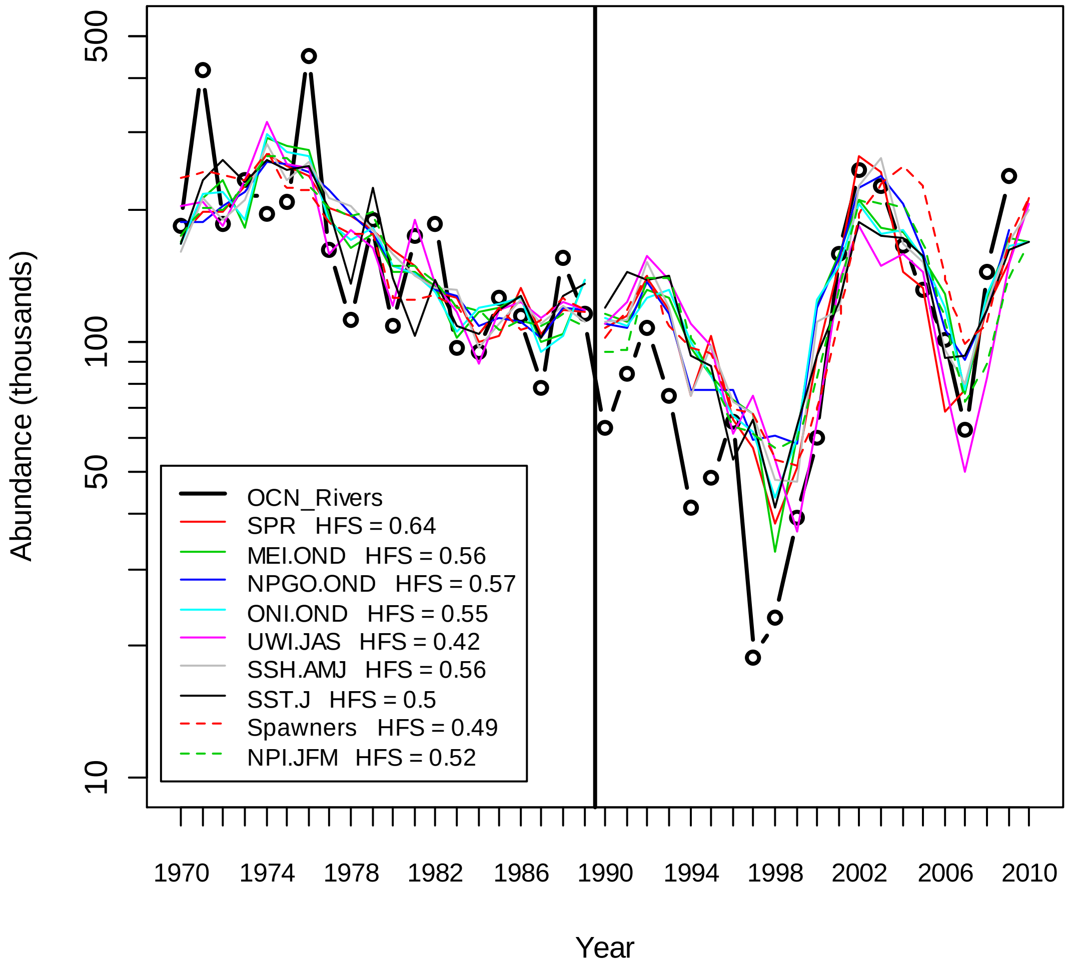

Fig. 3. Time series of observed Oregon coast natural river coho salmon adult recruits with forecasts from models using PDO.MJJ-4 combined with a second predictor variable (as given in the legend). The open circles with the thick line are the observations, the dashed/solid colored lines represent predictions/forecasts. The predictions shown prior to 1990 are from the models fitted to the 1970 – 1989 period, while the values for 1990 and after are 1-year lead forecasts from the models fitted to the data for all years prior to the forecast year (i.e., the models are refitted with the additional year of data prior to each forecast). Also shown is the "historical forecast skill" (HFS) for the period 1990 – 2009 (see text for details).

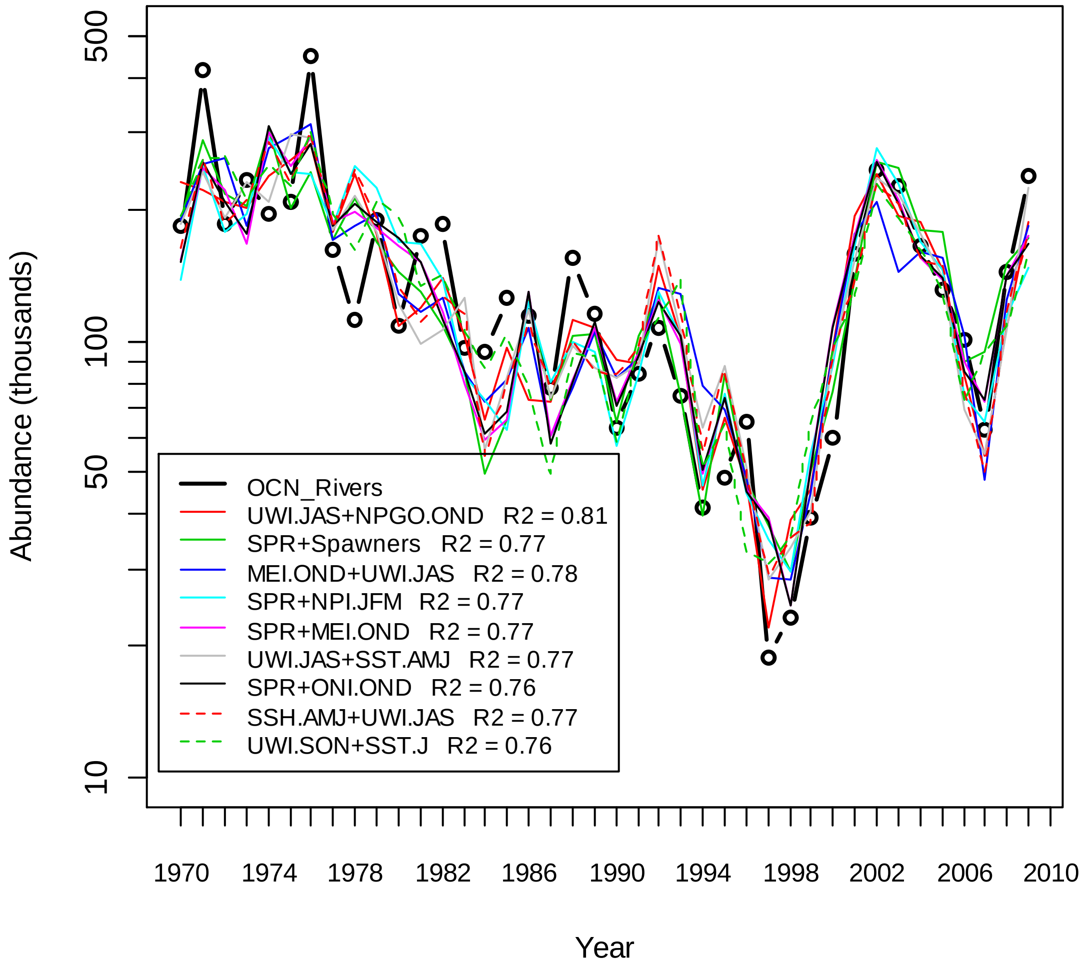

Fig. 4. Time series of observed and modeled Oregon coast natural river coho salmon adult recruits. The open circles with the thick line are the observations and the colored lines represent the predicted values from selected three-variable models.

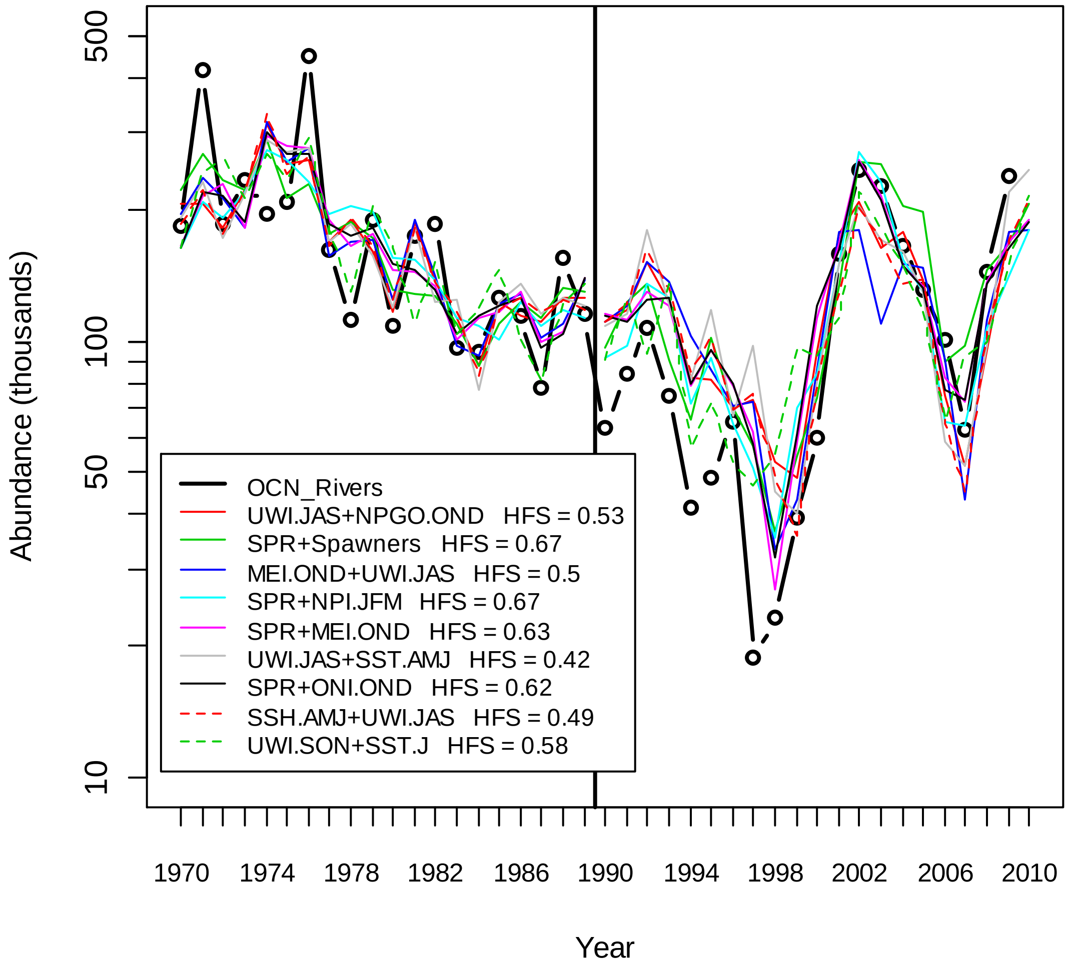

Fig. 5. Time series of observed Oregon coast natural river coho salmon adult recruits with forecasts from selected 3-variable models. The open circles with the thick line are the observations, the dashed/solid colored lines represent predictions/forecasts. See Fig. 5 caption for details.

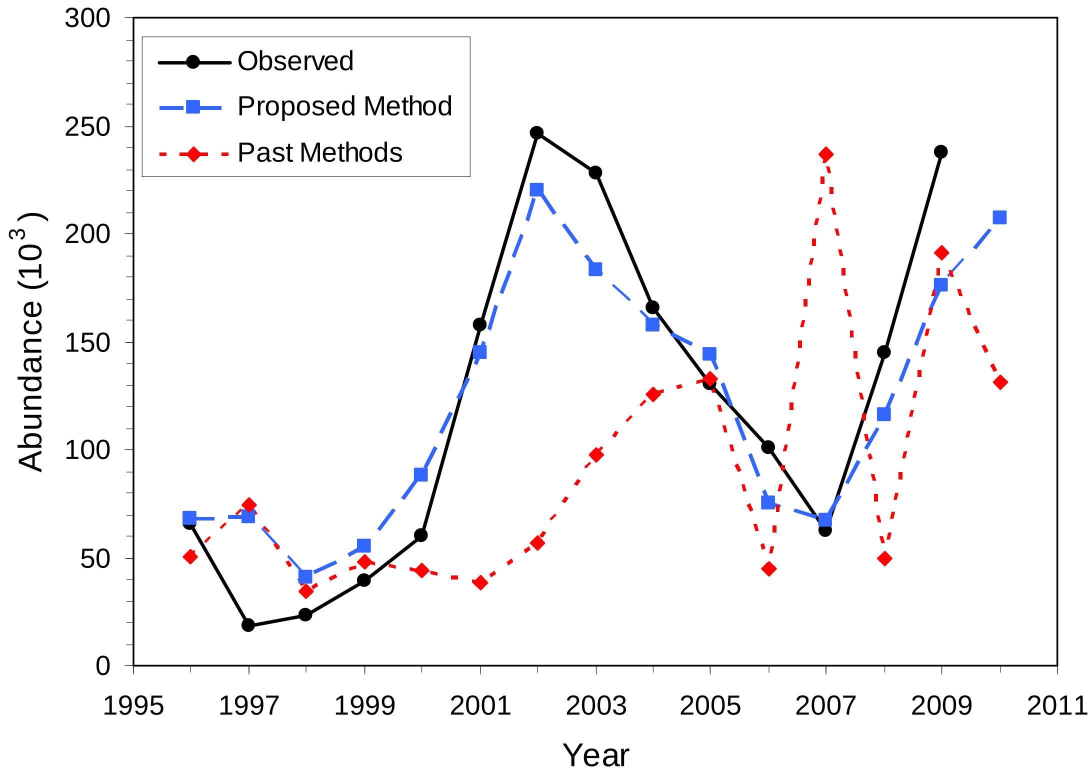

Fig. 6. Observed and forecasted Oregon coast natural river coho salmon adult recruits for the period 1996 – 2010. The blue dashed line shows the forecasts that would have been made using the method proposed in this report and the red dotted line show the actual forecasts that were made using the past methods summarized in Table 1.

Appendix B: Partial regression plots for selected GAMs

This appendix provides partial regression plots for the GAMs of Oregon coast natural river coho salmon adult recruits. Confidence limits (95%; dashed lines) and partial residuals around the fitted lines are shown.

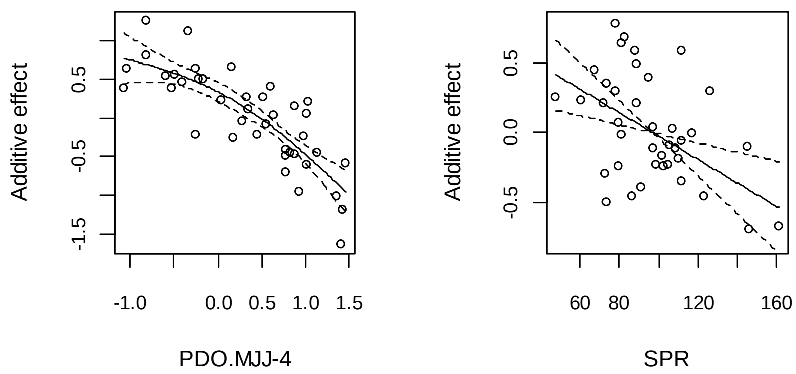

Fig. B1. Partial regression plots for log recruits against PDO.MJJ-4 and SPR.

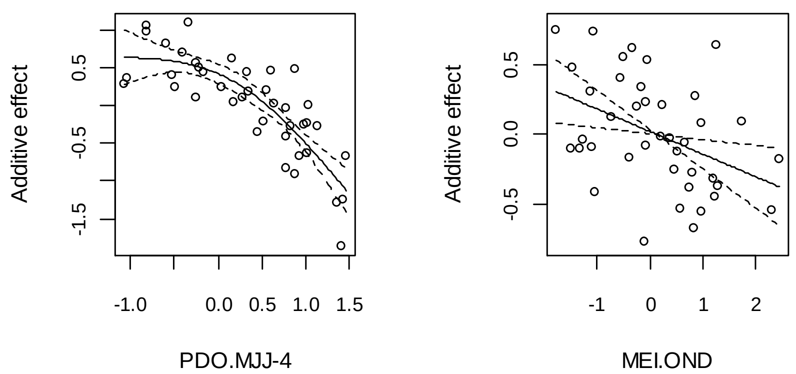

Fig. B2. Partial regression plots for log recruits against PDO.MJJ-4 and MEI.OND.

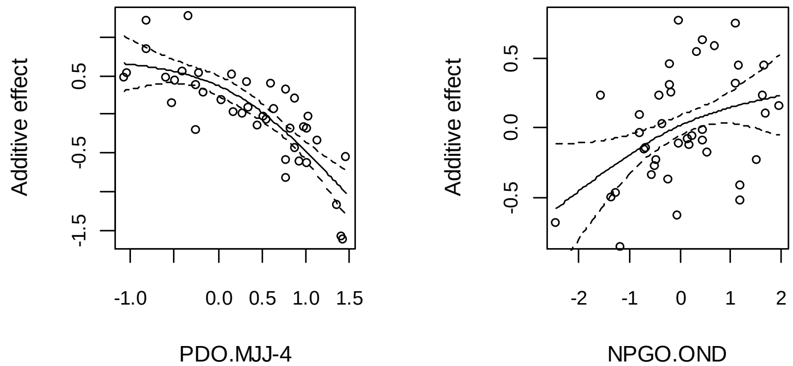

Fig. B3. Partial regression plots for log recruits against PDO.MJJ-4 and NPGO.OND.

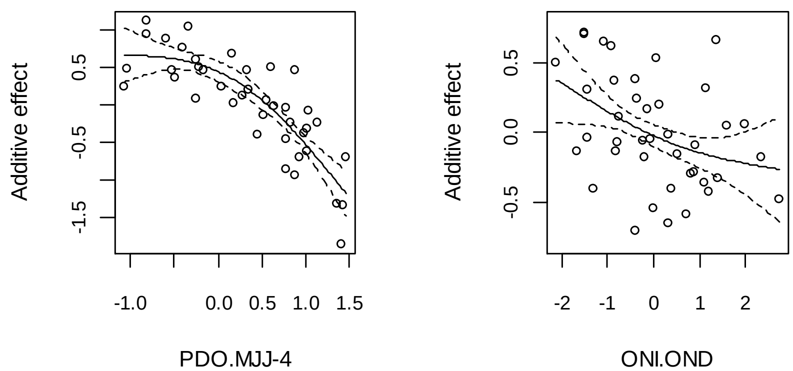

Fig. B4. Partial regression plots for log recruits against PDO.MJJ-4 and ONI.OND.

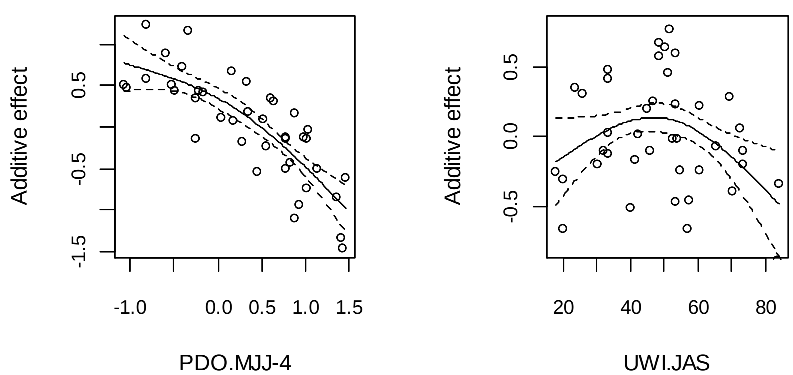

Fig. B5. Partial regression plots for log recruits against PDO.MJJ-4 and UWI.JAS.

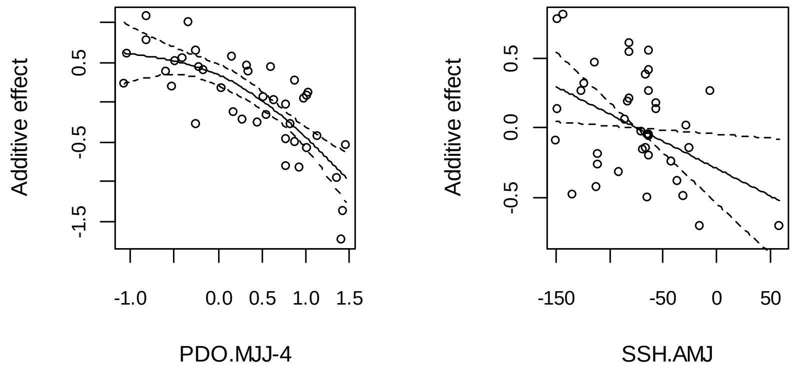

Fig. B6. Partial regression plots for log recruits against PDO.MJJ-4 and SSH.AMJ.

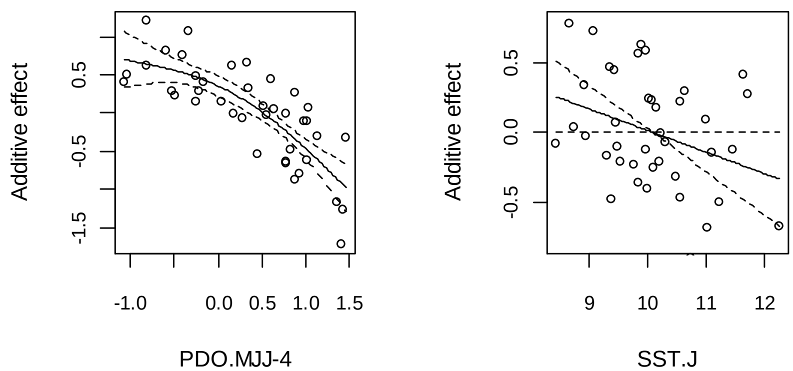

Fig. B7. Partial regression plots for log recruits against PDO.MJJ-4 and SST.J.

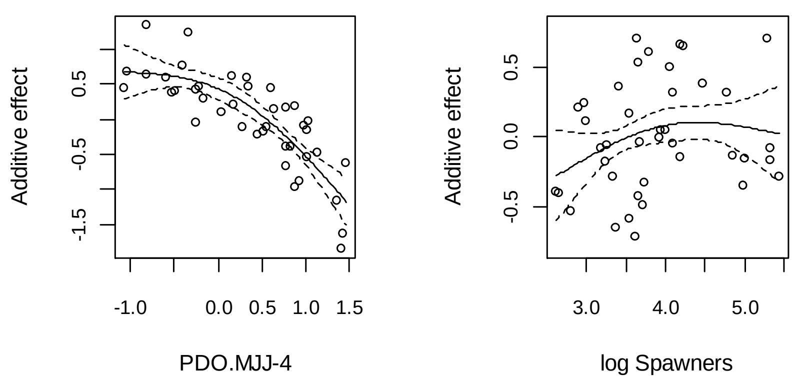

Fig. B8. Partial regression plots for log recruits against PDO.MJJ-4 and log Spawners.

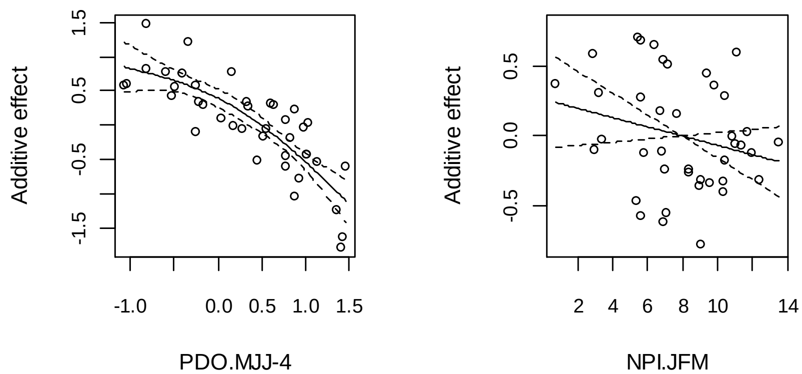

Fig. B9. Partial regression plots for log recruits against PDO.MJJ-4 and NPI.JFM.

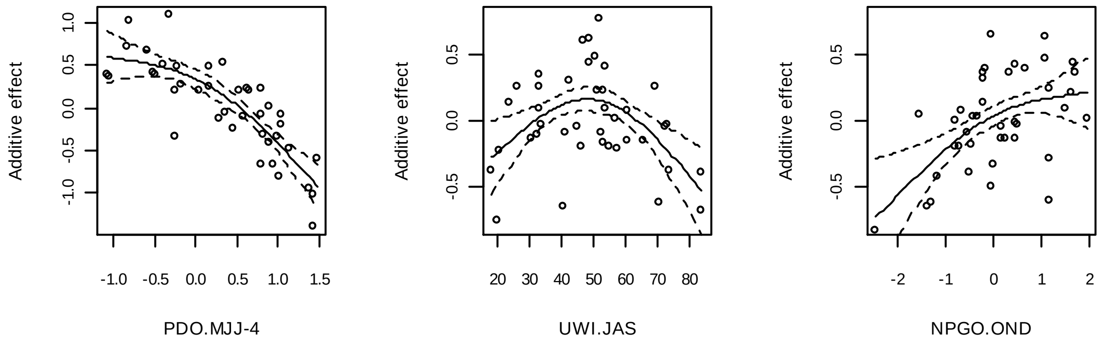

Fig. B10. Partial regression plots for log recruits against PDO.MJJ-4, UWI.JAS and NPGO.OND.

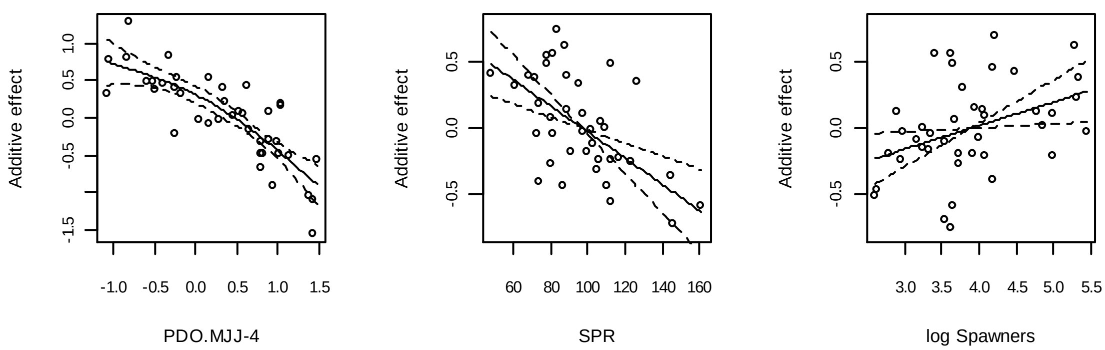

Fig. B11. Partial regression plots for log recruits against PDO.MJJ-4, SPR and log $N_{spawners}$.

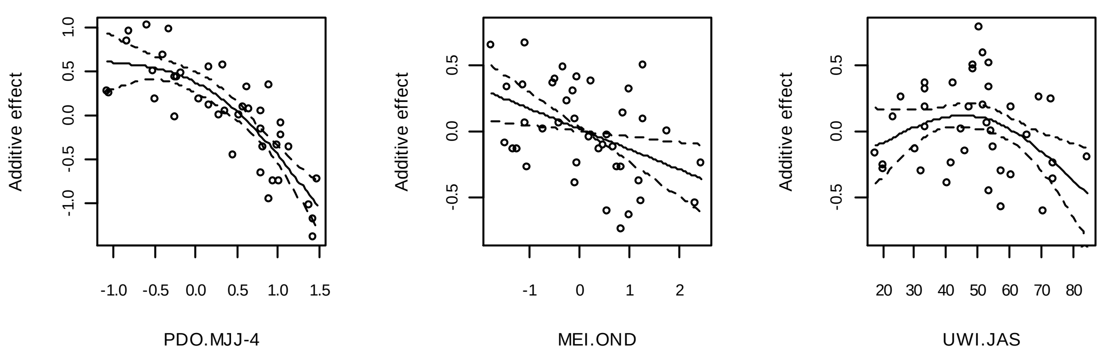

Fig. B12. Partial regression plots for log recruits against PDO.MJJ-4, MEI.OND and UWI.JAS.

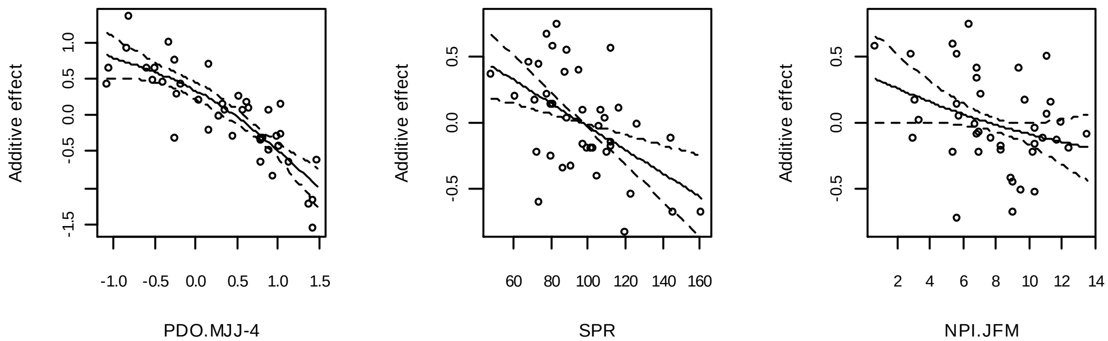

Fig. B13. Partial regression plots for log recruits against PDO.MJJ-4, SPR and NPI.OND.

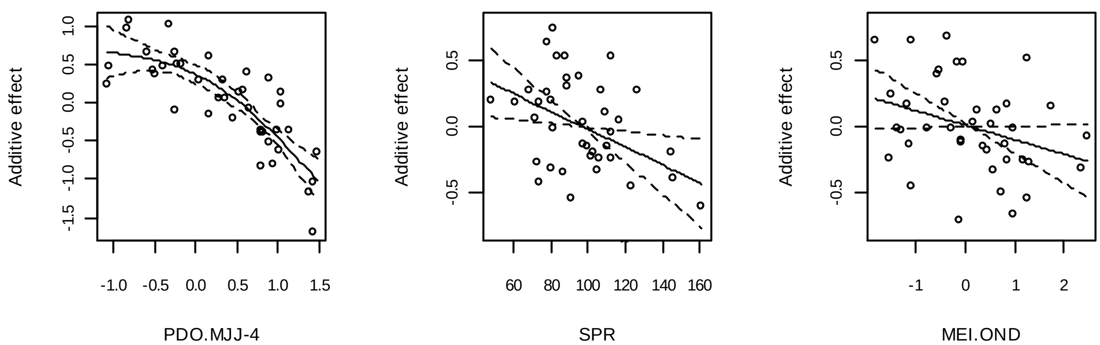

Fig. B14. Partial regression plots for log recruits against PDO.MJJ-4, SPR and MEI.OND.

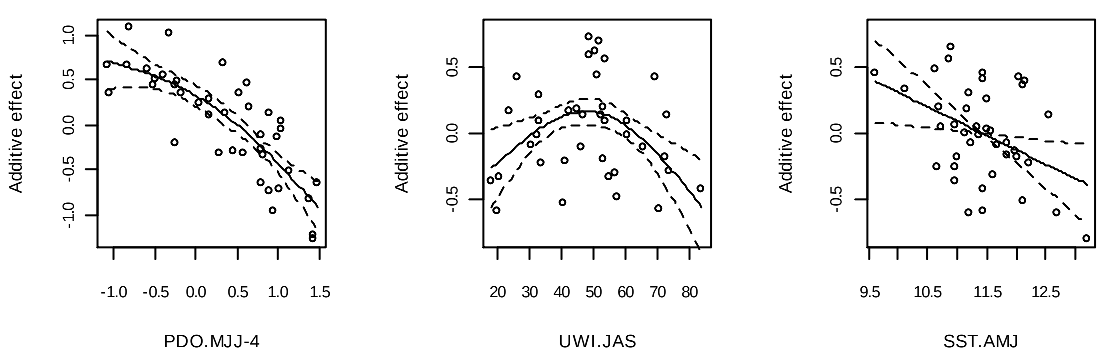

Fig. B15. Partial regression plots for log recruits against PDO.MJJ-4, UWI.JAS and SST.AMJ.

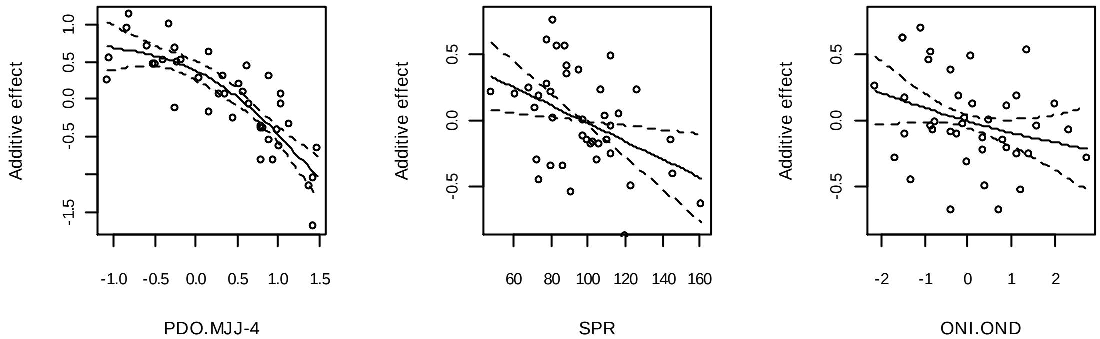

Fig. B16. Partial regression plots for log recruits against PDO.MJJ-4, SPR and ONI.OND.

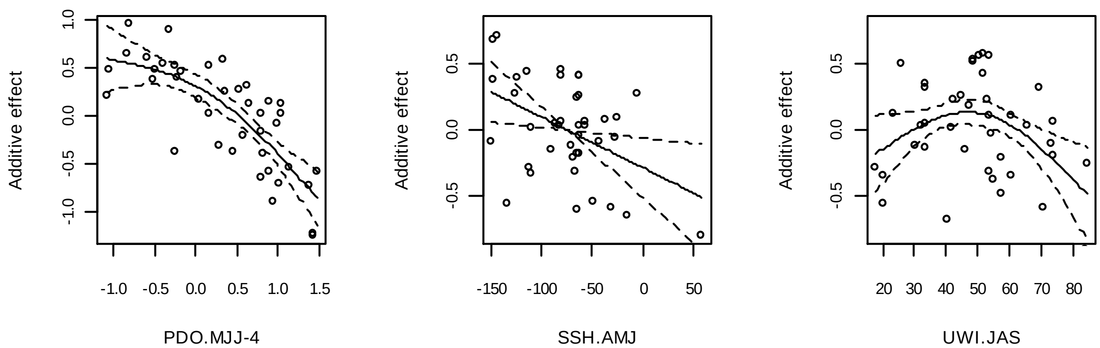

Fig. B17. Partial regression plots for log recruits against PDO.MJJ-4, SSH.AMJ and UWI.JAS.

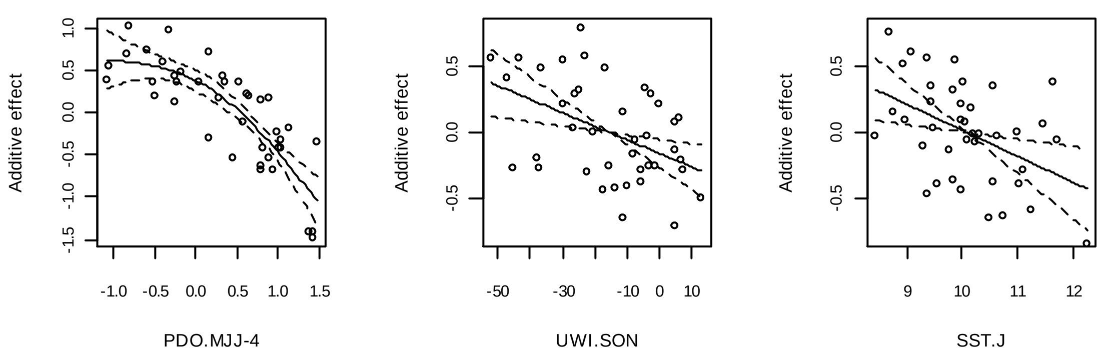

Fig. B18. Partial regression plots for log recruits against PDO.MJJ-4, UWI.SON and SST.J

Salmon Methodology Review

Coded-Wire Tag Representation for Columbia River Summer Chinook in FRAM

October 20, 2010

Prepared by Larrie La Voy, STT/MEW

BACKGROUND

The current run of Columbia River summer Chinook produced in areas upstream of Priest Rapids Dam is descended from the Chinook populations that were blocked by construction of Grand Coulee Dam in 1939-41. The Grand Coulee Fish Maintenance Project was a federally funded program that was intended to relocate salmon runs blocked by the dam into tributaries located downstream via hatchery programs and adult fish transfers to spawning areas. Historically, upper Columbia summer Chinook were considered to be "ocean-type" fish that migrated to the ocean as fingerlings as opposed to "stream-type" which migrate as yearlings; a life history commonly associated with spring run Chinook. Production from the federal hatcheries funded under this program located on the Methow and Entiat rivers, and Icicle Creek (Wenatchee Basin) initially released several salmon species/runs but had limited success with most stocks and became entirely used for spring Chinook production in the mid-1970's. Wells Hatchery located at the base of Wells Dam began operation in 1967 and has released summer Chinook and steelhead since then. Coded-wire tagging of summer Chinook from Wells Hatchery began in the late 1970's and has continued as an annual program to produce tag groups to represent summer Chinook in fisheries exploitation analysis for all of the production in tributaries and mainstem areas upstream of Priest Rapids Dam. Hatchery supplementation in the upper Columbia was expanded in the late 1980's to produce a wide range of salmon species/stocks including a significant number of yearling summer Chinook from acclimation ponds in the Wenatchee and Methow basins.

The Chinook Technical Committee (CTC) under the direction of the Pacific Salmon Commission (PSC) conducts an annual exploitation rate analysis of ongoing CWT indicator tag groups and these studies have shown a greater contribution of upper Columbia summer Chinook to marine area fisheries south of the U.S. and Canada border. Since the mid 1990's, scale age readings have shown a substantial portion of the juvenile summer Chinook are overwintering in the mainstem Columbia reservoirs and out-migrating in the late winter/spring similar to a stream-type life history. As part of their annual exploitation rate analysis, the CTC uses a combination of yearling and fingerling coded-wire tag groups from Wells Hatchery when both release types have been tagged. A review of the CWT data representing upper Columbia summer Chinook was warranted given this information on life history patterns, increases in hatchery supplementation of fingerling and yearling production and results from the PSC CWT indicator tagging program.

METHOD

CODED-WIRE TAG GROUPS

The current FRAM base period dataset contains 1976-77 brood fingerling tag groups from Wells Hatchery (Table 1). Survival of these tag groups was relatively poor and may not have been high enough to provide recoveries in fisheries that were not in the main migration/rearing path of this stock. The number of recoveries of the proposed additional CWT groups is higher, especially for the yearling tag groups. The proposed CWT groups were selected because of their higher survival and availability across a wide range of fisheries in 2000-2005 including the Vancouver Island troll fishery that has a different season structure than during the base period. The blending of the recovery data from the base period tag groups with the recoveries from the new tag groups was done after the "Out-of-Base" (OOB) simulation process was performed on the new groups.

Table 1. Coded-wire tag release groups from Wells Hatchery used to represent Columbia River summer Chinook in FRAM Base Period data set.

		Recoveries	
Tag Code	**Brood Year**	**Observed**	**Estimated**
Current Base Period Groups			
631607	1976 Fingerling	46	117
631642	1976 Fingerling	173	322
631762	1977 Fingerling	82	177
Proposed Additional Groups			
631018	1998 Fingerling	147	350
631061	1998 Yearling	3809	9171
630267	1999 Fingerling	207	511
630468	1999 Yearling	540	1581
630775	2000 Fingerling	81	189
630995	2000 Yearling	3018	8105

OUT-OF-BASE SIMULATION AND FRAM BASE PERIOD DATASET

An estimate of the number of tags from the proposed groups that would have been recovered during the base period was calculated using OOB process. Available CWT data for the OOB tag groups are translated to equivalent base period recovery and escapement data using known fishing effort and harvest relationships between recovery years. For this OOB exercise, FRAM based fishing effort scalars from post season runs for the 2000-2005 fisheries were used to simulate the number of base period recoveries by fishery, age, and time period from the recoveries that did occur for the 1998-2000 brood year tag groups. See MEW (2007b) for a more detailed description of the development of the Chinook base period data.

Because of the large differences in the number of tag recoveries between the base period fingerling groups and the OOB tag groups of fingerlings and yearlings, the estimated number of recoveries was adjusted to weight the base period and OOB tag data. Combining both base period and OOB tag data provides representation for Columbia summer Chinook across a wide range of fisheries and season structure. For the OOB broods, the number of fingerling recoveries by fishery, age, and time period were increased so that the sum was equal to the total recoveries for the yearling counterpart. This 1:1 relationship between fingerlings and yearlings is approximately the proportion observed in the scale readings from naturally produced summer Chinook in the upper Columbia River. The adjusted tag recoveries were then combined to produce a single dataset for each brood representing fingerling and yearling production. The simulated recoveries from each of the OOB brood groups were merged with the Wells Hatchery base period tag recovery data to create one recovery dataset representing Columbia River summer Chinook in FRAM.

Using this new dataset representing Columbia River summer Chinook, a new FRAM base period dataset was developed from a cohort reconstruction for each of the FRAM stocks using the calibration programs CHDAT and CHCAL (MEW 2007b).

BASE PERIOD COMPARISON

Exploitation and river return rates were compared for the two FRAM base period runs (Table 1). Exploitation rates were similar in northern fisheries (southeast Alaska and Other BC), but dramatically different for Vancouver Island. Some or all of this difference may be attributed to the different impact rates for the new tag groups as a result of the different season structure in the Vancouver Island troll fishery that began in the late 1990's. For the new base period, the exploitation rate in Council fisheries of 3.9% is more than double the current base period but is still below 5% total.

Adult equivalent total fishing mortality in Council fisheries does not show the same patchwork pattern using the new base period dataset as the current dataset that uses only 1976-77 brood tag recovery data (Table 2). Fishery mortalities are distributed more appropriately across time and fishery under the new base period. The presence or absence of impacts in adjacent fisheries is the strongest evidence that the current base period dataset is inadequate to properly represent impacts in Council fisheries.

Table 1. Chinook FRAM Base Period (BP) adult equivalent (AEQ) exploitation and river return rates for Columbia River summer Chinook.

Fishery/Region	Base Period Rates Current BP	New BP
S.E. Alaska	0.165	0.157
Other BC	0.233	0.194
West Coast Vancouver Is.	0.135	0.329
Council-No. of Falcon	0.011	0.028
Council-So. of Falcon	0.006	0.011
Other U.S. marine	0.000	0.003
River Return (fisheries +esc.)	0.448	0.278

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Table 2. AEQ total mortality for Columbia River summer Chinook during the FRAM Base Period.

	Current Base Period						New Base Period				
	Time 1	Time 2	Time 3	Time 4	Annual		Time 1	Time 2	Time 3	Time 4	Annual
PFMC Fishery	Oct-Apr	May-Jun	Jul-Sep	Oct-Apr	Total		Oct-Apr	May-Jun	Jul-Sep	Oct-Apr	Total
NT Area 3,4 Trl	0	0	0	0	0		0	97	123	0	220
T Area 3,4 Trl	183	1	8	183	192		160	23	34	160	217
NT Area 3,4 Spt	0	0	0	0	0		0	4	16	0	20
NT Area 2 Trl	0	0	0	0	0		0	250	161	0	411
T Area 2 Trl	0	0	0	0	0		0	3	3	0	6
NT Area 2 Spt	0	406	12	0	418		0	543	238	0	781
Area 1 Trl	0	0	0	0	0		0	420	48	0	468
Area 1 Spt	0	0	0	0	0		0	61	239	0	300
Central OR Trl	0	136	16	0	152		4	469	101	4	574
Central OR Spt	0	1	198	0	199		0	29	139	0	168
KMZ Troll	0	0	0	0	0		1	6	1	1	8
KMZ Spt	0	0	0	0	0		0	64	3	0	67
Ca Troll	0	0	0	0	0		0	14	1	0	15
Ca Spt	0	0	0	0	0		78	6	3	78	87

Comparisons in exploitation rates were made to the rates estimated by the CTC during their annual exploitation rate analysis process. Exploitation rates estimated by CTC for yearling CWT groups (Table 3) and fingerling (Table 4) show the annual variability that occurs by analyzing ongoing CWT indicator tag groups. Rates in Council fisheries are generally low (<10%) with rates for yearlings slightly higher (but not significant) than fingerlings. Generally, exploitation rates during 2001-05 were higher in Council fisheries than those during the adjacent years. The new base period data combines new and old tag groups so the effect of these higher impact years is dampened in the dataset that is intended to cover an "average" condition.

Exploitation rates using the current and new base period FRAM datasets were also compared to the CTC's annual CWT estimates of exploitation for 2003-08 (Table 5). Because of the annual variability in exploitation rates using ongoing CWT tag groups, it is unlikely the FRAM estimates will exactly match the CTC rates for any given year. On average though, the exploitation rate range for a fishery/region should be similar. Percentage of the marine area impacts in the 2003-07 fisheries occurring in the northern fisheries (Alaska and Canadian combined) was similar between the new base period and CTC estimates (86% vs 82% of marine fishery impacts, respectively) although the rates in each of the component fisheries differed considerably. Impacts in Council fisheries measured as exploitation rates or as percentage of marine area impacts were similar between the new base period model runs and the CTC estimates and both were much higher than the values using the current base period data for 2003-07.

CONCLUSIONS:

1. **The current FRAM base period dataset that uses only 1976-77 brood fingerling CWT groups from Wells Hatchery does not adequately represent all life history types of Columbia River summer Chinook.**
2. **The low survival and low number of recoveries for 1976-77 brood fingerling CWTs probably contributed to the patchwork pattern of recoveries in Council fisheries during the base period years.**
3. **Combining the tag recovery data from the original base period CWT groups with recovery data simulated back to the base period for 1998-2000 brood fingerling and yearling groups would provide better estimates of impacts to Columbia River summer Chinook covering a broad range of season structure in Council area and northern area fisheries.**

Supplementary Reference

MEW. 2007b. Chinook FRAM Base Data Development (Document prepared for the Council and its advisory entities). Pacific Fishery Management Council, 7700 NE Ambassador Place, Suite 101, Portland, Oregon 97220-1384.

Table 3. Distribution of total fishing mortality and escapement for PSC CWT indicator tag groups representing Columbia River yearling summer Chinook.

Catch Year	AK-BC	PFMC North of Falcon	PFMC South of Falcon	Other So.US Marine	Terminal	Escapement	Estimated CWT's Catch	Estimated CWT's Esc	Estimated CWT's Total
1986	30%	10%	0%	0%	13%	47%	14	14	28
1987	29%	8%	18%	4%	7%	34%	47	34	81
1988	44%	3%	0%	2%	18%	33%	156	97	253
1989	35%	11%	5%	4%	8%	37%	371	251	622
1990	42%	4%	4%	1%	10%	39%	491	352	843
1991	17%	3%	1%	1%	4%	74%	175	533	708
1992	41%	3%	3%	3%	1%	50%	124	141	265
1993	26%	6%	2%	0%	3%	64%	62	120	182
1994	35%	0%	0%	0%	0%	65%	5	15	20
1995	13%	0%	0%	5%	0%	82%	16	143	159
1996	31%	0%	2%	2%	6%	59%	104	247	351
1997	15%	0%	3%	0%	2%	80%	228	1028	1256
1998	15%	1%	1%	0%	5%	78%	276	1130	1406
1999	34%	6%	5%	0%	5%	51%	242	352	594
2000 a/	45%	3%	3%	1%	3%	45%	868	931	1799
2001 a/	39%	10%	11%	1%	2%	37%	3834	2668	6502
2002 a/	56%	7%	6%	0%	3%	28%	6983	3034	10017
2003 a/	55%	3%	5%	0%	9%	29%	4717	2101	6818
2004 a/	37%	4%	7%	3%	22%	27%	2920	1229	4149
2005 a/	30%	2%	4%	0%	15%	48%	4414	4459	8873
2006	26%	2%	1%	0%	19%	52%	1813	2108	3921
2007	18%	2%	1%	0%	16%	63%	1959	3622	5581
2008	11%	1%	0%	0%	35%	53%	438	518	956
1985-2008	30%	4%	3%	1%	13%	49%			
1979-1984	0%	0%	0%	0%	0%	0%			
1985-1995	28%	4%	3%	2%	15%	48%			
1996-1998	20%	0%	2%	1%	4%	72%			
1999-2008	35%	4%	4%	0%	13%	43%			

a/ Catch years associated with 1998-2000 brood year CWT groups

Table 4. Distribution of total fishing mortality and escapement for PSC CWT indicator tag groups representing Columbia River fingerling summer Chinook.

Catch Year	AK-BC	PFMC North of Falcon	PFMC South of Falcon	Other So.US Marine	Terminal	Escapement	Estimated CWT's Catch	Estimated CWT's Esc	Estimated CWT's Total
1979	63%	3%	4%	0%	4%	27%	110	54	164
1980	67%	2%	0%	0%	1%	30%	222	109	331
1981	38%	1%	0%	0%	1%	60%	123	189	312
1982	46%	0%	0%	0%	0%	54%	11	13	24
1983	--	--	--	--	--	--	0	0	0
1984	--	--	--	--	--	--	0	0	0
1985	30%	0%	0%	0%	0%	70%	3	7	10
1986	59%	0%	0%	0%	20%	21%	37	12	49
1987	49%	0%	13%	0%	26%	13%	36	6	42
1988	--	--	--	--	--	--	8	0	8
1989	--	--	--	--	--	--	0	7	7
1990	--	--	--	--	--	--	4	1	5
1991	14%	14%	0%	0%	0%	73%	6	16	22
1992	29%	6%	0%	0%	12%	53%	8	9	17
1993	53%	0%	0%	0%	7%	40%	16	12	28
1994	29%	0%	0%	0%	24%	47%	9	8	17
1995	--	--	--	--	--	--	0	0	0
1996	--	--	--	--	--	--	0	1	1
1997	56%	0%	0%	0%	2%	42%	17	18	35
1998	6%	0%	0%	0%	27%	67%	20	47	67
1999	26%	7%	4%	0%	0%	63%	60	157	217
2000 a/	46%	0%	1%	0%	2%	51%	261	318	579
2001 a/	40%	3%	9%	0%	9%	40%	161	132	293
2002 a/	52%	5%	8%	0%	6%	29%	252	125	377
2003 a/	62%	2%	6%	0%	8%	22%	299	100	399
2004 a/	25%	3%	9%	0%	19%	44%	242	211	453
2005 a/	28%	3%	6%	0%	8%	55%	320	427	747
2006	17%	0%	2%	0%	23%	58%	184	286	470
2007	20%	1%	0%	0%	15%	63%	191	381	572
2008	12%	2%	1%	0%	24%	61%	189	319	508
1979-2008	32%	2%	2%	0%	10%	43%			
1979-1984	36%	1%	1%	0%	1%	29%			
1985-1995	33%	2%	1%	0%	15%	40%			
1996-1998	21%	0%	0%	0%	10%	70%			
1999-2008	33%	3%	5%	0%	11%	49%			

a/ Catch years associated with 1998-2000 brood year CWT groups

Table 5. AEQ exploitation rates for Columbia River summer Chinook from FRAM post season runs and PSC Chinook Technical Committee (CTC) CWT analysis.

	2003 Fishing Year				2004 Fishing Year				2005 Fishing Year			
Fishery	**Current BP**	**New BP**	**CTC CWT Fing**	**CTC CWT Yrlng**	**Current BP**	**New BP**	**CTC CWT Fing**	**CTC CWT Yrlng**	**Current BP**	**New BP**	**CTC CWT Fing**	**CTC CWT Yrlng**
S.E. Alaska	0.083	0.096	0.288	0.289	0.090	0.124	0.106	0.160	0.093	0.122	0.123	0.097
Other BC	0.313	0.231	0.119	0.143	0.302	0.200	0.044	0.073	0.302	0.147	0.063	0.089
WCVI	0.038	0.177	0.208	0.117	0.048	0.133	0.100	0.136	0.059	0.228	0.090	0.114
PFMC NoF	0.002	0.031	0.020	0.031	0.003	0.030	0.027	0.043	0.002	0.046	0.032	0.024
PFMC SoF	0.028	0.093	0.064	0.046	0.028	0.037	0.094	0.071	0.030	0.053	0.061	0.042
Other U.S. marine	0.000	0.005	0.000	0.001	0.000	0.002	0.000	0.026	0.000	0.003	0.000	0.002
River Rtn	0.536	0.368	0.301	0.373	0.529	0.474	0.628	0.489	0.513	0.403	0.631	0.632

	2006 Fishing Year				2007 Fishing Year				2008 Fishing Year			
Fishery	**Current BP**	**New BP**	**CTC CWT Fing**	**CTC CWT Yrlng**	**Current BP**	**New BP**	**CTC CWT Fing**	**CTC CWT Yrlng**	**Current BP**	**New BP**	**CTC CWT Fing**	**CTC CWT Yrlng**
S.E. Alaska	0.104	0.125	0.057	0.109	0.126	0.171	0.102	0.098	0.089	0.121	0.094	0.073
Other BC	0.280	0.238	0.029	0.042	0.367	0.298	0.035	0.024	0.318	0.174	0.013	0.012
WCVI	0.032	0.085	0.086	0.104	0.032	0.091	0.066	0.052	0.026	0.108	0.015	0.020
PFMC NoF	0.001	0.027	0.002	0.019	0.001	0.024	0.013	0.017	0.002	0.023	0.021	0.010
PFMC SoF	0.009	0.011	0.018	0.010	0.013	0.020	0.005	0.015	0.000	0.000	0.008	0.001
Other U.S. marine	0.000	0.003	0.000	0.002	0.000	0.003	0.000	0.001	0.001	0.002	0.000	0.000
River Rtn	0.573	0.512	0.809	0.713	0.461	0.394	0.780	0.792	0.565	0.571	0.848	0.883

	2003-07 Average		
Fishery	**Current BP**	**New BP**	**CTC Fing+Yrlng**
S.E. Alaska	0.099	0.128	0.143
Other BC	0.313	0.223	0.066
WCVI	0.042	0.143	0.107
PFMC NoF	0.002	0.032	0.023
PFMC SoF	0.022	0.043	0.043
Other U.S. marine	0.000	0.003	0.003
River Rtn	0.522	0.430	0.615

	2003-07 Average % of Marine Area Fisheries		
Fishery	**Current BP**	**New BP**	**CTC Fing+Yrlng**
S.E. Alaska	0.208	0.224	0.371
Other BC	0.655	0.390	0.171
WCVI	0.088	0.250	0.279
PFMC NoF	0.004	0.055	0.059
PFMC SoF	0.045	0.075	0.111
Other U.S. ma	0.000	0.006	0.008
Marine Fish	1.000	1.000	1.000

MODEL EVALUATION WORKGROUP REPORT ON SALMON METHODOLOGY REVIEW

Members of the Model Evaluation Workgroup (MEW) attended the Salmon Methodology Review meeting in October and offer comments on the following topics:

1) Factors affecting Fishery Regulation Assessment Model (FRAM) mark-selective fishery (MSF) bias when both MSF and non-selective fisheries (NSF) occur simultaneously in a model time step, along with an evaluation of potential bias-correction methods. Presented by Henry Yuen and Bob Conrad.
2) Evaluation of indicator stock groups for Columbia River summer Chinook. Presented by Larrie LaVoy.
3) Forecast models for Oregon coastal natural (OCN) coho salmon. Presented by Pete Lawson.

FRAM

Promising methods to adjust FRAM calculations of MSF related mortalities were presented and discussed. The presentations showed that the MSF induced bias in FRAM is greater than originally demonstrated. The MEW is concerned about the potential level of bias. Over the next year, MEW will continue to assess the magnitude of the bias, refine the bias-correction equations, and develop the bias-correction methodology that can be applied on an individual or aggregate stock basis. The associated program code will be incorporated into FRAM when verified.

Progress continues to be made toward understanding how MSFs introduce bias into the FRAM estimation of fishing-related mortalities. At last year's Methodology Review meeting we demonstrated a theoretical model to estimate the bias mark-selective fisheries introduce into FRAM's calculation of unmarked fish mortality within MSFs. FRAM underestimates the mortality of unmarked salmon when there is a MSF during the model time step. A method was subsequently developed to correct for this particular bias within FRAM. However, there was concern that this equation did not capture all aspects of the interactions of multiple fisheries and stocks within FRAM. Over this past year, Mr. Conrad and Mr. Yuen expanded the theoretical model to include simultaneous MSFs and non-selective fisheries (NSFs). Their findings demonstrated that the bias MSFs introduce into FRAM originates not only from potential multiple encounters of unmarked fish, but also from MSF induced changes to the mark rate of fish available to NSFs occurring during the same model time step. Corrections are needed in FRAM to account for underestimated unmarked mortalities in both MSFs and NSFs occurring during the same time step. More work is needed to confirm how to use the bias-correction equations within FRAM on the mix of marked and unmarked stocks.

However, presently the FRAM model is producing biased estimates of MSF induced mortality of unmarked salmon. This bias was shown to be greater than thought when the Council Guidance defining an "acceptable low level of MSF" was originally provided, two years ago. It may be useful to review the proposed suite of annual fisheries to evaluate whether they are consistent with the Council Guidance that was provided at the November 2008 Council Meeting.

Columbia River Summer Chinook

The methodology and results for incorporation of additional Columbia River Summer Chinook coded wire tag (CWT) recoveries into Chinook FRAM was presented by Larrie LaVoy. The past representation for this stock's distribution in FRAM fisheries and time steps was based upon relatively few CWT recoveries during the base period. Mr. LaVoy used standard FRAM "Out-of-Base" procedures to incorporate an expanded set of more recent CWT recoveries into the FRAM profile for this summer Chinook stock. The resulting stock distribution through FRAM fisheries and time steps should provide increased confidence in our ability to evaluate the impacts of pre-season fisheries upon this stock, and upon other associated Chinook stocks.

OCN Coho

The presented forecast methodology for OCN coho (river component) used a unique approach that incorporated environmental conditions from the preceding four years. The MEW appreciated the presentation of this innovative approach. Preparing pre-season abundance forecasts, for all stocks, is always challenging given the uncertainty of ocean survival rates. If shown to be successful, the incorporation of multi-year environmental indexes may be applicable to other salmon stocks.

Agenda Item F.5.b
Supplemental SAS Report
November 2010

SALMON ADVISORY SUBPANEL REPORT ON 2010 SALMON METHODOLOGY REVIEW

The Salmon Advisory Subpanel (SAS) would like to address Agenda Item F.5 under the general rubric of "methodology review." This item consists of the meeting summary of the Tule Chinook Workgroup and we are particularly interested in consideration being given to abundance-based exploitation rates.

There is a fifth "h" in the all H model that seems to get left out of the discussions on Columbia River Salmon recovery, and that is history. Simply put, if harvest were culpable in any amount commensurate with the focus it receives, there would have been no fish to manage fifty years ago. Harvest is often the focus of regulation because it is a surrogate for a host of other problems, mostly related to water and habitat.

Those groups with the strongest ties in terms of economics and cultural heritage to the fisheries of their region are the most ardent supporters of salmon recovery. Ironically, the more restrictive the regulations, the less advocacy can be expected for the very stocks that need protection. There is vigorous competition for resources salmon need to survive. The advocacy provided by various fishing communities is a necessary counterbalance to avoid long-term adverse effects.

We believe that in order to avoid eventual museum status for our salmon populations, efforts must be made to keep users viable as well as the resource. We advocate an abundance-based harvest scenario for Tule Fall Chinook, but with a harvest floor that allows some level of *de minimus* fishing at low levels of abundance. Even a very few exploitation points of leeway on a particular stock can open up substantial harvest opportunities on other commingled harvestable stocks. A *de minimus* policy would also provide a measure of flexibility in cases where streams that hold little promise of recovery could "hold hostage" entire fisheries.

We firmly believe if the harvest sector ceases to become viable or is seriously disrupted for an extended period of time, the viability of the resource will also be greatly compromised, as the advocacy will diminish and ultimately disappear.

PFMC
11/05/10

SCIENTIFIC AND STATISTICAL COMMITTEE REPORT ON 2010 SALMON METHODOLOGY REVIEW

The Scientific and Statistical Committee (SSC) reviewed the SSC Salmon Subcommittee report on the Salmon Methodology Review. The methodology review occurred during a joint session with members of the SSC Salmon Subcommittee, the Salmon Technical Team (STT) and the Model Evaluation Workgroup (MEW) on October 19-20, 2010 in Portland. The review focused on: (1) new investigations into Fishery Regulation Assessment Model (FRAM) bias when there are both mark-selective fisheries and non-selective fisheries in a modeled time step and possible bias-correction methods; (2) new forecast methods for Oregon Coastal natural (OCN) coho salmon abundance (river component only); and (3) evaluation of new indicator coded-wire-tag (CWT) groups for Columbia River summer Chinook salmon to update the Chinook FRAM base period.

FRAM Bias and Bias-correction Methods

Previously, to minimize the impacts of bias in FRAM modeling, the SSC suggested a "30-10" rule which recommended that the FRAM is "suitable for modeling mark-selective fisheries of low intensity, with 'low intensity' provisionally defined as those fisheries with fishery-specific exploitation rates on marked stocks of less than 10 percent and overall selective fishery exploitation rates of less than 30 percent." Subsequently, Bob Conrad and Henry Yuen have produced two reports to further define the problem and recommend solutions (Agenda Items F.5.a, Attachments 1 and 2).

The most striking result of these analyses was that operating mark-selective fisheries simultaneously with a non-selective fishery introduces bias in the non-selective fishery impact estimate, which was unbiased in the single fishery case. This is because the mark-selective fishery selectively removes marked fish, so the pool of fish the non-selective fishery is operating on has a higher proportion of unmarked fish than assumed by any of the current management models. As mark-selective fisheries get more intense the differences and biases increase exponentially. Operating fisheries simultaneously also increases the bias in the mark-selective fisheries, because the stock proportions are changing more rapidly than they would with only a single fishery.

The SSC concludes that while progress was made in defining the potential impacts of bias, several issues still need to be addressed before bias correction can be implemented in FRAM:

1. The fundamental problem is that the best bias-correction methods need, as input, the total number of fish of all stocks available to the fishery. FRAM models each stock as a single pool, and does not distribute stocks by area.
2. Non-retention fisheries, drop-off mortalities, and mark-recognition errors are not included in the proposed bias-correction methods. It is not clear that these factors have enough influence on final estimates to warrant the extra complexity they would introduce into the modeling.

3. The “30-10” rule needs further clarification and interpretation in order to be implemented. The SSC will consult with the MEW and STT to help develop a way to evaluate fishery options for compliance with this rule during pre-season planning.

These issues should remain a high priority in the next year so that bias-correction methods can be implemented.

OCN Coho Abundance Forecast Models

Dr. Pete Lawson summarized the work done on developing a new forecast model for Oregon Coastal Natural (OCN) coho (river component) (Agenda Item F.5.a, Attachment 3). After evaluating numerous possible models, the authors decided upon nine models with the Pacific Decadal Oscillation (PDO) and one other variable, and nine models with the PDO and two other variables, as well as ensemble means of six of the predictors from both the two-variable and three-variable models as the most promising.

The SSC recommends that the three-variable ensemble mean form the basis for predictions for 2011 management.

Columbia River Summer Chinook Stock Representation in Chinook FRAM Base Period

Mr. Larrie LaVoy presented an evaluation of the effect of adding new out-of-base period CWT codes to the present tag codes used to represent Columbia River summer Chinook in the FRAM (Agenda Item F.5.a, Attachment 3).

The SSC agrees that incorporation of the proposed additional Columbia River summer Chinook CWT groups into the base period improves FRAM’s exploitation rate analysis for Council fisheries. The proposed revisions provide for an increased sample size of CWT recoveries from more recent brood years, and would better represent the life history strategies of the stock’s current hatchery and natural production.

The SSC supports the recommendation to incorporate the proposed additional CWT groups into the FRAM base period for 2011 management.

PFMC
11/05/2010

SALMON TECHNICAL TEAM REPORT ON 2010 SALMON METHODOLOGY REVIEW

Bias correction for mark-selective fisheries in FRAM.
The Salmon Technical Team (STT) and Salmon Subcommittee of the Scientific and Statistical Committee (SSC) reviewed two presentations on bias resulting from mark-selective fisheries in the Coho Fishery Regulation Assessment Model (FRAM). Two sources of bias were analyzed: 1) bias resulting from multiple encounters in mark selective fisheries, and 2) bias that results in non-selective fisheries due to changing marked/unmarked ratios when concurrent mark-selective fisheries occur.

Simulations of bias and potential bias corrections indicate that the bias occurring in Coho FRAM because of mark selective fisheries is large enough in magnitude to be of concern. Biases on the order of tenths of a percentage point are significant when management constraints on upper Fraser coho and listed Columbia River and Oregon coastal natural (OCN) coho have forced the Council to manage pre-season modeled exploitation rates to a finer resolution than that of the potential bias. Theoretical bias correction methods have been developed for a simplified single pool model with a single stock partitioned into marked and unmarked components. Comparison of FRAM outputs from recent years with bias corrected values using these methods suggests that bias corrections developed from a single stock, single pool model may not be directly applicable to the FRAM model, which has multiple stocks and pre-terminal and terminal fisheries.

The STT believes that further investigation is warranted and should focus on developing a bias correction method that is compatible with the structure and algorithms in FRAM.

OCN forecasts
The STT and Salmon Subcommittee of the SSC reviewed recent work on forecasting the ocean abundance of river-rearing stocks of OCN coho. The analyses explored the use of a variety of marine environmental indices, averaged over 3-month periods, in addition to parental spawning escapement to explain the variability in recruitment of OCN coho. The strongest correlation of any single index was with the May-June-July Pacific decadal oscillation (PDO). This correlation was improved by using a 4-year moving average of the PDO. Parental spawning escapement was combined with other environmental indices and the 4-year average PDO in generalized additive models (GAMs). The best fit was obtained by using an ensemble mean of six of the 3-variable GAMs. This ensemble mean is proposed for use in forecasting the river rearing OCN coho. Hindcasting indicates that this predictor would have performed substantially better than the predictors that were used over the past 15 years.

The STT recommends that the new predictor be used for 2011.

Columbia River summer Chinook CWT codes

Columbia River summer Chinook are represented in the FRAM by three coded-wire-tag (CWT) codes from Wells Hatchery fingerling releases from the 1976 and 1977 brood years. There were no yearling CWT releases during the FRAM base period, and the fingerling releases from the broods in the FRAM base period had relatively poor survival, resulting in low tag recoveries. Exploitation rates in Council fisheries during the base period on the CWT tagged fish were well below the 5 percent criterion for excepting stocks from overfishing provisions of the salmon FMP. Recent evidence indicates that summer Chinook in the Columbia River have a substantial component that exhibits a river-type life history with yearling smolts.

The Model Evaluation Workgroup (MEW) developed new base period data set that included six additional tag codes from Wells Hatchery fingerling and yearling releases from the 1998, 1999, and 2000 broods, in addition to the three tag codes currently used to represent summer Chinook in the FRAM. FRAM runs using the new base-period data agreed more closely with the exploitation rates calculated from CWTs for Summer Chinook indicator stock used by the Pacific Salmon Commission's Chinook Technical Committee. These runs with the new base-period data also indicate that base-period exploitation rates in Council fisheries were less than 5 percent, but that recent average exploitation rates in Council fisheries have been greater than 5 percent.

The STT believes that incorporating recoveries of CWTs from more recent broods, and both yearling and fingerling releases, more accurately represents the exploitation patterns of summer Chinook in FRAM and recommends that the new base period data be used for modeling 2011 management measures.

PFMC
11/05/10

MEETING SUMMARY
Ad Hoc Tule Chinook Workgroup

Pacific Fishery Management Council
Large Conference Room
7700 NE Ambassador Place, Suite 101
Portland, Oregon, 97220-1384
503-820-2280
September 30, 2010

The Ad Hoc Tule Chinook Workgroup (TCW) met at 9 a.m. on September 30, 2010 in the Pacific Fishery Management Council office large conference room. In attendance were:

Ray Beamesderfer (RB), Cramer Fish Sciences
John North (JN), ODFW
Guy Norman (GN), WDFW
Stuart Ellis (SE), CRITFC
Larrie LaVoy (LL), NMFS NWR
Bob Turner (BT), NMFS NWR
Tom Stahl (TS), ODFW
Matt Falcy (MF), ODFW
Cindy LeFleur (CL), WDFW
Tom Cooney (TC), NMFS NWFSC
Peter Dygert (PD), NMFS NWR
Chuck Tracy (CT), Council Staff

The TCW reviewed Council process and schedules associated with developing an abundance based harvest management approach for lower Columbia River (LCR) natural tule Chinook. Significant dates and work products included:

- November 2010 - A brief progress report for the Council meeting, with a briefing book deadline of October 15.
- December 2010 – Next meeting of the TCW and development of a progress report for the Recovery Board and for NMFS consideration in developing guidance on 2011 Council and Columbia Basin fisheries.
- April 2011 – Determination if a viable approach was likely to be developed in time to be integrated with the Council's 2011 salmon methodology review process.
- June 2011 – Possible brief progress report for the Council meeting.
- September 2011 – Determination if the final report write-up would be ready for review during the October salmon methodology review meeting, and if possible, including the final report in the September briefing book (deadline of August 23).
- October 2011 – Presentation of final report at the Scientific (SSC) Salmon Subcommittee and Salmon Technical Team review of proposed salmon methodology changes.
- November 2011 - Presentation of final report to the full SSC and Council for approval. If approved by the Council, the final report would be forwarded to NMFS for consideration in Endangered Species Act (ESA) consultations and guidance to the Council.

The TCW noted there were several abundance based approaches being used for various salmon stocks and fisheries including:

- Puget Sound coho
- Klamath River fall Chinook
- Oregon Coastal Natural coho
- Lower Columbia Natural coho
- Columbia Up-River brights
- Pacific Salmon Commission's aggregate abundance based management

The merits of several of these approaches were discussed and evaluated with regard to potential application to LCR tules.

Discussion points included:

GN - Objectives for the process were to reduce risk to the natural populations at low escapement levels while providing opportunity to harvest abundant stocks at higher abundance levels. The abundance metric should include an aggregate of both hatchery and natural tules to address both objectives. This will also help address data quality issues for wild fish populations, which is generally poor, but improving. This process should take advantage of new information when available. An initial approach could be to look at exploitation rates (ER) ±5% from the current 38% anchor point.

LL – suggested aggregate abundance should be scaled to hatchery release level to reduce uncertainty from production changes.

GN – An alternative would be to look at abundance later in the life history to account for marine survival.

TC – Suggested risk reduction should have a temporal scale, e.g., reduce risk more if abundance is low for consecutive return years.

LL – Suggested comparing wild population trends with hatchery trends to see how well an aggregate abundance tracks with wild population status.

TC – Recommended starting with Coweeman, East Fork Lewis (EFL), and perhaps Washougal natural populations, and to look at marine environmental factors for both hatchery and natural stocks.

TS – Recommended integrating weak stock management per the recovery plans into the analysis when sufficient information was available, including predictors that are used in the short-term.

PD – Noted that various wild populations have different ER limits.

LL – Noted that marine environmental factors affect 2-3 Chinook broods for a given return year, unlike coho where only one brood is affected.

TC – Proposed using an aggregate hatchery/natural stock approach that accounts for variability in return rates of component stocks. Marine environmental indices could also be incorporated.

CL – Proposed that age specific forecasts should also be investigated, and the effects of mark-selective-fisheries (MSF) should be considered at some point.

PD – Asked how merits of various strategies would be assessed.

TC – Species Life-Cycle Analysis Module (SLAM) model would be one possibility as it was set up to assess risk of variable harvest rates.

RB – Suggested quasi-extinction risk, escapement, proportion hatchery origin spawners (pHOS), and economics would be appropriate metrics, and they are typical outputs for several models. The results for each model should be similar as long as input data are consistent. The model used for the Lower Columbia Recovery Board was the one he was most familiar with. The initial step would be to define parameters, then conduct a trial run, and refine parameters later.

TC – Asked if this exercise would be looking at different base rates or just variations of existing base rate (38%).

PD – Replied the latter, at least initially.

BT – Recommended defining the relationship between harvest rate and recovery, and taking a simple approach first.

PD – Noted that pHOS reduction was partially dependent on harvest rate.

GN – Felt that was a related task affecting recovery, along with MSF.

TS – Asked if the Coweeman and EFL would be indicator stocks. Concerned that weak stocks without pHOS problems could be overexploited in an effort to reduce pHOS on other stocks.

PD – Replied that Coweeman and EFW were not necessarily indicator stocks, just the initial stocks included in the aggregate because of data quality.

GN – Noted that the MSF model being used by Lars Mobrand can assess effects on individual populations in the Columbia.

CL – Suggested defining acceptable risk, then determine ERs based on the model.

RB – Replied that would be possible but there would be different risks to the various populations. The model could determine what aggregate abundance based approach would result in similar balance of risks as a 38% constant ER limit, and population specific effects could be examined in more detail.

PD – Suggested using Chinook Fishery Regulation Assessment Model (FRAM) to determine effects on fisheries, with the goal of determining a minimum ER that would keep fisheries viable.

JN – Felt ER bounds should have a biological basis (risk to recovery) rather than be determined based on what fisheries can afford.

LL – Replied that a retrospective analysis from Chinook FRAM based on lower ER limits could provide insight.

RB – Indicated that biological limits could be subjective, so an analysis of fishery effects would help inform decisions.

GN – Asked if uncertainty in forecast when abundance is high could be accounted for.

RB – Replied yes.

Meeting Summary
The initial objective would be to explore increased fishery flexibility while keeping risks neutral. Subsequently, scenarios to reduce risk and maintain some fishery flexibility could be explored.

An example exercise will be attempted using the current 38% ER limit as a reference point for assessing risk, with ERs of 33%, 38%, and 43% associated with abundance levels of <20%, 20%-80%, and <80% of some average. The initial approach would be based on aggregate hatchery/natural tule abundance, standardized for hatchery release levels. The analysis will then be refined using actual abundance frequencies (with possible consideration of weighting recent abundance estimates), an assessment of correlation between natural and hatchery abundance, forecast uncertainty, and possibly marine environmental indicators.

A retrospective fishery analysis will be conducted to refine sideboards for ERs that would maintain viable fisheries.

Eventually, an approach should be considered that does not assume any specific ER anchor point and over which harvest options are assessed to determine risk to both population and fishery viability.

Follow-up assignments, products, meetings:
Retrospective fishery analysis – LL.
Risk analysis, initial matrix approach – RB.
Forecast uncertainty and age specific errors – CL.
Marine environmental indicators principal components analysis for predictors – MF.
    Data sources from Scheuerell Report – TC.
    Data Sources from Rupp et al. – CT.
November 6, 2010 progress report to Council – PD.
December 9, 2010 – Next TCW meeting to review products, plan next steps, and draft progress report for submission to NMFS Recovery Board before end of the month.

PFMC
11/03/10