16.4.1

Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 "G" Street
Anchorage, AK 99501
Phone: (907) 278-8012 Fax: (907) 276-7178

Phil Mundy
Fisheries and Aquatic Sciences
1015 Sher Lane
Lake Oswego, OR 97034-1744

Dear Phil:

This letter is to confirm your invitation to the Wild Salmonid Stock Supplementation Workshop which is to be held January 12 and 13, 1995 in Anchorage, Alaska. The workshop will convene at 8:30 a.m. in rooms 133 and 135 at the Federal Building, 222 West 7th Avenue. Enclosed are the agenda, a list of participants, the travel instructions and a list of useful references. These references will be available at the Workshop.

As indicated on the agenda, you have been selected to be Keynote Speaker and Mixed Stock Fisheries Discussion Leader. Please be prepared to address questions listed with your discussion topic at the scheduled time. If you are available, I would like you to attend a brief organizational meeting at 9:00 p.m. on January 11 in the Anchorage Sheraton's Bistro Restaurant at 401 E. 6th Avenue. At this meeting we wish to discuss (1) the interaction between the facilitator and discussion leaders, (2) the importance of allowing all participants an equal opportunity to speak and (3) the need to keep the discussions moving toward logical conclusions.

You may stay anywhere you choose; however, convention rates of $74.00 per night are available at the Anchorage Sheraton. This hotel is located approximately six blocks northeast of the Federal Building. You can contact the Anchorage Sheraton at (800) 325-3535. When checking in at the Sheraton, be sure to mention that you will be attending an *Exxon Valdez* Trustee Council Science Workshop.

Melaine Bocsh of the Alaska Department of Fish and Game will make your airline reservations for you. You may contact her at (907) 267-2136. Please make your own hotel reservations. Due to recent changes in state travel regulations, you must save all receipts to receive reimbursement.

Should you have any questions, please call Cherri Womac at (907) 278-8012 or toll free (800) 478-7745 within Alaska and (800) 283-7745 outside of Alaska.

Sincerely,

Molly McCammon

Molly McCammon
Executive Director

Enclosures

Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 "G" Street
Anchorage, AK 99501
Phone: (907) 278-8012 Fax: (907) 276-7178

Bob Roys
306 Seventh Avenue
Juneau, AK 99801

Dear Bob:

This letter is to confirm your invitation to the Wild Salmonid Stock Supplementation Workshop which is to be held January 12 and 13, 1995 in Anchorage, Alaska. The workshop will convene at 8:30 a.m. in rooms 133 and 135 at the Federal Building, 222 West 7th Avenue. Enclosed are the agenda, a list of participants, the travel instructions and a list of useful references. These references will be available at the Workshop.

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Sincerely,

Molly McCammon

Molly McCammon
Executive Director

Enclosures

Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 "G" Street
Anchorage, AK 99501
Phone: (907) 278-8012 Fax: (907) 276-7178

Alex Swiderski
Alaska Department of Law
1031 W. 4th Avenue Suite 200
Anchorage, AK 99501-1994

Dear Alex:

This letter is to confirm your invitation to the Wild Salmonid Stock Supplementation Workshop which is to be held January 12 and 13, 1995 in Anchorage. The workshop will convene at 8:30 a.m. in rooms 133 and 135 at the Federal Building, 222 West 7th Avenue. Enclosed are the agenda, a list of participants and a list of useful references. These references will be available at the Workshop.

Should you have any questions, please call Cherri Womac at 278-8012.

Sincerely,

Molly McCammon

Molly McCammon
Executive Director

Enclosures

Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 "G" Street
Anchorage, AK 99501
Phone: (907) 278-8012 Fax: (907) 276-7178

C This was an addition. Need enclosures.

Don Campton
University of Florida
Dept. of Fish. and Aquatic Sciences
7922 NW 71 St.
Gainesville, FL 32653

Dear Don:

This letter is to confirm your invitation to the Wild Salmonid Stock Supplementation Workshop which is to be held January 12 and 13, 1995 in Anchorage, Alaska. The workshop will convene at 8:30 a.m. in rooms 133 and 135 at the Federal Building, 222 West 7th Avenue. Enclosed are the agenda, a list of participants, the travel instructions and a list of useful references. These references will be available at the Workshop.

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Should you have any questions, please call Cherri Womac at (907) 278-8012 or toll free (800) 478-7745 within Alaska and (800) 283-7745 outside of Alaska.

Sincerely,

Molly McCammon
Executive Director

Enclosures

Travel Instructions

* Reimbursement of actual lodging expenses plus a meal allowance of $36.00 a day. Anchorage Sheraton Hotel has a special Workshop rate of $74.00 a night. The Sheraton is the closest major hotel to the Federal building.

* Save all original receipts and attach to State of Alaska Travel Authorization (TA) for reimbursement.

* Other expenses associated with travel may be eligible to be claimed for reimbursement on this TA:
  Airport parking expenses;
  Limousine, bus, and taxi fares.

* The following items are NOT authorized and should not be claimed for reimbursement:
  Parking or moving violations;
  Skycap baggage handling;
  Tips or gratuities.

* Please Note: Alaska Administrative Manual 60.280: Hotel receipts (commercial establishments) are required from all non-employees or employees travelling in short term per diem status. The receipts will be used to determine if any of the per diem is to be reported as compensation required by the IRS regulations. If no receipts are attached, the difference from the per diem amount and the meal and incidental expense allowance will be reported as taxable compensation on the employee's payroll warrant.

* Not to exceed expenses of $150.00 per day.

* At the workshop you will receive a packet with an approved TA;
  1) Review and sign
  2) Attach receipts for reimbursement
  3) Return to Melanie Bosch, ADF&G H&R, 333 Raspberry Road, Anchorage Alaska 99518
  4) Reimbursement check will be mailed to you.

* When in doubt, contact Melanie Bosch, 1-907-267-2136.

WILD SALMONID STOCK SUPPLEMENTATION WORKSHOP

Exxon Valdez Trustee Council

December 22, 1994

Date: 12 - 13 January 1995

Location: Room 133 and 135
Federal Building
222 West 7th.
Anchorage

Purpose: To review and discuss the feasibility and risks of salmonid stock restoration techniques and to determine criteria for wild salmonid stock protection and supplementation

Goals of Workshop:

1. To briefly discuss applicability of restoration techniques that have been proposed for the EVOS area

2. To discuss criteria for acceptability of techniques and proposed projects, including:

   a. feasibility and effectiveness of restoration techniques
   b. maintenance of genetic integrity
   c. wild stock protection
   d. cost effectiveness
   e. legal considerations
   f. determination of need for supplementation
   g. monitoring for a measure of success

3. To review historic and proposed projects with these criteria

Proposed Restoration Techniques:

- Migration Corridor Improvements (e.g., fish pass, remove barrier)
- Egg incubation boxes
- Net pen rearing for captive wild stocks
- Hatchery rearing for captured wild stocks
- Habitat improvement (e.g., spawning channels, new rearing habitat)
- Relocation of hatchery runs
- Lake fertilization
- Eyed egg planting
- Development of new hatchery runs

- Other?

Expected Products:

- Set of criteria to evaluate proposed salmonid stock restoration projects
- One or more projects evaluated with these criteria

WILD SALMONID STOCK SUPPLEMENTATION WORKSHOP

***Exxon Valdez* Trustee Council**

December 22, 1994

AGENDA

Facilitator: Kimmel

Introduce Topics, Keep us on Schedule, Conclude Topics.

Are we on track? Will we accomplish the Purpose of our Workshop?

12 January

8:30 - Opening and Introductions (Spies)

- Review of Purpose of the Workshop (How can we do wild salmonid stock supplementation with minimal risk?)

9:00 - Keynote (Mundy) Overview of Techniques and applications, benefits and risks (Can these techniques do the job?)

9:30 - Termination or Trigger for Supplementation (Mundy) (How do we know when to supplement?)

10:00 - Break

10:20 - Genetic Risks (Allendorf) (Why do we need to worry about this? How can this be addressed in the EVOS area?)

12:00 - Lunch

1:00 - Mixed Stock Fisheries (Mundy) (Why do we need to worry about this? How can this be addressed in the EVOS area?)

2:45 - Break

3:00 - Legal Criteria (Brighton)

(Why do we need to worry about this? How can this be addressed in the EVOS area?)

4:00 - Evaluations/ Monitoring (Cramer)
(How do we measure success?)

5:00 - Break

<u>13 January</u>

8:30 - Review (Kimmel)
(What have we learned so far? What are the key items?)

9:30 - Criteria to Evaluate Project Proposals (Spies)
(Why do we need this? How can this work in the EVOS area?)

10:15 - Break

10:30 - Continuation of Criteria Discussion

12:00 - Lunch

1:00 - Review Criteria (Kimmel)
(How will proposals be evaluated?) Other concerns (e.g., NEPA Compliance, FTP)

1:15 - Case Studies (Spies)
Historic projects
Proposals on hand

2:45 - 3:00 Break

4:30 - Conclusions (Kimmel)
(How will proposals be evaluated? How will the Criteria be used?)

5:00 - End

Suggested References:

- EVOS Trustee Council Restoration Plan (need, techniques)

- EVOS Trustee Council Restoration Plan EIS, Appendix C (techniques, applicability, potential benefits and drawbacks)

- EVOS Trustee Council Draft Fiscal Year 1995 Work Plan

- Cuenco M., T. Backman, and P. Mundy. 1993. The use of supplementation to aid natural stock restoration, pp. 269 - 293. *In* Cloud, J. G. and G. Thorgard (eds.) Genetic Conservation of Salmonid Fishes. Plenum Press, New York.

- Supplementation in the Columbia Basin Report Series: Final Report, Project No. 85-62, Contract No. DE-AC06-75RL01830. December 1992.

- Prince William Sound Regional Plan (historic information)

- Cook Inlet Regional Plan (historic information)

- Kodiak Regional Plan (historic information)

- Other?

Note:

1. Copies will be available during the Workshop.

2. Contact Tom Namtvedt ((907)271-2753/ fax 271-3992) if you would like a copy before the Workshop.

List of Invited Participants, Wild Salmonid Stock Supplementation Workshop, Anchorage, Jan. 12-13, 1994

Achilles, Ted	Prince William Sound Aquaculture Corp.	P.O. Box 1110 Cordova, AK 99574
Allendorf, Fred	University of Montana	Missoula, MT 59812
Bachen, Bruce	Northern Southeast Regional Aquaculture Assn.	1308 Sawmill Creek Rd. Sitka, AK 99835
Berg, Catherine	U.S. Fish and Wildlife Service	1011 E. Tudor Rd. Anchorage, AK 99503
Brady, James	Alaska Department of Fish and Game	333 Raspberry Rd. Anchorage, AK 99518-1599
Brighton, Bill	U.S. Dept. of Justice/EES/ENRD	PO box 7611, Ben Franklin Station Washington D.C. 20044
Broderson, Mark	Alaska Department of Environmental Conservation	410 Willoughby Avenue, Rm 105 Juneau, AK 99801-1795
Bruce, David	Alaska Department of Environmental Conservation	410 Willoughby Avenue, Rm 105 Juneau, AK 99801-1795
Campton, Don	University of Florida	CAMP@GNV.IFAS.ULF.EDU
Cramer, Steve	S.P. Cramer and Assoc.	300 S.E. Arrow Creek Lane Gresham, OR 97080
Dudiak, Nick	Alaska Department of Fish and Game	3298 Douglas St. Homer, AK 99603
Duffy, Kevin	Alaska Department of Fish and Game	P.O. 25526 Juneau, AK 99802
Ellison, Terry	Alaska Department of Fish and Game	333 Raspberry Rd. Anchorage, AK 99518-1599
Fandrei, Gary	Cook Inlet Aquaculture Assn.	HC2, Box 849 Soldotna, AK 99669
Ferren, Howard	Prince William Sound Aquaculture Corp.	P.O. Box 1110 Cordova, AK 99574
Field, Wallace	Kodiak Regional Planning Team	P.O. Box 3407 Kodiak, AK 99615
Fries, Carol	Alaska Department of Natural Resources	3601 C Street, Rm 1210 Anchorage, AK 99503
Gharrett, Tony	University of Alaska-SFOS	11120 Glacier Highway Juneau, AK 99801
Gibbons, Dave	USDA Forest Service	709 W. 9th Street, Rm 831 D Juneau, AK 99802-1628
Gilbert, Veronica	Exxon Valdez Trustee Council	645 G Street, Rm 401 Anchorage, AK 99501-3451
Halgren, Kathy	Prince William Sound - Copper River Regional Planning Team	P.O. Box 17333 Seattle, WA 98107
Hard, Jeff	Northwest Fisheries Science Center	2725 Montlake Bld. East Seattle, WA 98112
Hartman, Jeff	Alaska Department of Fish and Game	P.O. 25526 Juneau, AK 99802
Hauser, Bill	Alaska Department of Fish and Game	333 Raspberry Rd. Anchorage, AK 99518-1599

List of Invited Participants, Wild Salmonid Stock Supplementation Workshop, Anchorage, Jan. 12-13, 1994

Heard, Bill	NMFS, Auke Bay Lab	11305 Glacier Highway Juneau, AK 99801
Hendrichs, Bob	Eyak Village Corp.	P.O. Box 299 Cordova, AK 99574
Hepler, Kelly	Alaska Department of Fish and Game	333 Raspberry Rd. Anchorage, AK 99518-1599
Hildebrand, Darlene	Cook Inlet Seiners Assn.	P.O. Box 4311 Homer, AK 99603
Holbrook, Ken	USDA Forest Service	3301 C St. Suite 300 Anchorage, AK 99503
Holm, Oliver	Kodiak Regional Planning Team	P.O. Box 3407 Kodiak, AK 99615
Hommold, Steve	Alaska Department of Fish and Game	211 Mission Rd. Kodiak, AK 99615-6399
Kimmel, Joy	Kimmel Consulting	P.O. Box 3017 Prescott, AZ 86302-3017
Koernig, Armin	Prince William Sound - Copper River Regional Planning Team	P.O. Box 191 Cordova, AK 99574
Lichatowitch, James	Alder Fork Consulting	182 Dory Rd. Sequim, WA 98382
Loeffler, Bob	Exxon Valdez Trustee Council	645 G Street, Rm 401 Anchorage, AK 99501-3451
Malloy, Larry	Kodiak Regional Aquaculture Assn.	P.O. Box 3407 Kodiak, AK 99615
Mears, Tom	Cook Inlet Aquaculture Assn.	HC2, Box 849 Soldotna, AK 99669
Montague, Jerome	Alaska Department of Fish and Game	1255 W. 8th Street Juneau, AK 99802-5526
Moore, Dan	Alaska Department of Fish and Game	333 Raspberry Rd. Anchorage, AK 99518-1599
Morris, Byron	National Marine Fisheries Service	11305 Glacier Highway Juneau, AK 99821
Mundy, Phil	Fisheries and Aquatic Sciences	1015 Sher Lane Lake Oswego, OR 97034-1744
Namtvedt, Tom	USDA Forest Service	3301 C St. Suite 300 Anchorage, AK 99503
Nelson, Beaver	Prince William Sound - Copper River Regional Planning Team	P.O. Box 130 Homer, AK 99603
Person, DeDe	Kodiak Regional Planning Team	P.O. Box 3407 Kodiak, AK 99615
Philipp, Dave	Illinois Natural History Survey	607 E. Peabody Dr. Champaign, IL 61820
Prestegard, Eric	Prince William Sound Aquaculture Corp.	P.O. Box 1110 Cordova, AK 99574
Rice, Bud	National Park Service	2525 Gambell, Rm 107 Anchorage, AK 99503
Riedel, Steve	Eyak Village Corp.	P.O. Box 1005 Cordova, AK 99574

List of Invited Participants, Wild Salmonid Stock Supplementation Workshop, Anchorage, Jan. 12-13, 1994

Roberson, Ken		0	P.O. Box 375 Glennallen, AK 99588
Roth, Barry	U.S. Dept. of Interior		1849 C. St. NW Washington, D.C. 20240
Roys, Bob		0	306 Seventh Avenue Juneau, AK 99801
Schmid, Dave	Forest Service		P.O. Box 280 Cordova, AK 99574
Seeb, Jim	Alaska Department of Fish and Game		333 Raspberry Rd. Anchorage, AK 99518-1599
Simpson, Ellen	Alaska Department of Fish and Game		333 Raspberry Rd. Anchorage, AK 99518-1599
Smoker, Bill	University of Alaska-SFOS		11120 Glacier Highway Juneau, AK 99801
Solaczi, Mario	Oregon Dept. of Fish and Wildlife		850 SW 15th St. Corvallis, OR 97333
Spies, Bob	Applied Marine Sciences		2155 Las Positas Court, Suite S Livermore, CA 94550
Sullivan, Joe	Alaska Department of Fish and Game		333 Raspberry Rd. Anchorage, AK 99518-1599
Swiderski, Alex	Alaska Department of Law		1031 W. 4th Avenue Suite 200 Anchorage, AK 99501-1994
Thomas, Lisa	National Biological Survey		1011 E. Tudor Rd. Anchorage, AK 99503
Thompson, Ray	USDA Forest Service		3301 C St. Suite 300 Anchorage, AK 99503
Thrower, Frank	NMFS, Auke Bay Lab		11305 Glacier Highway Juneau, AK 99801
Willette, Mark	Alaska Department of Fish and Game		P.O. Box 669 Cordova, AK 99574
Wilmot, Dick	NMFS, Auke Bay Lab		11305 Glacier Highway Juneau, AK 99801

Phillip R. Mundy, PhD

Fisheries and Aquatic Sciences
1015 Sher Lane
Lake Oswego, OR 97034-1744
503-636-6335, Voice or facs, auto-switch

January 3, 1995

Molly McCammon, Executive Director
Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 G Street
Anchorage, AK 99501
907-278-8012
800-283-7745

Via facsimile: 907-276-7178

Dear Molly:

This is to confirm that I will be attending the Wild Salmonid Stock Supplementation Workshop January 12 and 13 in Anchorage. I understand that I am to present a keynote address and chair the mixed stock fisheries session. I regret that I will eb arriving in Anchorage too late on the evening of January 11 to attend the organizatinal meeting at the Sheraton. I expect to arrive at the airport about 9:45P.

I have made least-cost air travel arrangements and I have booked a room at the Capt Cook at the government rate which is close to the rate at the Sheraton.

I am also confirming my attendance at the 1995 Restoration Workshop Review, Synthesis and Planning the following week. I have also made travel arrangements for this meeting.

Looking forward to the workshops.

Sincerely,

Signed/via facsimile

Phillip R. Mundy, PhD

cc: Cherri Womac
Bob Spies

Phillip R. Mundy, PhD

Fisheries and Aquatic Sciences
1015 Sher Lane
Lake Oswego, OR 97034-1744
503-636-6335, Voice or facs, auto-switch

January 3, 1995

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Exxon Valdez Oil Spill Trustee Council
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907-278-8012
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Phillip R. Mundy, PhD

cc: Cherri Womac
Bob Spies

FAX COVER SHEET

Tuesday, January 03, 1995 08:31:25 AM

To: EVOSTC Restoration Office
Attention: Molly McCammon
Fax #: 1 907 276 7178

From:
Fax: 1 page and a cover page.

Note:
Please copy Cherri Womac. Thank you.

Exxon Valdez Oil Spill Trustee Council

Restoration Office
645 G Street, Suite 401, Anchorage, Alaska 99501-3451
Phone: (907) 278-8012 Fax: (907) 276-7178

MEMORANDUM

TO: Restoration Work Force

FROM: Molly McCammon
Executive Director

DATE: December 29, 1994

SUBJECT: Wild Salmonid Stock Supplementation Workshop

The Wild Salmonid Stock Supplementation Workshop will be held January 12 and 13 at the Federal Building, 222 West 7th Avenue in Anchorage. The workshop will convene at 8:30 a.m. in rooms 133 and 135. Enclosed are the agenda, a list of participants and a list of useful references. These references will be available at the workshop.

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Should you have any questions, please call Cherri Womac at 278-8012.

Enclosures

XD. GIBBONS
XM. BRODERSEN/BRUCE
XJ. MONTAGUE
XB. MORRIS/WRIGHT

FAX COMPLETE

Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 "G" Street
Anchorage, AK 99501
Phone: (907) 278-8012 Fax: (907) 276-7178

MEMORANDUM

TO: Restoration Work Force members DATE: 12/29/94

FROM: Molly McCammon SUBJECT: Wild Salmonid Stock Supplementation Workshop

The Wild Salmonid Stock Supplementation Workshop will be held January 12 and 13 at the Federal Building, 222 West 7th Avenue in Anchorage. The workshop will convene at 8:30 a.m. in rooms 133 and 135. Enclosed are the agenda, a list of participants and a list of useful references. These references will be available at the Workshop.

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Should you have any questions, please call Cherri Womac.

Enclosures

Exxon Valdez Oil Spill Trustee Council
Restoration Office
645 "G" Street
Anchorage, AK 99501
Phone: (907) 278-8012 Fax: (907) 276-7178

MEMORANDUM

TO: Restoration Work Force members

DATE: 12/29/94

FROM: Molly McCammon

SUBJECT: Wild Salmonid Stock Supplementation Workshop

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Enclosures

SEE OSPIC STAFF FOR THE FOLLOWING TITLES UNDER 16.4.1
WILDSTOCK SALMONID STOCK SUPPLEMENTATION WORKSHOP
JANUARY 12-13 1995

The Hatchery Program and Protection of Wild Salmon in Alaska: Policies and Regulations, compiled by Steven G. McGee, January 1995

Kodiak Regional Comprehensive Salmon Plan 1982-2002, developed by Kodiak Regional Planning Team

Kodiak Regional Comprehensive Salmon Plan 1982-2002 Phase II Revision, developed by Kodiak Regional Planning Team, March 1992

Prince William Sound - Copper River Comprehensive Salmon Plan: Phase I - 20 Year Plan (1983-2002), Prince William Sound Regional Fisheries Planning Team

Prince William Sound - Copper River Comprehensive Salmon Plan: Phase II 5-Year Plan (1986-1991), Prince William Sound Regional Planning Team

Supplementation in the Columbia Basin, Part I: Rasp Summary Report Series

16.4.1

Exxon Val. .z Oil Spill Trustee Co...cil

Restoration Office
645 G Street, Suite 401, Anchorage, Alaska 99501-3451
Phone: (907) 278-8012 Fax: (907) 276-7178

February 2, 1995

Don Compton
UF, Dept. of Fish & Aquatic Sciences
7922 N.W. 71st Street
Gainesville, FL 32602

Dear Mr. Compton:

Thank you for participating in the January 12-13, 1995 Wildstock Salmonid Stock Supplementation Workshop. The biological and policy questions involved in making decisions regarding supplementation efforts are extremely complex, and I appreciate your involvement in helping the Trustee Council address these issues.

At the workshop you requested copies of reference materials that were on display. Enclosed are the documents that you requested. A complete set of these materials is also available at the Oil Spill Public Information Center (OSPIC) at 645 G Street, Anchorage, Alaska. The OSPIC phone number is (907) 278-8008 (toll free inside Alaska 1(800) 478-7745 or outside Alaska 1(800) 283-7745).

Again, thank you for your interest and involvement.

Sincerely,

Molly McCam

Molly McCammon
Executive Director

Enclosures

Don Compton
Dept of Fish & Aquatic Sciences
University of Florida
7922 N.W. 71st Street
Gainsville, FL 32602

Eric Knudsen
NBS-Alaska Science Center
1011 E. Tudor Road
Anchorage, AK 99503

Bob Spies
AMS
2155 Las Positas Court, Suite S
Livermore, CA 94550

Bobbi Pierson
LGL Alaska Research Associates
4175 Tudor Centre Drive, Suite 101
Anchorage, AK 99508

Doug Palmer
U.S. Fish & Wildlife Service
POB 1670
Kenai, AK 99611

Jeff Heard
NMFS/NWFSC
2725 Montlake Blvd E.
Seattle, WA 98112

Nick Dudick
ADF&G
3298 Douglas Street
Homer, AK 99603

C. Estes
ADF&G
333 Raspberry Road
Anchorage, AK 99518

USFS-Glacier
POB 129
Girdwood, AK 99587

Tony Gharret
JCSFOS/UAF
11120 Glacier Highway
Juneau, AK 99801

Frank Thrower
11305 Glacier Highway
Juneau, AK 99801

Bruce Bachen
NSRAA
1308 SMC Road
Sitka, AK 99835

Wayne Donaldson
ADF&G
211 Mission Road
Kodiak, AK 99615

Bill Spearman
USFWS
1011 East Tudor Road
Anchorage, AK 99503

Jim Seeb
ADFG
333 Raspberry Road
Anchorage, AK 99518

Gene Sandone
ADFG
333 Raspberry Road
Anchorage, AK 99518

Dave Gibbons
US Forest Service
709 West 9th Street, Room 549
Juneau, AK 99801-1628

Fred Allendorf
University of Montana
Division of Biological Sciences
Missoula, MT 59812

Phil Mundy
1015 Sher Lane
Lake Oswego, OR 97034

Tom Mears
CIAA
HC2, Box 849
Soldotna, AK 99669

Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska

Applying Cost-benefit analysis to Salmon Restoration Projects studied in the "Restoration Survey" of the EVOS Restoration Program (Draft 11/3/93 - Jeff Hartman, ADFG, Juneau and Jim Richardson, ResourcEcon, Anchorage)

The Use of Supplementation to Aid in Natural Stock Restoration (1993 - M.L. Cuenco, T.W.H. Backman, & P. Mundy)

International Symposium on Biological Interactions of Enhanced and Wild Salmonids (June 17-20, 1991 - Dept of Fisheries & Oceans, Biological Sciences Branch/Salmonid Enhancement Program, Pacific Region - Nanaimo, British Columbia, Canada)

The Hatchery Program and Protection of Wild Salmon in Alaska: Policies & Regulations. Compiled by Steven G. McGee. ADF&G, Commercial Fisheries Management & Development Division, POB 25526, Juneau, AK 99802-5526, January 1995.

Kodiak Regional Comprehensive Salmon Plan 1982-2002 Phase II Revision. Developed by Kodiak Regional Planning Team, March 1992.

Kodiak Regional Comprehensive Salmon Plan. Developed by Kodiak Regional Plannning Team, April 13, 1984.

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Applying Cost-benefit analysis to Salmon Restoration Projects studied in the "Restoration Survey" of the EVOS Restoration Program.

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Background

Restoration as defined under the Natural Resource Damage Assessment regulations, does not clearly require that social benefits must be in excess of social costs for a given project to be accepted. However, where restoration involves the expenditure of federal funds (which include any funds obtained under litigation), it may generally adhere to the guidelines for public expenditures and public work projects in NEPA and various Executive Orders (Appendix X). Much of this law refers to and in some cases mandates the use of economic assessment such as formal cost-benefit analysis. Thus, it is advisable, where practical, to apply standard economic methods to evaluating the restoration projects associated with the EVOS oil spill. At this time the trustees to the EVOS spill have not established standards for economic assessment of restoration projects. Some limited economic assessment has been incorporated into the EVOS Restoration Plan Draft EIS. This analysis has consisted of regional economic impact assessment using a modified version of the IMPLAN model. The preliminary work under the NEPA process not include any assessment of net social benefits.

As far as we are aware, no efficiency assessment, such as the estimation of the net social benefits for a restoration project has been initiated by the Trustees. A proposal for a restoration economic assessment model for commercial salmon fisheries affected by the EVOS was proposed by Jeff Hartman, John Boyce, and Matt Berman in 1991. It was not, however, funded.

This proposal describes the general methods and data that were used in a rough projection of the Net Benefits of restoration projects that could alter future commercial and sport catches of salmon in the oil spill affected regions of Alaska. The purpose of this Cost-Benefit Analysis (CBA) is to satisfy the reporting requirements of the Restoration Survey. The purpose of the Restoration Survey is to evaluate the technical feasibility of a series of fish passes and spawning channels designed out by Mark Willette, Nick Dudiak and Lonnie White of the Alaska Department of Fish and Game.

This CBA study compares the net benefits of fourteen salmon restoration projects dealing with four species of salmon and various restoration methods, including spawning channels and fish passes. This analysis was completed in a very short time period with limited funding. Given those limitations, the goals of the analysis are to project the change in harvests and gross earnings to commercial fishers, gross costs to commercial fishers and average net willingness to pay for sport fish users, in a manner that is sufficient for comparing the individual projects. The projects were aggregated into high, medium, and low categories of net present value. These projections of present value of net benefits should be regarded as preliminary until more rigorous techniques can be applied.

The State of Alaska, unlike any other coastal area of North America has invested a significant amount in efficiency studies of its salmon fisheries. Efficiency studies, concern themselves with the determination of the producer and consumer surplus, generally derived from evaluating a realized or proposed policy change. While there are still more questions than answers regarding efficiency implication of various policy actions such as salmon allocation, management, regulation or investment questions, data from the newest and most applicable portions of the existing studies are drawn upon to assess and compare the net benefits of the fourteen projects. Several of the major recreational fisheries in Alaska have been evaluated with three major studies by Jones and Stokes 1986, 1988, and 1991. These studies include the development of models for approximating the consumer surplus of specific site, and salmon species combinations around the state and in some of the oil spill affected areas. An additional series of efficiency studies on commercial salmon fisheries also provide some background information on the performance of fisheries exposed to increased or decreased harvests of salmon. They include Boyce, Herrmann, Greenburg, and Bischak 1993, Herrmann and Greenburg 1993, and Boyce 1993. No formal consideration of other sources of net benefits such as existence and option value, nor use associated with Subsistence, or personal use fishing of the projects were included.

Methods:

The purpose of this project is to project the producer and consumer surplus for fourteen projects and compare the surpluses with the production costs the restoration projects. Since the estimation of producer surplus for approximately fourteen projects were addressed in a short period of time, some simplifying assumptions were made regarding how the supply and demand markets would behave under different restoration scenarios. The basic project question that the CBA will addressed is: "If efficient distribution of resources between projects is one goal of EVOS restoration, which proposed projects produce the largest (smallest) net benefits to society?" To evaluate these questions, trade-offs between the projects were be considered. These tradeoffs between projects were evaluated by projecting the net benefits for each in the form of a net present and a benefit:cost ratio.

Whether the efficient use of restoration resources is a significantly important goal is in the eyes of the beholder. Many economists believe that economic studies, and particularly the application of CBA techniques, are one among many criteria that could be of importance to society in considering its investment options. Complications arise when CBA itself is used as a final arbitration device, especially when there is great uncertainty about the variables that may affect the net benefits of the policy being evaluated . It is the intention of the authors of this study to offer this analysis with these background cautions.

Many cost/benefit analyses involving fisheries, will either formally apply a bio-economic model or apply relevant components of a bioeconomic model to address a policy question. Applying bioeconomic reasoning to a restoration project requires a use of (1) a population size/population growth estimate that responds to changes in fishing effort, (2) a demand model, (3) an industry supply function that is responsive to the catchability of the fish (frequently this is a fishing cost model if the market is analyzed at the point of landing), (4) a method for discounting benefits and costs in time, and (5) a method of accounting for the social costs of labor and capital in the fishing fleet and for the government inputs.

These five basic components will be applied to the suite of restoration projects defined in the Restoration Survey. The more rigorous form of a bioeconomic model, which involves linking the feedbacks from changes in fishing effort to harvesting and population level changes, in a simultaneously estimated model will not be applied for this assessment. Four species of salmon would be impacted by the restoration projects, including: sockeye, coho, chum pink and coho. The production of fish from each project is projected by ADF&G staff in the form of a with-project and without-project case.

Population and Harvest Projections from Restoration Projects

The following physical science data was projected for each project by Willette, Dudiak and White (1993).

1. A general description of each project, identifying the target species, the starting and ending date of restoration, location of restoration, location of expected harvests from the project by major statistical areas that are to be impacted.

2. Projected Adult harvest data for each affected species in a project by year, and aggregation of statistical areas with and without the project. These projections must produce a time series of expected harvests from the start of the project to approximately 20 years.

The variables in the database are as follows:

- Restoration Project Name.
- Year.
- Species 1, 2, 3.
- Statistical Area(s).
- Month that harvest occurs.
- Commercial Gear type in stat area.
- Numbers of commercial fish harvested by species 1,2,3 etc. by stat area and gear type without project.
- Numbers of commercial fish harvested by species 1,2,3 etc. by stat area and gear type with project.
- Mean weight of commercial fish harvested (not necessary by year).
- Numbers of sport fish harvested by species 1,2,3 etc. by stat area without project.
- Numbers of sport fish harvested by species 1,2,3 etc. by stat area without project.
- Units of standard fishing days (effort in stat area) without sport fish project.
- Units of standard fishing visitor days (effort in stat area) with sport fish project.

3. For each restoration project, fishery managers in the oil spill affected area were asked whether the projects would (1) extend the length of existing openings, (2) create new openings in statistical management areas that are not currently being fished in the same period, or (3) generate change in the number of fishermen switching form other fishing sights to the stat areas targeting the fish from this project, or (4) generally creating a higher abundance of fish that will simply be harvested in the same amount of time with the same gear.

note: A fishing visitor day is one day if the fisherman visits the site and fishes for any amount of time in a day. If they stay for four days. the number of fishing days is four days, even if they fished 12 hours (or longer) per day.

note: The statistical management areas in the commercial fishery are generally aggregated across the area, eg. Cook Inlet, Kodiak, or Prince William Sound.

Demand and price assumptions for the fish at harvest

The analysis projects the change in total revenue to the commercial fishing fleet through the use of point elasticities and average prices for each species of salmon. The point estimates for mid point price and elasticity, were derived from several published studies that have been developed on markets for salmon. Some test cases were also be provided that assume no price response from the proposed projects. Some of the point price projections and elasticities were modified from Herrmann and Greenburg (1993). An International Marketing Model for Alaskan Salmon. Average point elasticities are summarized in Table X1. This analysis has been criticized by some researchers for attributing too much of the variation in price to Alaskan salmon supply (harvest levels). Thus, a second case for each of the 14 projects is generated by relaxing the point elasticities so that we may determine if higher elasticities (resulting in less price response) affect the ranking of projects by Net Present Value.

A third case was developed with no price response (implying perfectly elastic prices). Point prices used for the analysis are 0.15/lbs for pink salmon, $0.25/lbs for chum salmon, $0.65/lbs for coho, and $0.70/lbs for sockeye. While sensitivity testing is preformed on the assumed point elasticity for each project, no sensitivity testing is carried out on the price variable.

Table X1 Ex-vessel own price, own price elasticity, and relaxed price elasticity for 14 projects and 14 scenarios used in CBA of Restoration Survey.

Species	Own Price $/lbs	Own Price Elasticity	Relaxed Own Price Elasticity
Pink	0.15	-1.460	-2.92
Chum	0.25	-7.780	-15.55
Coho	0.65	-13.54	-27.07
Sockeye	0.70	-1.34	-2.68

Harvesting cost assumptions.

The approach for estimating the change in total revenue to the fishing fleet from a restoration project has been accounted for. To determine the net economic benefits of EVOS salmon restoration projects an additional element must be brought into the computation, namely, the costs of harvesting the stock of enhanced fish production. An industry supply function (which describes the costs of producing a given amount of a good) like a demand function can theoretically be constructed at any market level. Considering the available data on industry costs and production for salmon harvesting in the regions affected by the restoration survey, the most relevant industry supply function for this cost benefit analysis would be at the point of landing and associated with the opportunity costs of fishers.

Costs that are foregone in the process of harvesting the incremental catch must be subtracted from the change in total revenue. Three types of costs are important to the assessing net benefits: (1) the variable costs of the fishermen that are incremental, (2) the social costs of the capital related to fish harvesting that are incremental, and (3) the social costs of the labor employed in the processes of harvesting the increment.

There are two possible (opposing) cases for projecting fishing costs that are attributable to the various projects. First, it is possible that additional salmon production will simply increase the density of the fish run. The increased harvest could then be taken with about the same amount of operating costs, travel costs, and labor costs as before the projects existed. Since the fleet has sufficient fishing capacity to easily harvest the incremental harvest from each of these small projects, then no additional labor or capital will be required. This implies that no additional costs are involved and gross benefits are equal to net benefits. This case would tend to hold if all of the input choices were bound up because of perfectly effective fleet rationalization. Under these conditions little additional labor or capital may be required to harvest all the fish produced. This implies that no additional costs to the fishing fleets are involved and gross benefits are equal to net benefits.

A second case results from the assumption that the fleet will operate as an open access fishery. In this case, anticipated increases in gross revenues are immediately translated into increased fishing effort. The additional fishing power that is applied to the available stock of fish is not significantly restrained by time area openings, gear restraints, or area licensing. Additional vessels, and capital may enter the fishery until costs have risen by as much as the increase in total revenues. Rents accrue to the most efficient fishermen and other fishermen are earn no economic rent.

For the open access case in the long run, while individual fishing operations become more technically efficient in catching fish, the fleet in aggregate becomes economically less efficient. This extreme process would apply regardless of whether the harvest had been increased by a project (like a fish pass or spawning channel) or some management action that allowed for higher sustained harvests. This case would imply that the only rents that could be captured in a fishery would be by the fishermen who were highly skilled.

Interviews with fishermen, fisheries managers, and the existence of positive permit prices lead us to believe that neither of these two extreme cases will apply to the small scale restoration projects proposed for Prince William Sound, Lower Cook Inlet, and Kodiak salmon fisheries. Bruce Rettig, an OSU economist presents a convincing argument for conducting sensitive analysis for estimating fishing costs for improvements in Oregon salmon harvests in that state's gill net and troll fisheries. He recommends that Net economic values for salmon enhancement and mitigation projects in Oregon can be estimated at 50%, 75%, and 90% of gross economic value (Rettig andMcCarl 1984) .

A similar approach to projecting long run fishing costs was applied to the gillnet and seine fleets affected by the proposed restoration projects. Two constants modified from recently developed fishing cost models for Alaska salmon fisheries will be applied to estimation of fishing costs . The first is an elaboration of the open access case described above. It will be derived from the point estimates of incremental harvesting cost estimated in Boyce 1992 (Using Participation Data to estimate Fishing Costs for Commercial salmon fisheries in Alaska). Simulations from this model produced estimates of the amount of producer surplus created from a change in expected gross earnings of several Alaska salmon fisheries. The inverse of the average producer surplus per change in gross earnings, was used as a proxy for fishing cost in the identical fisheries in the Restoration Survey. Separate estimates of harvesting costs were estimated for the Cook Inlet Drift Net Fleet , Cook Inlet Purse Seine Fleet, Cook Inlet Set Net Fleet, Kodiak Purse Seine Fleet, Kodiak Set Net Fleet, Prince William Sound Drift Net, and Prince William Sound Purse Seine Fleet.

The average estimates of the ratio of fishing cost to total revenue for a given fleet is summarized in Table X. The Boyce analysis, has been criticized by some economists for underestimating producer surplus from marginal changes in fishery harvests. For this reason some limited sensitivity analysis will be applied to point estimates of fishing costs, by proportionally increasing the ratio of producer surplus to total revenues.

Table X. High case and low case of ratio of Producer Surplus to Total Revenues and ratio of fishing cost to total revenue for each fishing fleet used in the Restoration Survey CBA.

Fishing Fleet	PS/TR(1) Boyce	FC/TR(2) Boyce	PS/TR(3) relaxed	FC/TR(4) relaxed
Cook Inlet Drift Net	0.14	0.86	0.57	0.43
Cook Inlet Purse Seine	0.41	0.59	0.70	0.30
Cook Inlet Set Net	0.60	0.40	0.80	0.20
Kodiak Purse Seine	0.42	0.58	0.71	0.29
Kodiak Set Net	0.42	0.58	0.71	0.29
PWS Drift Net	0.17	0.83	0.58	0.42
PWS Purse Seine	0.24	0.76	0.62	0.38

(1) PS/TR, Boyce: Producer Surplus divided by Total Revenue taken from pg 23, Boyce (1993)
(2) FC/TR, Boyce: 1- Producer Surplus divided by Total Revenue taken from pg 23, Boyce (1993).
(3) PS/TR, relaxed: 1-1/2(FC/TR) One less, one half the Producer Surplus divided by Total Revenue taken from pg 23, Boyce (1993)

(4) FC/TR, relaxed: 1/2(FC/TR)- One half of the fishing cost divided by Total Revenue taken from pg 23, Boyce (1993).

In the initial stages of this study, a third approach was proposed for estimating opportunity costs for fishermen called the "engineering method". In this method,selected fishermen would have been surveyed to obtain information on their variable harvesting costs and estimating additional opportunity costs of labor and capital. This approach was not applied because of lack of resources and time for an appropriate survey.

Project cost assumptions

In theory the social costs of producing the restoration projects, include the resources foregone in the process of constructing, operating the facility. Also it includes the value of the site in its next best alternative. The project managers of the Restoration survey projected the accounting costs of each project over approximately 20 years. Accounting costs include construction, operations, maintenance, and incremental fishery management for each affected project. These accounting costs are used a proxy for the opportunity costs for the restoration projects.

Accounting Identities and Estimation of Net Present Value

In a publicly funded project it is necessary that accounting equations deal with both private and public benefits and costs (equation [1]). The level of profitability for each investment alternative is determined using equations that calculate the Present Value of the Net Benefits (NPV) and benefit-cost ratio of those cases. The equations applied to this study are the conventional equations used by economists to conduct benefit:cost analysis on publicly funded projects (Randall 1981):

Equation 1. B(pri) - C(pri) - C(pub) = Present value of the net benefits (NPV)

Where:

B(pri) = The present value of the benefits (revenue) to the private sector which results from a change in the amount or value of product harvested due to the enhancement project.

C(pri) = The present value of the costs to the private sector resulting from the enhancement project. (e.g. cost of harvesting and/or processing, etc.).

C(pub) = The present value of the public costs (pub) resulting from producing and managing enhanced stocks of fish.(e.g. operational cost, construction cost and planning costs of the enhancement facility).

The net present value of projects as well as the B:C ratio will be computed with a 3% and 5% interest rate. These two figures approximate the upper and lower bounds for the real discount rate (the interest rate minus the rate of inflation) for Alaska during recent years. For example, the real discount rate for 1992 was 3.62%, calculated using the average return for a 10-year government treasury bill minus the Anchorage consumer price index (CPI) as a measure of inflation. Choice between the two discount rates evaluated (3% and 5%) is a matter of personal selection as to which best represents conditions that will occur during the projected life of the project.

Recreational Valuation Assumptions

Valuing the potential benefits to recreational sport fishermen from these projects was a complex task. Generally, the revenue estimates for sport fishing involve a great deal more uncertainty than the equivalent calculations for commercial fishing. The steps involved reviewing and revising estimations of sport fish harvest, translating estimated additional (marginal) harvest into annual marginal fishing effort (in angler) days. Once the number of angler days for each project was calculated, the sport fishing benefits associated with that level of new fishing effort was estimated, using previously developed net willingness to pay point estimates.

Initially, the projects were grouped into two classifications: those that provided sport angling benefits and those that did not. The production data developed by the project design team did not identify sport fish marginal harvest estimations for all seven projects in the Kodiak area and the Cook Inlet project located at Port Dick. The reasons for not including sport benefits in the initial assessment were as follows:

- The projects were in remote locations which receive very low levels of angling effort. For the sport fishing which does occur in these locations, abundance of salmon was not seen to be a limiting factor in angling success.
- When salmon are present in these locations, there are sufficient numbers to provide for the current and anticipated levels of sport fishing effort. Greater abundance would not necessarily result in increased harvests.
- The species produced in these proposed projects were chums and pinks. Generally, these species are less attractive to sport fishermen than chinook, coho or sockeye.

With a very large number of potential alternate choices for remote sportfishermen, particularly for these species, the additional abundance of salmon created by the projects would probably not attract new anglers to the area. Therefore, the basic sport fishing assumption for these sites was that **marginal fishing effort would be negligible.**

For the same reasons, two of the six sites in Prince William Sound also received an the initial designation of negligible benefits to sport harvests by the design team. However, four other projects in the Valdez area were initially assessed as having very high sport fishing benefits.

To investigate the sport fishing benefits further, we interviewed several sportfishing biologists with experience in the area to evaluate impacts of each of the individual fishing sites. Sportfishing in the Valdez arm is currently carried on almost entirely in marine waters, primarily for pinks and coho. The fishery predominantly targets salmon returning to the Solomon Gulch Hatchery, located near the head of Valdez Arm. After several lengthy discussions, it was decided that there likely be negligible benefits to sport fishermen from incremental numbers of pinks and chums. We relied on the judgement of the regional biologists that pink and chum harvests were not limited by abundance during the period they were present in the marine fishery. In addition, consideration of a potential fresh water fishery was dropped since it would not be possible under the existing management regime. Therefore, after consideration of these factors, sport fishing benefits from pink and chum salmon production in Prince William Sound was assumed to be negligible, although there would be some project fish harvested in the marine fishery. This sequential examination of sport benefits left only benefits from coho production to be quantified.

The projected marginal coho harvests for the two remaining projects under consideration for contributions to sport fish benefits was calculated using a factor of two days of effort for each coho harvested. This factor was developed by ADF&G Sport Fish Division for use in their annual management planning.

With estimates in hand on the potential marginal effort for coho production from the two projects, the remaining task was to translate angler days into angler benefits. There are little data available for use in valuing angler days. The primary source in Alaska are from a series of studies contracted by ADF&G (Jones & Stokes, Inc., 1987, 1987 and 1991). Unfortunately, none of these studies estimated valuation of angler effort in the Valdez area. The closest example we found was from the 1987 Southcentral study, which calculated estimates for silver (coho) fishing in Resurrection Bay. This provided a net willingness to pay for this fishery of $1,352,000 for the year in which the study was completed, 1986. To convert this estimate into an average per-day figure, we needed to divide the total by the total effort expended in sport fishing for coho in Resurrection Bay during 1986. This information was obtained from ADF&G (personal communication, Doug McBride) to be approximately 25,000 angler days. The estimate of angler days for coho fishing in Resurrection Bay comes from a combination of crees census data and other information.

Using the figures above, an average net willingness to pay for coho fishing in Resurrection Bay in 1986 was $54.08. Using the Anchorage consumer price index from the U.S. Bureau of Labor Statistics to adjust the estimate to 1993 equivalent value, the result is $65.97 per angler day. When this figure is compared with other point estimates from the Jones and Stokes studies, it is towards the low end of the range for average willingness to pay for various coho fishing regions in Southeast Alaska.

In applying the average net willingness to the estimated increase in effort, we have applied a couple of factors to compensate for our basic uncertainty about fishermens' effort response to increased harvest in the Valdez marine coho fishery. It does not seem a reasonable assumption to utilize a constant marginal effort increase to apply to increased harvests of project-produced coho. However, we have almost no information that tells us how to translate changes in harvest to changes in effort. Based on data presented in the Southcentral Sport Fishing Economic Study (Jones & Stokes Associates, Inc., 1991), a constant factor of .5 was selected to represent the elasticity of fishing effort for additional salmon.

Finally, a factor was applied to translate the average net willingness to pay for an angler day to a marginal net willingness to pay. Although there is not a great body of research in this area, there are recent studies which suggest that sportfishing effort response to higher success rates and the effect that higher success rates have on angler demand (Shaffer & Associates, Ltd., 1987). The factor of .5 representing this marginal elasticity has been utilized in several recent studies by Fisheries and Oceans Canada. Until further research revises this elasticity estimate for Alaska's fisheries, this estimate is utilized as the best information available.

Results

Twelve simulations are made by varying three economic variables for the 14 projects. Appendix X3 summarizes the results of the simulations and presents the mean net present value for the twelve cases. It is ranked by descending order of the mean net present value. Appendix X4 is a summary of the benefit:cost ratio for each project. It is also ranked by descending order of the net present value.

The ranked projects are then aggregated into three groups. For Table X1, projects with net present values greater than $0. This implies that the projects would at least have benefits equal or greater than the costs of production. This category includes five projects. They include the 6.5 Mile Richardson Highway Project, Horse Marine Fish Pass Project, Cold Creek, Fish Pass, Waterfall Fish Pass, and Pink River Fish Pass.

Table X1 Summary of Mean Net Present Values and B:C ratios from twelve simulations of 14 restoration projects.

Projects with Positive NB (greater than $0)	Net Benefit	Benefit/Cost
6.5 Mile Richardson Highway Project	$910,912	2.85:1
Horse Marine Fish Pass Project	$727,420	3.47:1
Cold Creek Fish Pass	$193,214	6.14:1
Waterfall Fish Pass	$141,674	1.62:1
Pink River Fish Pass	$ 33,207	1.86:1
Projects with NB less than 0 and greater than -$400,000	Net Benefit	Benefit/Cost
9 Mile Richardson Spawn Channel	($27,509)	0.91:1
Port Dick Spawning Channel	($116,357)	0.40:1
Pipeyard Spawning Channel	($243,196)	0.27:1
Softball Field Spawn. Channel	($289,110)	0.37:1
Complex Creek Spawning Channel	($338,015)	0.12:1
Betttles River Fish Pass	($373,908)	0.11:1
Projects with NB less than -$400,000 and greater than -$1,055,000	Net Benefit	Benefit/Cost
Viekoda Fish Pass	($425,781)	0.14:1
Seven Rivers Fish Pass	($473,794)	0.05:1
Baumans Creek Fish Pass	($1.055,305)	0.22:1

When projects are ordered by descending net present value, this order does not correspond identically to the descending order of project benefit:cost ratios. This is because of the relative size of each project. For example, two projects (1) a small project with benefits of $1,000 and costs of $500 has a net present value of $500 (1,000-500) and a benefit :cost ratio of 2:1, (1,000/500), while project (2), a larger project with benefits of $2,000, and costs of $1,500 will also have a net present value of $500 (2000-1500) but a benefit: cost ratio of approximately 1.33: 1.

While the target species of many of the 14 restoration projects are pink salmon, restoration projects which did not have much additional production of chum, coho, or sockeye had low net present values. This largely because of the elasticities applied to pink salmon in the range of 1.5 and 3.0. Projects, clearly falling into this group consisting of predominantly pink salmon harvests were Bauman′ s Fish Pass, Seven Rivers Fish Pass and Viekoda Fish Pass.

In the first grouping of restoration projects, with net present values of greater than $0, four of 5 projects are Kodiak area fish passes. These projects appeared in the highest grouping for two principal reasons. First, some of the projects have very low projected operating and construction costs. Kodiak staff projected that the initial construction projects associated with both Cold Creek Fish Pass and Pink Fish Pass were respectively $25,000 and $26,000 with annual operating costs of $1,000. This is very low compared with most of the other restoration projects. A second reason that the other fish pass projects are in the high NPV group is because of significant production of other less price responsive salmon species (species with higher elasticities, such as chum and coho). Rankings of projects in Kodiak were also influenced by lower harvesting costs as determined by the average producer surplus estimates from Boyce 1993.

The potential for increasing recreational fishery harvests and fishing effort in the Valdez area, significantly influenced the NPV of two spawning channel projects. They are the Richardson Highway 6.5 mile and 9 mile spawning channels. The 6.5 mile Richardson Highway project had the highest potential NPV of any project, as an increment of approximately 8,000 angler days was projected to occur from the site by the year 2000.

Discussion

The intent of this CBA analysis is not to determine whether these projects produce positive net social benefits. This would be a large undertaking, and thus it is possible that none of the projects would have positive net benefits, or that more projects than identified would have positive net benefits. Its purpose is to order and group project Net Present Value's relative to each other. This is a much more modest and feasible undertaking.

The differences in the net present values between projects are sufficient to draw some tentative conclusions of how these projects compare with each other. Given that the staff biologists projections of harvests are good forecasts, we are reasonably confident that projects falling into the highest NPV group are significantly different from projects falling into the lowest NPV group. The position of projects in the middle group is shrouded with uncertainty. Some of the projects could easily be shifted into the upper or lower NPV group with small changes in the biological, fishery, or economic assumptions. These assumptions and their relative importance as variable in the groupings are discussed further below.

Principal Variables in the models Sources of Error and Potential Biases.

1. Biological:

One of the critical biological variables appears to be how quickly spawning area is utilized by the species in the systems restored. For both spawning channels and fish passes, it was assumed that the available spawning habitat would be utilized "optimally". This utilization would not occur in the first life cycle, rather it would be phased over three full life cycles. The first cycle was assumed to utilize 20% of the optimum spawning habitat. The second cycle utilized 50% and the third cycle utilized approximately 60% to 75% of the habitat.

Other variables affecting the present value of an individual projects include the rate of exploitation in the commercial and recreational fishery, and size at harvest. These assumptions were generated by Mark Willette, Lonnie White, Steve Honnold, and Nick Dudiak, and are reported in the overall Restoration Survey report.

2. Demand model and price assumptions.

Assumptions made regarding the stability of prices and own price elasticities, are significant variables in the projection of the net present value of each project. Potential errors from the model and data used could arise from in the following areas:

- Technical reviews of the demand models which were used to generate the point elasticities used in this study raise serious questions about the confidence that may be placed in the Herrmann model (Wilen 1993). Mean own price elasticities are extracted from a specific simulation case which assumes that harvests wild salmon which would be equivalent to the largest historical ten year harvest period in Alaska's history. These assumptions and others may overstate the price response if wild stock production falls.
- The econometric models created by Herrman and Greenburg cannot empirically forecast some potential structural and supply changes that could affect ex-vessel prices in Alaska. For example, potential market changes that could result from increased Russian salmon exports into Alaska export markets would be difficult to determine. Also, new salmon product forms could also change create shifts in the demand for

salmon.

- The approach applied to relaxing elasticities is strictly ad-hoc.
- Potential price response effects from consideration cross price elasticities not included in the estimation of the change in total revenues.

Given these potential sources of error, there are no alternative demand models, recently published to draw from .

3. Fishing cost assumptions.

Based on current management regimes in the Kodiak and Prince William Sound areas, we determined that additional salmon returning through commercial fishing areas would not result in additional time or area openings. This means basically that the contribution from these projects to the commercial fishery would result in higher catch per unit of effort for fishing activities the fishermen would be engaged in, whether or not these projects were completed.

It could be argued that the marginal cost for harvest of project-produced salmon would either be very low or would be negligible. The only significant component of vessel operating cost that would be affected would be the crew share. The actual percentage of gross revenues that accrue to crew share depend on the type of fishing operation. A typical cost sharing system for a seine vessel allocates 50% of gross revenues to the crew, with some categories of vessel expenses (such as fuel and food) being taken off the 50% prior to calculation of crew shares. The captain typically gets a crew share, so if the captain is also the boat owner, crew share would go toward the net revenues of the fishing operation. Given the example above or an owner operated seine vessel, the crew share of marginal enhanced salmon revenues would probably be around 30% of gross ex-vessel value.

4. Interest Rates

While the testing of two interest rates did affect the net present value of all projects, the two levels chosen, namely 3% and 5% seem to have little effect on the overall ranking or placement of projects in the high, medium or low NPV groupings. This is because the stream of benefits and costs for these restoration projects are somewhat homogeneous in time. That is, no projects are building up to full production much more or less quickly than others because of the uniform assumptions imposed by the staff biologists forecasting the rate at which potential spawning habitat would be utilized. Interest rates might affect rankings of two projects when one was at full capacity in 1 salmon life cycle, and another was at full capacity in several life cycles, as may be the case when comparing planting projects which could conceivable produce large increments in catch in 1 cycle against a typical fish pass, which might take 10 or 15 years to build an equilibrium population level.

5. Items Omitted from Consideration

There were some areas of potential benefit that were not considered in this analysis. For example, the Bettles River project in Prince William Sound could increase the production of wild pink salmon. Given the current management difficulties in Prince Willliam Sound in protecting declining wild pink salmon, increases in wild stocks could serve to ease management constraints, thereby allowing for increased harvests in other areas even if the fish produced by the project were not directly harvested.

A second potential benefit that was not evaluated was the research benefits that would accrue from completion and operation of one or more of the projects. For example, the Complex Creek project may provide some research benefits in increasing knowledge about the survival of released fish in the PWS marine environment due to the tag recovery program associated with the project.

While these and other benefits were not specifically quantified in the cost benefit calculations, they would provide some level of benefit.

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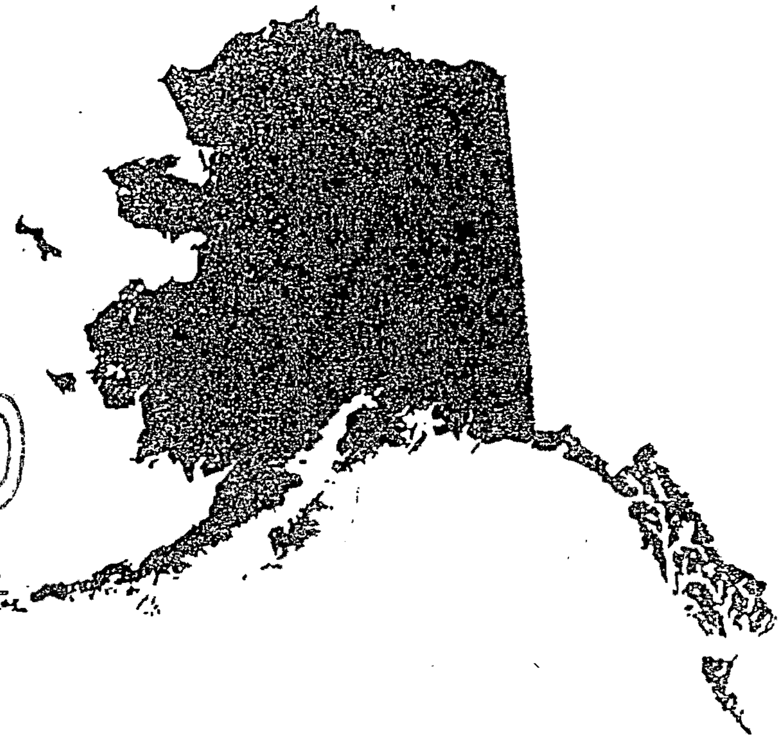
Appendix X

Some examples of the federal regulations directing economic efficiency in management of U.S. fisheries

- o Operational Guidelines :Fishery Management Handbook NOAA 1983.
- o Regulatory Flexibility Analysis: Costs imposed on small business must be scaled proportionally so that small business do not receive undue burden. Small Business Administration
- o Executive Order 12291 February 17, 1981 46 FR 13193 Describes overriding federal regulations affecting all actions taken in the interest of the Citizens of the U.S. Directs the use of resources in manner that produces positive Net Social Benefits.
- o NEPA Describes consideration and methods for socioeconomic analysis. NOAA must adhere to NEPA process in creation of new Federal fishery regulation.



Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska

Interim Report from the Cordova Workshop, November 10-15, 1991

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EXECUTIVE SUMMARY

O. A. Mathisen and G. L. Thomas

Genetic Considerations

It was agreed at the workshop that wild stocks in Alaska contain the genetic resources necessary for continued production of salmon under shifting environmental conditions. The Genetic Policy of Alaska[1] acknowledges that genetic diversity buffers biological systems against disaster, either natural or human-induced. There was almost universal agreement that maintaining genetic diversity both within and between local populations is essential for the long-term sustained production of Alaskan salmon.

A distinction must be made between preservation and conservation. In the strict sense preservation implies leaving everything untouched, which excludes enhancement activities, while conservation denotes enhancement, which is in conformity with the inherent characters of the stocks being enhanced.

The same basic principle of the importance of genetic variability (both within and between stocks) applies equally well to the management of hatchery brood stocks. Loss of genetic variability can be brought about by inbreeding and selection; the rate of loss can, however, be reduced using a large number of spawners and approximately a 50:50 sex ratio. To minimize impacts of hatchery fish on native stocks, phenotypic variation in brood stocks should reflect the variation observed in wild populations. However, this should not preclude that there may be opportunities to use genetic differences to avoid interaction between hatchery and wild stocks.

Homing and Straying

The homing instinct of anadromous species leads to reproductive isolation of the various populations in their distinct environmental setting, which results in genetic adaptations to the local environment. Some hatchery fish with specific but different genetic characteristics will stray into wild populations. If they successfully interbreed with wild fish, the fitness of locally adapted populations may decrease.

Although the imprinting process is an important factor in homing, our knowledge about the imprinting process is still very limited. Additional studies are especially critical for species involved in remote releases.

Improperly imprinted fish tend to home less accurately. Introduced populations and salmon whose rearing history involves displacement or changes in water source often stray more than members of native stock and those released on-site.

The genetic impact of strays on local gene pools depends not only on the prevalence of straying and the mating success of the strays, but also on the differential survival of the populations. Because remote released fish may have a high straying rate, continuation of

[1]Alaska Department of Fish and Game Genetic Policy. 1985. R. Davis, ed. Special Report of the Division of Rehabilitation, Enhancement, and Development. 25 p. (Appended to the Legislative Review of the Alaska Salmon Enhancement Program by the Senate Special Committee on Domestic and International Commercial Fisheries, Feb. 19, 1992.)

remote site releases without knowledge of the underlying biological processes may lead to loss of the original genetic diversity through undesirable gene flow from hatchery populations to wild populations.

Because of the potentially negative consequences, a funding base should be established so that appropriate research of these problems can commence without delay. At the same time, remote site releases should be limited until their effects on the adjacent wild stocks are understood and can be considered.

Ocean Carrying Capacity

Density dependent growth in the ocean or nearshore marine environment has been documented more exactly in recent years, especially for Bristol Bay sockeye salmon and Japanese chum salmon. In Japan the size of chums has been decreasing, and the average ages of the returning chums have decreased in recent years.

For Alaskan pink salmon there is strong evidence that survival and final length or weight are largely determined by the growth conditions when the pink larvae reach the estuaries and while they continue to feed in inlets and nearshore waters. For sockeye salmon, it appears that final size is largely determined during the last months of ocean residence. The average length or weight of pink salmon decreased sharply in 1991, for both North American and Asian stocks. This coincided with record catches in the Far East, 216,248 metric tons or about 216 million fish, as well as large catches in Alaska, about 140 million fish. In an even year like 1992 the Far East catches will be down, and reduced catches are also expected in North America. The length or weight to be observed in 1992 should, therefore, contribute greatly to our understanding of the carrying capacity of the North Pacific Ocean for salmon.

Management of Mixed-Stock Fisheries

Pink salmon.—For pink salmon (*Oncorhynchus gorbuscha*) the most successful hatcheries are found in Prince William Sound, where returns range from 30 to 40 million fish. However, data presented at the workshop pointed out the need for larger escapements of the wild stocks in the region before these runs would reach their maximum productivity. In order to increase escapements, mixed stock fisheries must be reduced and enhanced stocks harvested closer to the hatchery. Such a management scheme could reduce the quality of the fish and the value of hatchery production.

If enhancement activities are conducted over broad areas, the risk of losing genetic diversity is increased. It might be suggested that new hatcheries be confined to restricted areas, at least until our knowledge of straying and the importance of genetic structures and variates has been expanded vastly.

Chum salmon.—Some chum salmon (*O. keta*) hatcheries have been very productive. Harvest of mixed stock fisheries at a high rate of exploitation, however, can result in an excessive harvest rate on the less productive stocks. Tagging or marking of enhanced and wild fish stocks or both chums and pinks followed by in-season test fishing can be used to design a harvest strategy to maximize harvest of enhanced stocks in mixed wild and enhanced areas while meeting escapement goals for wild stocks. Because chum salmon operations are smaller in scale than for pink salmon, interaction problems are not as visible. Chums deteriorate rapidly in terminal areas, which makes large-scale chum enhancement projects difficult for optimizing effects.

Coho salmon.—For coho salmon (*O. kisutch*), as for all other species of Pacific salmon, the statutes and regulations are to manage for the natural stocks with enhancement as a supplemental tool. Most of the production of coho in southeast Alaska is from natural stocks; the average harvest of enhanced coho from 1986 through 1990 was 8.1% of the total harvest. Even though enhanced cohos represent a small percentage of the total production, similar concerns exist regarding straying and inbreeding, especially with projected future increases in the enhancement program. Other concerns, such as predation by coho salmon on pink salmon larvae and juveniles, are surfacing, although no conclusive research has been conducted to date. Coho smolts today are commonly released after the pink salmon larvae have left the estuaries, but the pink fry or juveniles may not leave the inshore area before July, which leaves ample time for predation to become a reality.

Since more coho smolts are tagged with coded wire, there are means available to study the changes brought about by expanded enhancement programs.

At the present time, the coho enhancement program appears to be meeting the original legislative intent of supplementing the harvest of coho salmon while not negatively impacting wild stocks.

Chinook salmon.—The chinook salmon (*O. tshawytscha*) is the least abundant but the most prized salmon species. Fifteen enhancement programs operate at the present time in southeast Alaska, but none were built on extant wild chinook streams. Four primary hatchery stocks, derived from regional wild stocks, are used. Movements of eggs between hatcheries are carefully regulated based on stock, disease history, and location of hatchery.

The small numbers involved—average harvest since 1985 has been only 19,590 chinooks or 10.2% of total production—seemingly have had no adverse effect. If numbers of enhanced chinook should increase, some interaction problems may arise, especially due to straying. It is noteworthy that although the production of wild chinook salmon in southeast Alaska is small, it is increasing.

Sockeye salmon.—Sockeye salmon (*O. nerka*) stocks are less enhanced than other species at the present time. There are several attempts to accelerate the smolting process for early releases to sea after 3 months or so in freshwater. Many large streams have populations of sockeye which migrate to sea after 3 months' rearing in the rivers or estuaries, but these races are not always used in sockeye enhancement projects.

In view of the anatomical and physiological changes taking place at time of smoltification, the early releases carry with them the possibility of improper imprinting and subsequent straying at time of return unless natural zero age sockeye are used for brood stocks (Ebbesson, abstract).

Atlantic Salmon

The Atlantic salmon (*Salmo salar*) has been under enhancement for 40 to 50 years in Norway and Sweden under two different regimes and with different results.

Large-scale enhancement of the Atlantic salmon commenced in Sweden in the late forties when most of the major streams were developed for hydroelectric power, thus eliminating most of the natural habitats. In order to compensate for this loss, one hatchery was built for each stream and smolts were released only in the stream of their origin. This program proved so successful that the Swedish salmon stocks were not only maintained, but increased. In later years, an intensified high seas fishery has increased the total fishing mortality. The enhanced stocks have been able to tolerate it, but this rate of exploitation has placed an undue strain on the small remaining natural stocks of salmon, which are in decline. In spite of the success of their hatcheries, the Swedes are managing their salmon fisheries with primary focus and priority on natural populations, by attempting to bring the harvest back to the estuaries and eliminating the mixed stock fisheries. According to the Swedes, management without a primary focus and priority on natural populations is a serious mistake.

In order to satisfy the demand of its rapidly expanding pen farming of the Atlantic salmon, Norway allowed free import of smolts from a number of European countries and from any stream in Norway with a smolt surplus. What was not anticipated was the large number of salmon escaping from the farm pens, with the result that some rivers contain spawning stocks made up of 80% or more of cultured fish. Attempts are under way to create sperm banks in order to save what may be left of the original gene pool, if any.

Conclusions

As our knowledge of salmon increases, there is emerging a picture of an organism closely tuned to its environment as an integral component in a complex environmental system. Synchrony between stock characteristics and the environment requires working with the native gene pool and avoiding contamination from other sources. Early enhancement projects in Alaska did not pay enough attention to the origin of the brood stocks in order to get started, and a number of sources were used and eggs have been shifted around, especially for chinook and coho. So far there is little evidence of harmful effects, probably because of the low level of enhancements as well as our inability to measure the effect.

The contrast between what has happened in Sweden and in Norway contains some important guidelines for good and less desirable enhancement practices. It points out the need in new enhancement projects to work in conformity with the life history strategies of the enhanced stocks of salmon and not consider the most convenient procedures from a construction or operational standpoint.

II.
INTRODUCTION

The Problem

Hatchery operations of salmon and trout have been in progress for more than a century in Europe, North America, and Asia. For a long time there was little effect on the natural stocks because the operations were small or were generally unsuccessful due to a lack of understanding of the reproductive process and survival mechanisms in salmonid species. In later years new knowledge and better techniques brought about major changes in salmonid enhancement programs throughout the world, especially in Alaska.

Non-profit hatchery operations and ocean ranching were legalized by the Alaska State Legislature in 1972. This occurred when natural production of salmonids was at low levels, which also coincided with cool ocean temperatures. The objective of the hatchery and ocean ranching programs was to supplement the production of natural fish during years of low abundance. In the beginning, enhancement was on a limited scale and not a problem, but in recent years with favorable survival conditions both natural and enhanced stocks have reached unprecedented levels of abundance. Further complicating matters has been a dramatic increase in the world supply of salmon. During the last few years the cumulative production of salmon has created such an oversupply that markets have been saturated and prices for some species have collapsed, profoundly affecting fishing, processing, and marketing of Pacific salmon.

The growth and success of the hatchery and ocean ranching programs has also created concern about the potential effects of enhanced fish on natural stocks of Alaskan salmon. Conflicts have arisen between the non-profit enhancement organizations and the State's regulatory agencies, who manage by protecting the escapement of natural stocks. The Alaska Legislature established this agency policy in order to protect wild stocks of Pacific salmon from potentially irreversible changes. Despite the magnitude of the enhancement programs and Alaska's mandate to protect wild salmon stocks, no environmental impact statement has been required for developing the enhancement programs.

Early in 1990 the Prince William Sound Science Center and the University of Alaska Fairbanks began planning a workshop on the biological interactions of natural and enhanced fish stocks in Alaska. The workshop followed four international symposia on hatchery and wild salmon interactions: (1) in 1990 at the Institute of Nature Conservation, Norway; (2) in 1991 at the Department of Fisheries and Oceans, Nanaimo, British Columbia, Canada; (3) in 1991 at the University of Idaho, Moscow, Idaho, and at Washington State University, Pullman, Washington, which was sponsored by NATO; and (4) in 1991 at the University of Hokkaido, in Hokkaido, Japan.

In the 1991 Alaska State Legislature, four study groups prepared background material on wild and hatchery interaction issues for a legislative examination and debate. This workshop was independent of these legislative study groups, but complementary because of its focus on the *biological* questions related to salmon enhancement. For practical purposes in the workshop, salmon enhancement is used synonymously with ocean ranching, and pen farming, lake fertilization, or other indirect measures, such as habitat manipulation, were not addressed.

Goals and Objectives

In recent international scientific meetings the enhancement of salmon production has been challenged for its potentially detrimental biological impacts. Since Prince William Sound and southeast Alaska have significant salmon enhancement programs, it was thought appropriate to bring together a group of scientists and public to examine the biological basis for maintaining strong coexisting stocks of natural and enhanced salmon stocks in Alaska. This issue has raised specific concerns that are related to the effects of enhancement on the genetic composition, behavior, survival, and fitness of natural stocks, and the carrying capacity of the marine ecosystem. The goal of this workshop was to define the scientific basis for demonstrating a biological impact of enhanced salmon on natural stocks, the nature and magnitude of the impact, and identifying available and missing information. With this goal in mind this workshop examined (1) evidence, or lack of, that enhanced stocks are affecting the genetic composition and behavioral characteristics of natural stocks of salmon in Alaska, and (2) the potential for a limited ocean carrying capacity for rearing salmon.

III.
THE PROCESS

The workshop was convened in Cordova, Alaska, from November 11 to 15, 1991, under the auspices of the Prince William Sound Science Center. The participants represented three categories: international experts, national experts outside Alaska, and experts from inside Alaska. The participants were asked to prepare abstracts, submit papers for publication, and bring information related to the workshop's goal and objectives. The public was invited to attend and participated in all phases of the process, including group authorship.

The workshop was organized into four primary sessions:

1) Genetic and behavioral characteristics of natural and enhanced stocks.
2) Ocean carrying capacity limitations on salmon rearing.
3) Mixed-stock management problems.
4) Case histories of natural and enhanced stocks.

A report was prepared for each section where the participants mainly relied upon their own knowledge and experience supplemented by the background papers presented at the beginning of the workshop. Time did not permit extensive analysis of individual salmon fisheries in Alaska. The conclusions reached and recommendations made should therefore be considered as the best advice this group could make at this time by pooling their combined experiences and wisdom accumulated over many years. In many cases it was impossible to make definite statements because of lack of knowledge and research. The only prudent course of action is a conservative approach to avoid making irreversible decisions in management of the state's renewable resources, which are the inheritance of all people of Alaska and not a few selected groups.

Following the workshop the conveners, Dr. Mathisen and Dr. Thomas, served as editors in assembling this report of the workshop and publishing individual papers in a peer-reviewed journal. As conveners we sought consensus, but in recognition of the complexity of this issue and the limited amount of information available for evaluating issues, where differences could not be resolved by the present level of understanding, we attempted to document the disagreement and suggest future avenues of research to resolve the disputes.

IV.
RESULTS

A.
Biological Interactions of Wild and Enhanced Stocks of Salmon in Alaska: Genetic Considerations

F. W. Allendorf, R. J. Everett, A. J. Gharrett, M. K. Glubokovsky, W. Jones, T. P. Quinn, J. E. Seeb, W. Smoker, and F. M. Utter

Salmon managers are stewards of a public resource. They are obliged to conserve the genetic diversity of wild salmon stocks. This diversity is the insurance for the future productivity of the resource; this diversity is essential to the continuing survival of the resource. Managers are obliged to hold paramount the genetic diversity of wild stocks in any calculation of costs and benefits of salmon enhancement. Carrying out this obligation is difficult because despite convincing evidence for the genetic basis of stock diversity, science has inadequate knowledge of this diversity. In many cases there is convincing evidence of genetic structure which includes genetic differences among populations of salmon as well as differences within populations that relate to productivity. However, in many other instances knowledge is limited. In the absence of specific information, managers must assume that spawning populations are genetically distinct and that even within populations there are important genetically based differences.

Our recommendations for managing wild and enhanced stocks of salmon in Alaska to conserve genetic diversity reflect the collected knowledge of participants in the workshop.

Recommendation 1.—Follow the Alaska Department of Fish and Game Genetics Policy in all enhancement programs. Understanding of the conservation biology and genetics of salmon is advancing rapidly; therefore, it is important that the policy be reviewed by the scientific community frequently.

Recommendation 2.—Develop and use effective methodology to monitor the genetic makeup (genotype and phenotype) of natural salmon stocks and to measure the extent of introgression by straying fish. Monitoring should be continuous and a prerequisite of all enhancement projects and should focus on the parent stream used for broodstock and the most vulnerable neighboring streams.

Recommendation 3.—Develop and use the best available mark or tag technology (e.g., coded wire, otolith, genetic) to determine the extent of straying by hatchery and wild stocks.

Recommendation 4.—Treat all remote release sites as *de facto* hatchery operations. Increased straying is likely from releases at a distance from hatcheries and such releases should be evaluated accordingly. Monitor remote releases for straying and introgression into wild stocks and change practices or terminate the releases if introgression is observed.

Introduction

The central goal of salmon management, as trustee of the resource, is to conserve and stabilize productivity of fishery resources and increase them where possible. In this workshop Allendorf and Washington each presented historical examples that rapid expansion of hatchery production coupled with increased exploitation rates usually results in the eventual collapse of the wild stock (option A, Fig. 1). In contrast, a more measured rate of increase can be sustained and, thus, is preferred in the long term (option B, Fig. 1). Option B shows the result of increasing production while also protecting the genetic integrity of wild stocks. It is difficult to resist the opportunity to maximize production in the immediate future. Nevertheless, history demonstrates that this is an unwise choice for a variety of reasons.

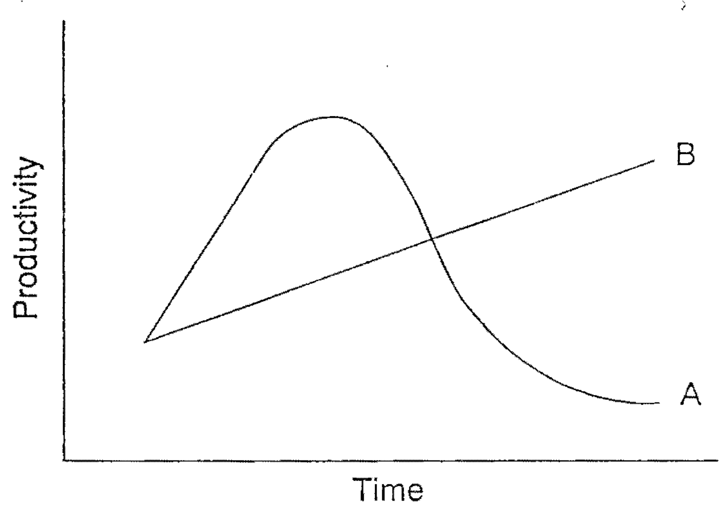

FIGURE 1.—Effects of maximizing immediate increase in productivity without regard to sustainability of the resource. Option A shows likely effect of the single objective of maximizing productivity. Option B shows likely effect of acting to increase productivity while safeguarding genetic resources.

For example, the abundance of coho salmon in the lower Columbia River, having been reduced by a period of severe overfishing below the hydroelectric dams, was greatly increased by the production of very few hatchery stocks. Enhancement was accompanied by greatly increased fishing pressure that, in combination with straying from hatchery stocks, has resulted in the extinction of wild stocks of coho salmon in the lower Columbia River. Washington (this workshop) added that the total catch of coho in the U.S. Pacific Northwest has decreased to less than 1 million fish since 1988 from an average of more than 2 million in the 1970s; this has been accompanied by a reduction of nearly 50% in the number of eggs per female since around 1970 in some hatcheries.

The Columbia River situation with coho and other salmon has been incorrectly labeled as "meat vs. museums." That is, we can either use the salmon as a resource or lock them up to preserve their genetic diversity. This characterization is untrue and dangerous; if we don't protect genetic diversity there won't be any resource to use in the future. A group of biologists at a recent workshop concluded that "sustainable increases in salmon and steelhead productivity in the Columbia River Basin can only be achieved if the genetic resources required for all forms of production, present and future, are maintained in perpetuity."

The genetic diversity of our natural stocks of salmon is the only insurance to protect fisheries resources in the future. In recognition of that fact, the Alaska Department of Fish and Game (ADFG) developed its Genetics Policy in 1985. The policy is based upon the principle that the long-term productivity of Alaska's fisheries resources depends on the genetic resources necessary for continued production in an uncertain future. The team of scientists and resource managers, representing both the private and public sectors, wrote, "Certainly in Alaska, where wild stocks are the mainstay of the commercial fishery economy, it is necessary to protect these stocks through careful consideration of the impacts of enhancement activities." The authors recognized that in Alaska, hatchery production is meant to stabilize or augment wild stock production, not to replace it. The precedence of wild stock diversity must continue as the first principle in salmon enhancement in Alaska.

The ADFG Genetics Policy is based on the principle that diversity buffers biological systems against disaster, either natural or human-induced. In this report we discuss the biological basis for maintaining genetic diversity within and among local populations of salmon in Alaska. We discuss possible interactions between wild and enhanced populations and the importance of maintaining their genetic diversity, and make a series of recommendations to protect these important resources.

Interactions of Enhanced and Wild Populations

Hatchery supplementation of natural production of salmonids, which has been practiced for well over 100 years, has increased the harvest of salmonid fisheries in some instances. However, problems involving long-term survival and loss of diversity of wild stocks have arisen as a direct result of these practices. The conflicts are both genetic and nongenetic.

The genetic concerns are derived from the large number of distinct local populations that have arisen from the strong homing instincts of anadromous salmonids and the differential patterns of natural selection among rivers. Examples were presented by Allendorf, Everett, L. Seeb, J. Seeb, and Utter at the workshop. Reproductive isolation of these populations in their distinct environmental settings has resulted in genetic adaptations to the local environment. Examples were described by Brannon, Smoker, and Gharrett. As a result of both inadvertent and intentional unnatural selective pressures in the hatchery environment and bottlenecks, hatchery stocks often diverge genetically from their wild counterparts.

Inevitably, some hatchery fish will stray into wild populations (Quinn, this workshop). The genetic outcome of such straying is unpredictable. Hatchery fish that successfully produce progeny when they interbreed with wild fish (introgress into the wild population), may reduce fitness of the local populations. Reduced fitness may result from the displacement of locally adapted genes or the disruption of coadapted gene complexes (described by Gharrett at this workshop). Introgression can only be detected through genetic monitoring. Hatchery fish that do not successfully produce progeny when they interbreed with wild fish directly reduce the productivity of that wild population, and may—in the extreme—lead to its extirpation.

Hatchery practices may erode the homing precision of the enhanced populations, resulting in an increased tendency to stray into wild populations (as described by Quinn). It is important to emphasize that even a small straying rate from a large hatchery may produce a large number of strays in comparison to local wild stocks. If the number of strays is large enough, it will almost certainly overwhelm the native fish, regardless of any survival differential favoring the wild stock.

The return of large numbers of enhanced fish also can make conservation of wild populations difficult. In the absence of programs that monitor interactions of enhanced and wild fish, large numbers of hatchery strays can mask the decline of wild fish. Consequently, the estimates of escapement and returns-per-spawner made by fisheries managers may be inaccurate. Furthermore, behavioral interactions with hatchery fish may affect the migratory behavior of wild fish; a disproportionate abundance of hatchery fish may increase the likelihood of interception of wild fish near the hatchery.

The objective of Alaska hatchery management is primarily to stabilize and secondarily to increase the harvest. The difficulty is that hatchery stocks tolerate much higher exploitation rates than wild stocks. As a result, wild stocks commingling with hatchery fish during harvest may be exploited at intolerably high rates, significantly threatening genetic diversity. Such management conflicts should be addressed prior to development of a production facility.

There are a number of additional biological concerns related to hatchery and wild stock interactions. These include increased potential for disease transmission from hatchery to wild stocks, potential of competition for food resources which may be limiting particularly for young fish, and the attraction of more predators than normal.

Importance of Genetic Diversity Among and Within Stocks

The productivity (fitness) of a regional system of salmon stocks depends on variation among populations. It is likely, for instance, that different stocks may feed in different parts of the marine environment or may use an area at different times, as suggested by Brannon and Washington. A system that relies on a variety of stocks is more likely to take advantage of localized areas of abundant food and to avoid density-dependent effects of overpopulating such localized areas.

Similarly, Smoker and Gharrett pointed out that an important component of the productivity of a stock is the phenotypic variability for numerous traits such as size, age, migration and spawning times, or emergence times. Most such phenotypic traits have a significant genetic component. For a stock which faces unpredictable environments from generation to generation, genotypic and phenotypic variation in a population increases the likelihood that its members will distribute to different places and times where opportunities for food, growth, and survival may present themselves. Maintenance of genetic variations within a population is analogous to "bet hedging."

Geneticists are able to obtain biochemical genetic information with which populations can be characterized and often differentiated. However, these are very simple characters that usually have little effect on the productivity of a population. More critical to the production of a population are the much more complex life history traits. We are just learning which of these characteristics have important genetic components and how to identify and monitor those traits. With currently employed biochemical genetic techniques, science can document introgression of individuals and genes from one salmon population to another; however, we are not yet able to measure the effects of this introgression on population productivity.

Hatchery Broodstock Management

It is inevitable that enhanced fish will stray into wild stocks. Wild stocks close to the source of the enhanced fish will probably receive relatively more strays. Because it is not yet possible to project the effects of the interactions between enhanced and wild fish, proper hatchery broodstock management has a critical role in conservation of the genetic diversity of wild stocks. At the same time it has an important positive relationship to the hatchery stock.

The importance of genetic variability, both within stocks and between stocks, has implications both for donor stock selection and for the actual management of broodstocks. Donor stocks must be chosen judiciously to optimize their hatchery performance and minimize their effects on local wild stocks. Broodstock management practices in hatcheries can alter the genetic composition of a hatchery stock. The primary causes are inbreeding and selection, whether inadvertent or directed. Inbreeding which results from using too few parents can rapidly reduce genetic variability. Domestication selection, an unavoidable consequence of hatchery production or inadvertent selection of broodstock (e.g. for size or timing,) usually results in some loss of variability. Loss of genetic variability from inbreeding can be reduced by using a large number of spawners and approximately equal numbers of males and females.

Phenotypic variation in broodstocks should reflect variation observed in wild populations in order to reduce the effect of inadvertent selection. The broodstock should include an array of individuals that represent the extent of variation normally observed in a population, especially with respect to timing (migration, spawning, smolting, emergence), and size (and correlated traits such as fecundity, egg size, age). Even if the practice is inconvenient, hatchery broodstock managers should use spawners from the entire stock. Failure to do so is likely to cause the loss of the stock's valuable variety of traits. Particular practices that perhaps should be avoided are inadvertent selection for run timing (for example, using the earliest returns to ensure adequate egg numbers) and selection against jacks.

It is important that broodstock managers monitor the performance of the broodstock over the generations. Without a recorded history, changes will not be apparent. If changes are not apparent and understood, broodstock management practices cannot adapt to changes. At the least, the broodstock manager of a hatchery stock should monitor such fitness-related traits as timing of migration and maturation, size and age of spawners, and egg size and egg number in spawners.

Recommendations

Therefore, we recommend the following policies and activities.

Policies

1. ***Abide by established genetic policy.***
   The Alaska Department of Fish and Game, with public input, has developed a genetic policy. The policy was written to protect Alaska's valuable salmon resource. Wild stocks are the mainstay of the Alaska fishery economy; hatchery enhancement is meant to supplement but not to replace them. Hatchery programs must be carefully designed to

protect wild stocks, and all aquaculture programs, present and future, should be reviewed for compliance with the ADFG Genetic Policy.

2. ***Assume that all local populations are genetically distinct.***
Unless otherwise indicated, spatially or temporally distinct spawning aggregations should be presumed to be reproductively isolated populations.

3. ***Use best possible marking or tagging strategies to monitor interactions between hatchery and wild populations and the genetic "health" of wild and enhanced populations.***
Marking techniques might include coded-wire tags, otolith marking, genetic marking or other methods appropriate to the species and logistical constraints of the facility. Genetic marking would be especially valuable for monitoring introgression of hatchery stocks with natural populations. Genetic stock identification or other appropriate techniques should be used to facilitate in-season management of mixed-stock harvests.

4. ***Remote releases of hatchery fish should be conducted in a manner that minimizes potential gene flow to wild populations.***
Remote releases have been identified as a source of heightened gene flow from hatchery populations to wild populations. The use of remote releases should be approached conservatively. Best available practices should be used to insure maximum imprinting. Juveniles for remote releases should be held for an appropriate amount of time for imprinting at a release site possessing a freshwater source devoid of conspecifics. A remote release site, even if designed for complete mop-up fisheries, should be considered to be a *de facto* hatchery site (see Genetic Policy for broodstock/hatchery site guidelines).

Activities

1. ***Keep genetic policy current and pertinent to Alaska's resources and industry.***

2. ***Describe genetic population structure to identify genetically distinct populations and to describe genetically distinct components within populations that may contribute to long-term stability.***
Traits examined should include life history, production, and molecular genetics. Populations should be surveyed prior to any aquacultural activity to provide a baseline for subsequent genetic monitoring. The genetic consequences of hatchery production on adjacent populations should be evaluated during phased-in expansion, and production increases should be halted at the first indication of adverse effect.
Local populations may consist of temporally or spatially distinct components that contribute to the productivity and long-term survival of these populations. This substructure should be identified and considered when making management decisions.

3. ***Monitor wild and hatchery stocks for extent of straying and introgression.***
Long-term monitoring of genetic traits of adjacent wild populations should accompany any aquaculture program. Again, production strategies should be adjusted to eliminate any observed straying or introgression.

4. ***Evaluate the homing of remote-released fish to make the practice as safe as possible.***
Evidence is accumulating that the remote release of salmon away from natal hatcheries can increase straying. Such remote releases are often advocated as production or management tools despite this increased risk. All remote releases should be treated in the same manner as releases from hatcheries and should be evaluated accordingly. They should be monitored for straying, and where straying is observed, for introgression into wild stocks. Remote releases should be planned conservatively and should be modified or terminated if introgression is observed.

B.
OCEAN CARRYING CAPACITY
R. T. Cooney

THEORETICALLY, POPULATIONS OF CONSUMERS IN MARINE ECOSYSTEMS exist in dynamic equilibrium with naturally occurring levels of food. It is generally believed that when environmental factors favor greater-than-average survival in a population, the biomass per individual will be reduced if forage populations limit growth. This density-dependent "effect" has been observed in historic salmon population data. For pink salmon particularly, but including the other species as well, the largest returns are generally composed of smaller fish, whereas the smaller runs are usually characterized by larger individuals (see workshop abstracts by Rogers, Eggers, Ida, and Pearcy). These size trends occur in both wild and enhanced salmon populations, but there are exceptions (Olsen, workshop abstract).

As enhanced stocks grow in response to improved culturing techniques and relcase strategies that favor greater survival, there will eventually be an upper limit to the ability of coastal, shelf, and oceanic ecosystems to support these stocks. In the past, nature has conspired to produce cycles of greater or lesser wild salmon abundance in the Gulf of Alaska. These natural trends are now being augmented by ocean-ranched salmon in increasing numbers. In view of the success of ocean ranching in Alaska and elsewhere, it is not unreasonable to formally begin investigating what is presently understood about the carrying capacity of the ocean, and recommend actions that will improve this understanding before limitations on ocean growth are exceeded. Unusually small adult sizes of some species of salmon this past year (see abstracts by Olsen and Rogers) are indicators to some that the problem of sufficient ocean forage is more immediate that generally acknowledged. However, without information about the other factors that influence growth (temperature fields and migratory feeding patterns), alternative explanations cannot be ruled out.

Carrying Capacity Concerns

Production-related density-dependent growth leading to smaller-than-average sizes of maturing individuals is a concern for several reasons. Japanese ocean-ranched chum salmon have been declining in size and increasing in age at maturity over the past decade in concert with increasing hatchery production (Ida, workshop abstract):

	1975	1980	1985	1990
Adult age, yr	3.30	3.90	4.47	4.20
Mean weight, kg	2.42	3.39	3.54	3.12

These fish exhibit reduced condition factors and lower fecundity with smaller size, a distinct biological impairment. Pushed to the limit, unregulated hatchery production could theoretically produce very small fish with greatly reduced reproductive and market potential. Of perhaps greater concern is the effect that international ocean ranching practices may have on all salmon stocks (wild and hatchery) that use the northern Pacific Ocean as a feeding ground. Because there is competition for food and overlapping ocean distributions, greatly increased production by one or two countries could conceivably affect the growth conditions for all stocks using the region. Moreover, it is not known what effect the increase in salmon production could have on the overall structure and function of coastal, shelf, and oceanic ecosystems. Salmon share forage resources with other consumers (fishes, marine mammals, and seabirds), some of which may be seriously disadvantaged by increased salmon abundance.

It is not known exactly how adult size is influenced by growth during each of the major life-history stanzas (early marine, oceanic or adult migration). Some contend that both size and abundance are determined by events occurring during the first 2-4 months of early ocean residence, perhaps due to competition occurring in large schools of juveniles. Other observations indicate that growth during the later stages of the oceanic migration (prior to spawning) most influences adult size. Rogers (workshop abstract) observes that for Bristol Bay red salmon, growth constraints are associated with the last year at sea, presumably resulting from dense schooling during the spawning migration. Clearly, understanding which variables influence adult size is fundamental to any long-term evaluation of salmon management and enhancement.

Workshop Recommendations

(1) In order to understand where growth reduction may be occurring, studies documenting the growth histories of individuals using scales, coded-wire tags and otolith structure are needed. The technologies for these studies are available and should be applied in long-term investigations of salmon and their feeding environments. Parallel but interacting studies are recommended, such as: (a) growth studies of juveniles and returning adults (in the escapement and/or commercial catch) to elucidate interannual and seasonal patterns of growth relative to the numbers of wild and hatchery salmon released and surviving to adulthood; and (b) studies of the growth environment of the fish to include nearshore distributions of wild and hatchery fry, temperature and salinity conditions, current patterns, and the kinds and abundances of forage stocks present.

When possible, mass marking techniques (thermal and other) should be used to identify ocean-ranched juveniles released from hatcheries. The ability to separate wild and hatchery fish will establish a powerful tool for comparing growth and survival during all phases of their life histories.

(2) Direct estimates of losses to predators have not been possible in most cases. Observations at some hatcheries suggest that large fish (cod, pollock, and other) and birds (terns, gulls) occasionally concentrate around net pens to feed on fry escaping or being released. However, beyond published accounts of salmon preying on other salmon (cohos on pinks and chums), very little information is available in the literature about the direct effects of other fish and bird predators. Furthermore, little is known about which other fish share food resources with juvenile and adult salmon. The problem of carrying capacity will eventually have to be addressed in terms of how matter and energy are distributed in food webs supporting the salmon. These food webs do not ignore other consumers in the system.

We recommend that all hatcheries keep records of the obvious occurrence of fish and bird predators each year. Casual observation suggests that predation pressure varies from year to year, and perhaps location to location. In addition, emerging technology in quantitative acoustics provides a highly efficient means to "survey" stocks of predators within geographic regions. Information on the biomass and relative size of "targets" could be used to begin assessing variability in other fish populations.

We also recommend that field studies of juvenile and adult salmon feeding dependencies also collect food information on incidentally captured species to further our understanding of which other consumers share or compete for specific forage stocks.

Observations of recent marine mammal declines in the North Pacific (sea lions, fur seals) suggest, among other factors, that some major change in forage stocks is probably occurring. While the nature of these changes is not fully understood, any ocean-wide shift in forage abundance must be viewed as potentially interactive with the salmon portion of the ecosystem. We recommend that this broader phenomenon be followed closely for correlation with salmon production and adult size changes.

(3) It is generally believed that overall levels of salmon survival are set early in the life history of each species. This means the "critical period" occurs in the freshwater or nearshore coastal environments. We recommend that ongoing investigations, like Cooperative Fisheries and Oceanographic Studies (CFOS), designed to characterize the growth environment for juvenile pink and chum salmon each year in Prince William Sound, be continued and when possible, extended to other regions of Alaska. CFOS includes research contributions from the Alaska Department of Fish and Game and the non-profit hatcheries in the region and oceanographic observations and experimental studies from the University of Alaska (temperatures, current fields, meteorology, food field composition and energetics). An expansion of this study to other regions of the state as an Alaska Ocean Watch program would provide critical and now missing insight about salmon production responses to growth conditions experienced by juveniles each year.

CFOS is using satellite and RF-linked oceanographic buoys and satellite-sensed thermal and optical information of the northern Gulf of Alaska to characterize the coastal and shelf growth environment for salmon each year. These technologies are available and should also be applied to other regions of the state.

(4) An immense state- and federally-funded research program on salmon is now in its concluding phase in Prince William Sound as part of the damage assessment following the grounding of the Exxon Valdez in March, 1989. To date, only a tiny fraction of that information has entered the public domain. Because much of the research focused on the freshwater and early marine stanzas of resident salmon, that database is potentially of great value relative to questions about the carrying capacity of the region. The workshop recommends a speedy release of all data (salmon and other) so that the results of these studies can be examined from the perspective of wild and hatchery salmon growth and feeding dependencies on the region.

(5) The international scope of carrying capacity issues requires that questions concerning production limitation in the open North Pacific Ocean be pursued through multinational cooperative management and research programs. Open-ocean studies of salmon growth and ecology and the oceanic environment may need to be renewed if density-dependent growth and mortality is demonstrated from the oceanic (different from the nearshore coastal) phase of salmon life history. Jointly sponsored U.S., Canadian, Japanese and

Soviet investigations could address the boarder question of oceanic food limitation on salmon growth in those parts of the North Pacific that serve as the major feeding regimes.

(6) Several large federally funded and mandated studies of the atmosphere and ocean, responding to questions about global change, have components in the North Pacific. These programs (like the World Ocean Circulation Experiment [WOCE], and the Coastal Ecology Program) will provide data that should contribute to a better understanding of nearshore ocean processes in relationship to the larger oceanic environment. The workshop recommends that, whenever possible, advantage be taken of these large-scale oceanographic and meteorological studies to build databases relevant to the issue of carrying capacity and wild and hatchery stock interactions in Alaska and elsewhere.

Summary

Workshop participants evaluated several examples where the time-series of the size of both wild and hatchery salmon in the Gulf of Alaska suggested that food-limited density-dependent modification of adult size is occurring. Although a theoretical evaluation of the effects of present levels of fry feeding (wild and hatchery) on forage stocks in Prince William Sound demonstrated only minor apparent effects (Cooney, abstract in this report), this assessment was based on several untested assumptions.

Workshop participants agreed that salmon production in the North Pacific at some as-yet-to-be-determined level will be limited by food stocks in coastal, shelf, and oceanic environments. The level at which this will occur cannot be predicted from present information. However, Japanese chum salmon appear to be approaching a size limitation that is seriously impairing their reproductive potential, condition factor, and market value. This has not been observed for wild or hatchery salmon in Alaska, although record or near-record returns of pink salmon to most regions of Alaska last year were characterized by unusually small individuals. Much smaller than average red salmon have been observed recently in Bristol Bay.

This workshop recommends several courses of action to establish a framework for monitoring the growth environment and sizes of Pacific salmon. These efforts will track the carrying capacity issue and provide information to the management and enhancement sectors for mitigative purposes should that become necessary in the future.

C.
MANAGEMENT

Management of Mixed Stock Fisheries

O. A. Mathisen

THE BASIC PHILOSOPHY GOVERNING SALMON MANAGEMENT in Alaska is to separate the harvest by individual stocks. In practice this is difficult to achieve and there are all degrees of mixed fisheries. Until recently the high seas salmon fisheries intercepted large numbers of all species and stocks of North American and Asian origin. The next level of mixed fishery is harvest along the migratory path of adult salmon. A classical example is the False Pass fishery in western Alaska. There are many "cape" or outside fisheries both in southeast Alaska and Prince William Sound and elsewhere which operate on mixed stocks. Even in the estuaries of many large rivers fishing is on the mixed stocks belonging to that river or watershed or adjacent ones.

Mixed fisheries may not be detrimental as long as the different stocks have approximately the same survival rates. Otherwise the weaker races will decline with time. This is especially true in fisheries where enhanced stocks represent a strong and dominant component. If enhancement is successful the survival of the progeny to the larval or smolt stage is usually several percent higher than for the progeny from natural stocks, as demonstrated for pink salmon in Prince William Sound (Cooney abstract). Consequently, the fishing mortality which can be imposed on enhanced stocks for full utilization in a mixed fishery is higher than the natural stocks can sustain and they decline in numbers. This has happened in Sweden and Norway with the Atlantic salmon (Heggberget and Eriksson abstract), in the Columbia River and other Washington and Oregon coastal rivers for chinook and coho salmon (Washington abstract), and it may happen in Robertson Creek chinook hatchery in British Columbia if production there is expanded beyond its current level.

Larger escapements seem to be warranted for the natural runs of pink salmon in Prince William Sound according to the presented data (Eggers abstract), which implies that the present harvest rate on mixed stocks will have to be reduced to protect the weaker stocks of wild pink salmon.

Mixed stock harvest conflicts could have been avoided to a large extent if the planning process of enhancement installations had considered the distinctive biological requirements of the salmon populations being enhanced, and especially the timing of the returning adults. If enhanced stocks and natural runs overlap in space and time, mixed fisheries must be limited to an exploitation rate which the weakest of the natural stocks can tolerate while delaying the harvest of enhanced stocks until they reach the terminal areas. This of course is undesirable for pinks and chums whose truncated maturation process reduces their quality in the terminal areas. Thus, without sufficient biological criteria on the interaction of wild and hatchery fish, the management philosophy of "weakest run" provides at least a conservative if not the "best" criteria for predicting the limit for enhancement programs.

In other Alaskan fisheries, the chinook and coho fisheries of southeast Alaska, the harvest of mixed stocks is common rather than the exception. The absence of adverse effects is attributed to the relatively minor contribution of enhanced stock to the average harvest of these two species, 10.2% and 8.1%, respectively, since 1985 (Amend, this workshop). Were these percentages to increase, the situation might change drastically.

There is no reason not to believe that the two factors, survival rate and abundance relative to the natural stocks, will operate differently for any species of salmon. Management of enhanced stocks therefore reverts back to setting a rate of exploitation in mixed fisheries compatible with what the natural runs can tolerate and harvesting the excess enhancement production in the terminal areas. Because of the deterioration of the quality of the fish during the maturation process in pinks and chums, the exploitation rate on the weakest natural runs in the mixed fishery will ultimately determine the limits of the production of enhanced stocks, if wild stocks are to survive and preserve their genetic integrity.

Another alternative is to manage for enhanced stocks. One might successfully argue for this in light of our success in domestication and hybridization of terrestrial animals. However, this involves the risk of losing the production of enhanced stocks, if a calamity like diseases should decimate them one year. It might be difficult to rebuild such stocks unless there are sufficient wild stocks left to restore production. Whether Alaska is ready to embark on such a management strategy requires a very careful and cautious analysis.

For the enhancement installations already in operation an acceptable management strategy is to monitor the harvest in mixed fisheries and determine the contributions from enhanced and wild stocks and regulate the exploitation rate so that the desired escapement of wild fish can be secured. But this is a costly process involving extensive tagging or marking experiments combined with thorough recovery programs. Unfortunately, no explicit funding exists in the state's management budget or in the operational budgets of the hatcheries for such undertakings.

In future enhancement projects some of the problems discussed above can to a large degree be avoided by judiciously selecting sites and broodstocks which are in conformity with the life history strategies of the stocks of fish being enhanced.

Harvest Management of Mixed Stocks of Enhanced and Wild Pink and Chum salmon

D. D. Bailey

AMPLE EVIDENCE EXISTS IN PACIFIC SALMON HARVEST MANAGEMENT that harvesting has occurred above their sustainable capacity. Hatchery production in many cases has been a response to low production caused in part by environmental factors aggravated by over-harvesting. Evidence also exists that wild stocks can be harvested beyond their sustainable capacity when mixed with the more abundant and more productive enhanced stocks.

Depending on their productivity, wild pink and chum stocks may be able to sustain harvest rates of 50–70% while enhanced stocks should be able to sustain harvest rates of 85–95%. In British Columbia where enhanced and wild stocks coexist, exploitation level is based on the lower wild stock productivity and often on the weakest stock. Additional harvest of enhanced stocks is then carried out in terminal harvest areas. This is the procedure used to manage the south coast of British Columbia chum stocks passing through Johnstone Strait.

Data on the productivity of wild stocks is important both annually and during the fishing season in order to adjust harvest to meet fixed escapement goals. In the above example pre-season estimates via test fisheries and catch sampling for marked enhanced stocks are critical for management to fixed escapement goals. Careful management is especially critical when productivity is low. Pink salmon productivity has been related to Gulf of Alaska air temperature (Tom Royer, pers. commun.), which would indicate that pink salmon production may be lower in the future. Changes in stream flows from logging on the watershed are also known to seriously reduce the freshwater productivity of wild pink and chum stocks. Harvesting the forests in Prince William Sound and lower marine survivals for all regions in Alaska have the potential to result in wide variability in wild pink and chum productivity.

In order to maintain or increase wild pink and chum populations while maintaining or increasing enhanced production and maximizing its harvest the following recommendations should be considered.

(1) Marking of enhanced and wild pink and chum salmon stocks, both juvenile and adult, could and should be used to design a harvest strategy to maximize harvest of enhanced stocks in mixed wild and enhanced areas while meeting escapement goals for wild stocks. Use this data during and after fishing season to estimate wild and enhanced components of the catch. Research into mass marking of juvenile salmonids should be funded.

(2) Institute test fisheries in various locations (catch to be used to pay for charter) throughout the fishing areas to evaluate their use in wild escapement management. Sample catches for marks. These charters could also be used for adult tagging for timing and migration studies.

(3) Study the freshwater productivity of wild stocks by estimating egg deposition and fry output in index streams. This is especially important if escapement goals are increased to determine if increased escapement results in higher fry output. This should also be carried out in streams before and after logging.

(4) Evaluate the effect of logging on egg-to-fry survival and spawning habitat capacity.

(5) Consider increasing the escapement goal to maximize wild productivity.

(6) Evaluate the timing and migration of wild stocks and use stocks which will minimize wild and enhanced mixed fishery interception.

(7) Evaluate future enhancement for site location and stocks selected to minimize wild stock interception. Manageability should be a major criterion in the permission process.

(8) Hold a small workshop of pink and chum management biologists from Alaska, British Columbia, and Washington to make recommendations for the management of enhanced and wild pink and chum stocks in Prince William Sound and southeast Alaska.

Can Wild and Enhanced Coho Stocks Coexist in Southeast Alaska?

D. Amend

THE ALASKA LEGISLATIVE MANDATE DURING THE DEVELOPMENT OF STATUTES and regulations for the Alaska enhancement program was to manage for the natural stocks while enhancing salmon to supplement natural production. The enhancement of coho salmon in southeast

Alaska started in the mid-1970s by the FRED division and the private non-profit operations started in the early 1980s. These programs have now matured and production has stabilized.

The average annual harvest of coho salmon from 1980 through 1988 was 1.71 million. The average harvest of enhanced coho from 1986 through 1990 was 8.1% of the total harvest, but the average in the future, based on current production, is expected to average about 16%.

Coho in southeast Alaska are harvested primarily by trollers but significant harvest occurs by the drift gillnet and seine fleets as a by-catch during the conduct of traditional fisheries. Although some coho are harvested from Canadian systems, most are produced from southeast Alaska systems. Because most of the coho harvested in southeast Alaska are from natural production, it is important to maintain the wild coho stocks.

Enhancement Strategy

The enhancement strategy in southeast Alaska follows three basic courses: (l) release from freshwater raceways as smolts into adjacent rivers, (2) release from marine net pens as smolts at remote locations following an imprinting period, and (3) release of fed fry into non-anadromous lake systems and the fish immigrate after rearing and smolting in the lake. Typically, broodstock were secured from local wild stocks and the fry reared in hatcheries located on non-anadromous systems which are not near natural producing stocks. Fish released as smolts are typically reared about 18 months in a hatchery, and the fish return after about 18 months at sea. Fish released as fed fry are reared to about a 1 gram size in the hatchery, but they complete the remainder of their life cycle similar to wild coho.

Threats and Concerns

There are both intraspecies and interspecies concerns. The intraspecies concerns include wild stock interactions due to straying or competition and management implications. Interspecies concerns primarily involve predation.

There have been no documented negative impacts of enhanced coho on wild coho in Alaska. Hatcheries in southeast Alaska are located on non-anadromous systems; therefore, the smolts do not compete with wild stocks in the freshwater phase after being released. Coho salmon imprint well to the site where they are released and there have been no documented straying problems. Consequently, there have been no documented genetic problems. Potential exists for future problems if hatchery stocks become inbred and significant straying occurs. Continued monitoring is required. In addition, research should better define minimum conditions for imprinting for remote release programs. Enhancement practices should continue to follow policies that would minimize inbreeding or increased straying.

The recent past average of 8% enhanced coho salmon in the harvest has not been a management problem. Even with production capacity at a maximum, the forecast is to average 16% of the harvest. All coho releases include a coded wire tagging program. This allows managers to account for the hatchery contribution to the harvest. Due to the low percentage of enhanced coho in the total harvest, there should be no future management concern. However, the coded wire or marking programs should continue to avoid potential problems of local abundance near hatchery sites.

The interspecies concerns are primarily coho smolts preying on pink fry and to a lesser extent on chum fry. The scientific literature well documents that coho smolts will eat pink fry and in preference to chum fry. In areas where there is a high abundance of coho smolts, the potential exists for the coho to have a significant impact on pink salmon populations. Whether coho are a limiting factor overall to pink salmon abundance is a much broader question which can only be answered by resolving the overall predator–prey relationship among all predators. The coincidence of coho and pink abundance cycles appears to argue against coho limiting pink abundance. However, this does not resolve the concern of high coho abundance near hatcheries where wild pink fry are migrating.

Several studies have been conducted in southeast Alaska to answer concerns about coho preying on pink salmon fry. The results were inconclusive. Pink fry were occasionally found in the stomachs of coho fry, but the problem could not be fully resolved. Early life histories of pink salmon fry showed that they typically spend a short time in the inter-estuaries and 90% of them migrate offshore by late May. In order to minimize the impact period, hatchery releases of coho smolts have been delayed to after June 1. Although this is not considered to be the optimum release time for coho (mid-May would be better), satisfactory survival rates for coho have occurred. This appears to be a satisfactory compromise in order to reduce the concerns of high abundance of hatchery coho negatively impacting pink populations.

Conclusions and Recommendations

Enhanced coho stocks can coexist with wild coho stocks as long as current policies and practices are maintained. Coho hatcheries should not be located on anadromous systems or near major coho producing systems. Hatchery practices should be followed to minimize inbreeding and practices which would increase straying should be avoided. The current level of production should not be a management concern but tagging programs should be maintained to resolve concerns of local abundance. Research is needed to better define the conditions for optimum imprinting and the predator–prey relationship between coho smolts and pink fry should be better defined. The coho enhancement program in southeast Alaska appears to be meeting the original legislative intent of supplementing the harvest of coho salmon while not negatively impacting wild stocks.

Can Abundant Wild and Enhanced Stocks of Chinook Salmon Coexist in Southeast Alaska?

W. R. Heard

CHINOOK ARE THE LEAST ABUNDANT SALMON IN ALASKA but are among the most highly prized and are often at the center of controversial fishery issues. Coastwise declines in the wild chinook stocks, especially in Washington, Oregon, and British Columbia, along with mixed stock ocean-troll fisheries in both countries, were among the major factors leading to he Pacific Salmon Treaty between Canada and the United States.

One reason for the focus on chinook in the treaty was oceanic migration patterns of many stocks that migrate in a northwesterly direction along the U.S. and British Columbia coastlines. Many stocks of chinook become vulnerable to distant area fisheries. The troll fishery in southeast Alaska was especially important because it caught large numbers of non-Alaska chinook originating from southerly stocks. Among other things, the treaty called for limiting such interceptions of chinook between countries and states and for initiating a coordinated rebuilding program of depressed stocks along the coast. Other treaty provisions include a limited quota on numbers of chinook that could be caught in certain fisheries and an option for developing new stocks or groups of enhanced fish that could be harvested by the country or state of origin in addition to fish counted under the quota.

Chinook salmon hatcheries and significant related enhancement programs in southeast Alaska increased from two in 1976 to fifteen in 1990. New hatchery add-on provisions of the treaty were a major incentive for much of this development and the basic goal of this effort was to provide more chinook of local origin for southeast Alaska fisheries. The primary targeted user groups for chinook salmon in this region are the commercial troll and marine recreational troll fisheries.

Most hatcheries in the region were developed with principles to have minimal impacts of hatchery fish on endemic wild stocks of chinook. Alaska Fish Genetic and Pathology Policy statements were important guidelines for selecting chinook hatchery sites, brood stocks, and enhancement practices. Unlike chinook hatcheries in many other regions, none were built on extant wild chinook streams. Most are located on islands 50 km to 200 km distant from wild stocks that are, with one exception, on the mainland. Four primary hatchery stocks, derived from regional wild stocks, are in use in different parts of southeast Alaska. Three other stocks have been involved in supplemental enhancement of their depressed natal runs. Chinook brood stock selection for use in hatcheries and other enhancement efforts in this region is important because of differences in ocean migration patterns that result in different fishery contribution potentials for target fisheries. Upriver stocks from larger transboundary rivers (Taku, Stikine, Alsek) tend to have longer, more distant ocean migrations than stocks from shorter coastal streams. Movement of eggs between hatcheries is carefully regulated based on stock, disease history and location of hatchery.

A formal interagency chinook plan for the region, with an annual annex update, provides oversight guidance on hatchery and other chinook enhancement activity within the region. The Chinook Plan Team and Plan Annex also serves as an annual monitor of individual hatchery broods relative to stock performance, fishery contributions, and marine survival. Production from both hatchery and wild stocks of chinook salmon in southeast Alaska has steadily increased in recent years. Regional hatchery contributions to southeast Alaska fisheries have grown from an average annual catch of about 5000 fish (1980–85) to an actual estimated catch of 79,546 fish in 1991. After pre-treaty hatchery fish and risk factor adjustments are made, the hatchery add-on allowance for 1991 becomes 65,546 fish. One long-term goal of enhancement in southeast Alaska is to provide 100,000 add-on chinook to the commercial troll fishery. Total estimated escapements of wild chinook stocks in the region have doubled from an average of 43% of target goal (1975–80) to 84% (1986–90). Target escapement goals for several wild chinook stocks within the region are increasing as better knowledge of spawner distributions within river systems becomes available.

In view of the general increases in both hatchery and wild chinook production in southeast Alaska and taking into account the conservative approaches used in development of the chinook enhancement program, there do not appear to be major problem areas of adverse hatchery stock–wild stock interactions in this region. The only known possible exception involves small numbers of adult hatchery chinook recovered in non-natal areas. The majority of these known chinook strays have been recovered from areas without natural chinook runs, although a few hatchery fish have been found in some wild chinook streams. There is some concern for the specific stock presently used for hatchery and enhancement activity in the greater Juneau area because of the proximity of the Taku River and possibility of hatchery strays into that system. Steps are in progress to use a more suitable hatchery stock in this area. In other regions of Alaska where there are chinook hatchery and enhancement activities, including Cook Inlet, there also are no known major adverse enhanced stock–wild stock interactions.

Management of Mixed Enhanced and Wild Salmonids in British Columbia

D. D. Bailey

MIXED SPECIES AND STOCKS IN BRITISH COLUMBIA salmon management have been a problem since the Department of Fisheries first began to actively manage the fisheries. Overfishing, habitat destruction from forestry, industrial, and urban expansion, and poor marine survival all combined to seriously depress stocks in the 1960s and early 1970s.

The Salmonid Enhancement Program (SEP) was designed to double salmon catches in two phases starting in 1977 over a span of about 15 years. Fishery management plans were also devised to rehabilitate depressed stocks through conservation and enhancement. This paper will address enhanced and wild fishery management for chum salmon throughout British Columbia and for coho salmon in Georgia Strait.

SEP projects were planned to minimize species and stock management problems by selecting sites where terminal harvests were possible and where all stocks and more than one species were usually enhanced. Because of the high value of chum salmon roe in the late 1970s this species was the most enhanced in the early phases of SEP. Chinook were also enhanced because of the severely depressed state of many of the stocks. Species such as sockeye and pink salmon were enhanced at a lower rate particularly in the North and Fraser until international management treaties were negotiated.

SEP is still a bit player in enhancement with only 10% of the 1985 to 1989 mean catch of enhanced origin (Table 1). Except for chum at 33%, the catch of enhanced salmon for all other species is less than 15% of the total catch.

SEP has 11 major chum salmon facilities producing 90 million fed fry and 100 million unfed fry annually. Fed fry are produced from Japanese style hatcheries and unfed fry from spawning channels. An additional 5 million fed fry and 25 million unfed fry are produced from small facilities, mostly improved side channels.

TABLE 1.—SEP production, 1985–89 average.

Species	Total Catch (millions)	SEP Catch (millions)	% SEP	Technology
Sockeye	9.3	1.1	12	Lake fert./channel
Chinook	0.9	0.1	11	Hatchery
Coho	4.2	0.6	14	Hatchery
Pink	18.4	0.4	2	Hatchery/channel
Chum	4.3	1.4	33	Hatchery/channel
Total	37.1	3.6	10	

SEP chum enhancement maintains the genetic integrity of each stream and only releases fry into the stream of origin unless the stream is barren or has reached a very low level. It also attempts to utilize all portions of the run, although there is a tendency to enhance the early to middle portion of the run because of the tendency to ensure the project reaches its egg target. Because a hatchery works with a number of stocks, broodstock collection is a mix of enhanced fish and naturally spawning stocks.

Fishery Management of Enhanced Stocks

Pre-season estimates of returns for enhanced stocks are supplied by SEP to management biologists based on past survival of the enhanced stock and average age composition of return. Because of the high variability of survival and age of return, pre-season estimates are of limited reliability. In-season management through test fisheries and biological sampling are critical for management of enhanced and natural stocks.

At Pallant and Kitimat, where enhanced chum presently make up less than 20% of the total catch in the major fishing area (Table 2), total abundance of all stocks drives the fishing plan. Snootli chum were originally enhanced to buffer the high harvest rate on chum during the harvest of Area 8 pinks. Snootli hatchery has been so successful that its stocks make up only about 8% of the Area 8 chum escapement yet have risen to comprise 40% of the Area 8 chum catch. Harvesting of these enhanced stocks has increased harvest rates from the pre-enhanced average of about 8% to 76% between 1985 and 1989.

"Harvesting this very productive enhanced stock in the mixed stock traditional fishing areas at a high harvest-rate suitable for the enhanced stocks results in an excessive harvest rate on the less productive natural stocks. . . . The significant benefits of enhancement can be realized without serious loss of enhancement only if excess production is assessed through scientific index fisheries and harvested terminally to protect natural chum stocks." (Central Coast SSMP Report, DFO Internal Report 1991)

At Conuma and Nitinat, virtually all the chum stocks have been enhanced and the fishery is managed to achieve escapement goals for the mixed enhanced and wild stocks returning to the native streams. At both sites the fishery is conducted terminally with minimal interception of passing stocks.

Clockwork Strategy

In the Johnstone Strait Fraser River Study Area (i.e., all streams on the east coast of Vancouver Island and on the adjacent mainland plus the Fraser River) a plan was initiated in 1983 to try to rebuild the depressed chum stocks to historic levels in 12 to 15 years by limiting fishing to a predetermined harvest rate schedule. Wild escapement levels would be raised from the previous 10-year average of 1.2 million to 1.8 million in the 1983 to 1986 period and then in stages every four years to 2.5 million in 1995. For 1987 to 1990 the total stock would have to be greater than 3.0 million (i.e. 2.0 million wild escapement goal and 0.9 million enhanced production plus 0.1 million U.S. production) before fishing would take place. Depending on stock size, harvest rate could increase to a maximum of 40% when stock size was over 5.2 million (Table 2).

TABLE 2.—Clockwork harvest rate schedule for Johnstone Strait, 1987–90.

Wild Stock (millions)	Total Stock (millions)	Harvest Rate (%)
0–2.0	0–3.0	10
2.0–2.7	3.0–3.7	20
2.7–4.2	3.7–5.2	30
over 4.2	over 5.2	40

Early season (third week of September) commercial fisheries and all-season test fisheries in Johnstone Strait are used to estimate total run size. Analysis of mark returns from in-season sampling of chum catches is used to estimate enhanced production.

As a result of this strategy, harvest rates of East Coast of Vancouver Island chum (Puntledge, Big Qualicum and Little Qualicum) and Fraser chum (Inch, Chehalis, and Chilliwack) in Johnstone Strait totaled only 21% and 29%, respectively, from 1984 to 1989 (Table 3).

An additional terminal harvest for East Coast Vancouver Island stocks has raised harvest rates to 64% for these stocks. A minor terminal harvest in the Fraser River increased the total Fraser harvest rate to 35%. The late timing Fraser enhanced stocks have had a lower harvest rate because of a late timing component which misses being harvested. In 1985, a new strategy was put in place to select eggs from those portions of the escapement of the component stocks which migrate in the middle portion of the Fraser timing. Weather problems and market quality make late Fraser fisheries undesirable. Harvest of early timing Fraser chums conflicts with the valuable migration of North Thompson steelhead. We are just starting to evaluate the success of this strategy of selecting the mid timing.

As a result of these low harvest rates on Fraser enhanced chum excess escapements have occurred chiefly to Chehalis Hatchery. In 1989 Chehalis had a surplus of 27,000 chums. Because of the depressed nature of many of the stocks, these surpluses have increased the natural spawning escapement.

TABLE 3.—Production of enhanced chum salmon, 1984–89 total.

Hatchery	Catch Area	Enhanced Catch	Exploitation Rate (%)	% of Catch Enhanced
Pallant	Area 2E	273,656	54	20
Kitimat	Area 6	42,620	29	9
Snootli	Area 8	990,569	89	40
Conuma	Area 25	218,858	46	55
Nitinat	Area 21	3,099,608	74	72
ECVI	Johnstone Strait	627,539	21	18
	Area 14	1,341,795	44	70
	Total	1,969,334	64	
Fraser	Johnstone Strait	372,507	29	10
	Area 14	15,896	1	2
	Fraser	70,473	5	37
	Total	458,876	35	
ECVI +	Johnstone Strait	1,000,046	23	28
Fraser	Area 14			72
	Fraser			37
Total		7,053,521	65	

Georgia Strait Coho Problem

Declining coho stocks in the Strait of Georgia are believed to have been caused by overfishing and habitat loss. Currently, about 40% of the Georgia Strait troll and sport catch is made up of Canadian enhanced salmon. Exploitation rates have averaged 80% (1985 to 1988) compared to the 65–70% considered acceptable for wild coho stocks.

Management of the Georgia Strait coho stocks is complicated by the fact that they are harvested in troll, net, and sport fisheries, both inside and outside Georgia Strait. A consultation process has been occurring through which options for rebuilding can be developed and evaluated with all interested parties. These include habitat protection and restoration, enhancement, and harvest restrictions.

One of the most interesting proposals is for all hatchery fish to be marked and sport regulations would set a higher bag limit for marked than for unmarked fish. Wild fish would be conserved, while hatchery benefits would increase. Fewer enhanced coho would return to the hatcheries where their market value is low. The catch of enhanced Georgia Strait coho averaged 578,000 for the 1985 to 1989 period. Hatchery coho surpluses average approximately 100,000 for the same period. Commercial harvest limitation is complicated by the fact that many Georgia Strait coho are caught incidental to large sockeye, pink, and chum fisheries. Whatever options are chosen, the decision will not be an easy one.

D.

Interactions Between Wild and Cultured Salmon in Norway and Sweden

T. G. Heggberget and T. Eriksson

ATLANTIC SALMON SMOLTIFY AND LEAVE FRESHWATER at sizes between 12 and 17 cm. The smolt ages vary between 1 and 6 years, depending on growth conditions during the presmolt freshwater period. The salmon return to freshwater to spawn after 1–4 years, at sizes from 1 to 25 kg.

Some significant life history variations between stocks exist. Examples of variations between stocks are: timing of spawning, timing of emergence of fry, timing of smolt migration, timing of return migration, and age and size at maturity. Atlantic salmon in Norway are genetically distinct from the Baltic salmon.

Norway

In Norway there are three main sources of cultured fish (1) presmolt salmon released for general enhancement of stocks, (2) smolts released to compensate negative effects due to hydropower development and ocean ranching along the coast, and (3) escapees from pen farms along the coast.

There are about 500 streams with natural stocks of salmon in Norway. The production of farmed salmon in Norway was about 150,000 tonnes in 1991, while the natural production was about 2000 tonnes.

A number of problems have occurred. Due to pen farming activities a great number of farmed salmon have escaped and are now mixing with the wild stocks. Proportions of cultured fish in spawning populations have increased during the last decade, and now exceed 80% of the total number of spawners in some streams. Parasites and diseases introduced with import of smolts from other countries have been transferred to wild stocks with some dramatic effects; high mortality of wild salmon has occurred both due to the parasitic monogean *Gyrodactylus* and due to furunculosis. Ecological interactions—for instance, competition during spawning and presmolt stages—between wild and cultured fish have been observed. Interbreeding may result in erosion of local adaptations in wild stocks of Atlantic salmon in Norwegian streams. As well, ocean ranching increases fishing pressure on wild stocks.

Several attempt to minimize the negative effects of interactions between cultured and wild fish have been or are being tried: conversion from pen farming to land-based salmon farming; minimizing numbers of strayers from ocean ranching to wild stocks; releasing in connection to rivers, not directly in the sea; harvesting ocean-ranched fish apart from wild stocks; releasing away from important salmon streams; emphasizing locally and regionally based salmonid aquaculture and not transporting live fish material between regions; and practicing effective and intensive health control of release material.

Sweden

The Baltic stocks of Atlantic salmon have been exploited by humans for many centuries. At the end of the 19th century salmon spawned in 60–70 rivers in the Baltic. From 1940 onwards many of the large salmon rivers were dammed and destroyed as spawning habitats. To compensate for the losses hatcheries were established at the rivers used for hydroelectric power production.

Several problems persist. Most of the natural populations have disappeared due to human activities in the rivers. Today between 80 and 90% of the catches in the fishery have a hatchery origin. The catches are dominated (80-90%) of offshore catches on mixed stocks and represent a high exploitation rate on wild stocks. Wild stocks are unable to cope with the present exploitation rate while the reared stocks can, due to high egg-to-smolt survival in the hatcheries. Thus only about 20-25% of the production potential in the natural rivers is actually met today. Management plans are proposed, including a reduction of the offshore fishery.

V.
ABSTRACTS

A.
Genetic Considerations

Conservation of Salmonid Fishes: Why, What, and How

F. W. Allendorf

Three questions must be addressed before we can develop objectives and methods for conserving salmonid fishes: (1) Why should we preserve salmonid fishes? (2) What should we attempt to preserve? and (3) How should we conserve salmonid fishes? It is important to address the issue of why we want to conserve salmonids in order to unify our efforts and to obtain the resources that are necessary to do it. The question of what we should be preserving is an important and perhaps surprisingly difficult one. Loss of local salmonid populations is occurring throughout the world. We cannot halt this ongoing process; that is, we cannot conserve all local salmonid populations. Therefore, choices and compromises must be made. How do we best use our limited resources to conserve genetic diversity in salmonid fishes? Our first priority should be to protect extant wild populations and their habitat. The loss of genetic diversity is usually irreversible. Therefore, our primary efforts should be to prevent such losses.

Do Culture Conditions of Hatchery-Reared Salmon Affect Return and Straying of Adults?

S. O. E. Ebbesson

Available data indicate that caution should be exercised in rearing certain species of salmon under accelerated growth regimes; additional research is needed to determine if such regimens result in straying. We know from our experience in Alaska with accelerated rearing programs for chinook salmon, for example, that the result is significantly lower returns of adults and returns characterized by a high percentage of jacks. The reasons for this are unknown, but a better understanding of factors affecting smolt transformation and development in general are likely to lead to augmentation of current rearing strategies which will result in better developed smolts. Recent studies have revealed the importance of thyroid hormones on olfactory imprinting and development in general.

Studies comparing saltwater survival of yearling and zero-age coho salmon have showed differential rates of survival related to the timing of release into salt water and to the timing and extent of the plasma thyroid hormone surge. In a 1982 study by Dickhoff and others, about 5 times as many yearling smolts survived as compared to zero-age smolts. Those data, taken together with the information that the thyroid hormone surge (T_4) during smolt transformation in the zero-age fish was half the amplitude of the yearlings', indicate that in addition to poor survival as postsmolts, some zero-age fish may not imprint properly on the stream where they are released. The reason for that is that thyroid hormones play an essential role in olfactory imprinting. Our studies on brain chemistry and brain circuitry changes during smolt transformation revealed sequential surges of select neurotransmitters before, during, and after the plasma T_4 surge. Irregularities in any of these surges may result in inadequate imprinting or lead to inadequate brain development, which in turn could affect subsequent behavior and survival.

There is to my knowledge no direct evidence for straying of zero-age fish, but research in this area should, in my view, be carried out before accelerated rearing programs are implemented.

Adaptive Importance of Genetic Infrastructure in Salmon Populations

A. J. Gharrett and W. W. Smoker

Genetic differences among populations of Pacific salmon are well known, both for neutral biochemical traits and to a lesser extent for quantitative, ecologically adaptive traits. This knowledge is the basis for present day genetic policy which seeks to conserve the genetic variation which underlies that variability. There is increasing evidence of adaptively important genetic variability within populations; that is, genetic infrastructure. In Auke Creek pink salmon, for instance, there is genetically based variability of timing of anadromous migration that is important to the survival of offspring. The adaptability and productivity of commercially important populations are dependent on that infrastructure and rational resource management should seek to conserve it.

Homing, Straying, and the Interaction Between Wild and Hatchery-Produced Salmon

T. P. Quinn

This paper reviews studies on the patterns of straying of adult salmonids from their river or hatchery of origin, with an emphasis on Pacific salmon. The prevalence of straying varies greatly among populations. In general, introduced populations and salmon whose rearing history involves displacement or changes in water source may stray more than native stock and those reared and released on-site. Normal hatchery practices do not necessarily increase the tendency of salmon to stray, although evidence indicates that this may occur. While a generalized estimate of the proportion of salmon that stray would be useful, none seems appropriate because rivers and hatcheries vary so greatly in their tendency to produce and attract strays. There is evidence that the offspring of hatchery-produced salmon may be less viable than those from local wild fish, hence straying between hatcheries and spawning grounds is cause for concern. Whether or not strays actually affect local gene pools depends not only on the prevalence of straying but on the degree of assortative mating and differential survival between populations. At present, fundamental gaps in our understanding of the genetic and environmental factors influencing straying hinder accurate prediction of the levels and consequences of straying.

Complementary Uses of Ecological and Biochemical Genetic Data in Identifying and Conserving Salmon Populations

F. M. Utter, J. E. Seeb, and L. W. Seeb

This paper addresses the need to define distinct population segments within species of salmonid fishes. The focus is on identifying the smallest detectable population with unique sets of characters (i.e., a "species" under the phylogenetic species concept); such units require identification prior to any subsequent groupings under which individual populations may ultimately be managed. The inability of stream distances between populations to identify ancestral discontinuities excludes such measurements as a basis for estimating relationships. The requirement for genetic information in distinguishing populations has been met through characters reflecting ancestral lineages (including adequate biochemical genetic surveys and some meristic information), and those reflecting local adaptations (such as timings of migration and spawning, and distinct temperature tolerances). These different types of genetic information comprise complementary data sets for distinguishing populations because they reflect different evolutionary processes and time scales. Within distinct ancestral groupings defined by biochemical genetic data (supplemented with some meristic information) may exist adaptively distinct populations that cannot be distinguished in the absence of life history and ecological information. Examples are summarized in which a logical process has been applied for distinguishing populations including an initial survey focusing on identifying ancestral groupings followed by a systematic search for adaptive distinctions within these groupings.

Genetic Stock Identification Study of Yukon River Chum and Chinook Salmon

R. L. Wilmot, W. J. Spearman, R. Everett, and R. Baccus

The United States and Canada opened negotiations in 1985 concerning the allocation of Yukon River chum and chinook salmon. Approximately 90% of the in-river harvest is by U.S. fishermen. An unknown proportion of this catch would have returned to the Canadian portion of the Yukon Drainage. In order to negotiate an equitable treaty between the two countries, it is necessary to determine what proportion of the U.S. harvest is of Canadian origin. In 1987, the U.S. Fish and Wildlife Service began a genetic stock identification (GSI) study in the Yukon River to address this problem.

Tissue samples were taken from 34 chum salmon populations and 30 chinook salmon populations and genetically characterized using enzyme electrophoresis. Nineteen variable characters were used to analyze the population structure of Yukon River chum salmon, and 22 variable characters in chinook salmon. Genetic separation between the summer run and fall run of chum salmon was very good as determined using simulations of stock mixtures of given contributions of each stock. Separation between U.S. fall run stocks and Canadian fall run stocks was also good. Estimates down to the stock level are not reliable for management purposes at this time. Resolution of an additional known 14 variable characters, and the use of mtDNA variation, may allow reliable estimates to the stock level. Genetic separation

between U.S. and Canadian chinook stocks was very high as determined by simulations. Separation was also very good for subgroups within both the U.S. and Canadian groups. Accuracy down to the stock level is substantially better for chinook salmon than for chum salmon, but is still not reliable for management purposes. Resolution of an additional 13 variable characters, and use of mtDNA variation, may allow discrimination to the stock level.

Samples have been taken from the mixed-stock fishery at the mouth of the Yukon River and estimates of stock contribution were calculated for the years 1987–90. Due to legal problems concerning management of the Yukon River fishery, these results will not be released until a thorough peer review of the data.

B.
OCEAN CARRYING CAPACITY

A Theoretical Evaluation of the Carrying Capacity of Prince William Sound, Alaska, for Juvenile Pacific Salmon

R. T. Cooney

Present levels of feeding on zooplankton resources by wild and ocean-ranched juvenile Pacific salmon in Prince William Sound are estimated to be between 1% and 4% of the annual macrozooplankton production in the region. When annual fry losses to early ocean mortality are taken into account, the feeding demand associated with growth rates averaging 3–4% of the body weight per day fall to 0.4–1.6% of the total herbivore production and 1.5–5.0% of the macrozooplankton production. Uncertainties associated with the numerous assumptions used in this analysis are discussed in relation to what is understood about the biology and ecology of salmon in Prince William Sound and elsewhere.

Density Dependent Changes in Chum Salmon, *Oncorhynchus keta*, Returning to Iwate Prefecture, Japan

H. Ida

In the last two decades in Iwate prefecture, Japan, hatchery operations were prolonged in order to overcome several problems: (1) to reduce natural mortality in early life stages, (2) to supply food for increased numbers of fry from hatcheries, and (3) to adjust the time of release from the hatchery, where fry hatch much earlier than in the natural beds because of higher temperature of incubating water in the hatchery.

Release after feeding of chum fry started in the early 1970s in Iwate, and the method prevailed throughout the prefecture in the later seventies. In addition to this feeding in freshwater, feeding of fry in cages set close to shore started in the early eighties. The rate of return of adults to Iwate for brood year 1970 was 0.82%; for 1975 it was 1.52%; and for 1985, 3.50%. Thus, the rate of return increased serially. In the earlier stages of this change, feeding or prolonged hatchery operations seemed to accelerate maturation, especially in males; the number of precocious 2-year-old males ("jacks") reached 25–30% in some rivers. There was a tendency toward decreased mean age and mean size, but this lasted only a few years.

Size of fry at the time of release was increased from about 1 gram in the 1970s to several grams in the early 1980s. Mean age and weight of adults returned were as follows.

	1975	1980	1985	1990
Mean age	3.3	3.90	4.47	4.27
Mean weight (kg)	3.42	3.39	3.54	3.12

On the whole, the effort of raising chum fry up to a certain size seemed to increase the survival rate of their early life history stages in coastal areas. At the same time, the number of fry released from Iwate prefecture increased from 30 million in 1970 to 400 million in 1990. Both of these efforts accelerated the biomass of chum salmon originating from Iwate, and as a result growth was stunted and the mean age at maturity was increased.

Factors Affecting Marine Growth of Bristol Bay Sockeye Salmon

D. E. Rogers and G. T. Ruggerone

Growth of Bristol Bay sockeye salmon in freshwater and in the last few months at sea. had been shown to be dependent on their density (higher density, poorer growth) and temperature (colder temperature, poorer growth). In both 1990 and 1991, the sockeye salmon returning to Bristol Bay was unusually small; i.e., for a given age and sex the fish were smaller than expected from the number of fish in the run and the prevailing spring temperatures. The pronounced increase in North Pacific salmon catches in recent years combined with the small size of sockeye in Bristol Bay prompted a reexamination of the factors influencing marine growth. We estimated the annual runs of sockeye and chum salmon in the North Pacific (central and western Alaska plus Asia) and compiled air and water temperature statistics for southwestern Alaska from 1952 to 1991. We estimated the annual mean lengths and weights of adult sockeye in Bristol Bay runs during 1959–91 and marine growth was estimated from scale measurements on samples from Nushagak sockeye catches during 1959–89. We used data plots, linear correlation, and step-wise multiple correlation analyses to relate the various measures of abundance (Bristol Bay, western Alaska, Asia, sockeye and chum) and measures of temperature (air and water for various monthly combinations).

The inclusion of numbers of sockeye and chum salmon from other areas did not improve on the inverse correlation between numbers of Bristol Bay sockeye and the mean lengths in the run. The inclusion of sea surface temperatures during late winter improved the multiple correlation (only April–May had been used before); however, the overall correlation with Bristol Bay lengths was poorer with the addition of the 1990 and 1991 observations. Scale radii measurements of Nushagak sockeye during each year at sea (1956–88) indicated that growth was positively related to temperature during the first (ages 1.2 and 1.3) and second (age 1.3 only) years at sea. Growth during the last year at sea of age 1.2 and 1.3 sockeye was not correlated with sea surface temperature nor salmon run size. Scale growth during the first and second years at sea was not correlated with adult length; however, growth during the third year (age 1.3) was positively correlated with adult length. These data indicate that abundance of Bristol Bay sockeye most affects their growth in the final months before their return, which is a time when they are probably most concentrated.

Table: PWSAC Adult Pink Salmon Weight Relative to PWS Return

J. Olsen

PWS PINK RETURN	YEAR	AFK LB.S	AFK KG	WNH LB.S	WNH KG	CCH LB.S	CCH KG
15,723,637	1980	3.30	1.50			?	?
22,085,837	1981	3.50	1.59			?	?
23,051,963	1982	3.20	1.45			?	?
16,696,998	1983	3.00	1.36			?	?
26,476,567	1984	3.40	1.55			?	?
28,254,589	1985	3.30	1.50			?	?
12,771,529	1986	3.40	1.55			?	?
31,544,027	1987	3.60	1.64	3.65	1.66	?	?
13,126,476	1988	3.10	1.41	3.48	1.58	?	?
24,157,149	1989	3.30	1.50	3.45	1.57	3.65	1.66
43,831,188	1990	3.00	1.36	2.99	1.36	2.97	1.35
38,354,826	1991	2.40	1.09	2.33	1.06	2.43	1.10
	1992						
	1993						
	1994						
	1995						
	1996						
	1997						
	1998						
	1999						
	2000						
	AVG						
24,672,899	1980-91	3.21	1.46	3.18	1.45	3.02	1.37
	1980-90	3.28	1.49	3.39	1.54	3.31	1.51
	MIN	2.40	1.09	2.33	1.06	2.43	1.10
	MAX	3.60	1.64	3.65	1.66	3.65	1.66

Regression Output:

Constant		3.51
Std Err of Y Est		0.31
R Squared		0.14
No. of Observations		12.00
Degrees of Freedom		10.00
X Coefficient(s)	-0.00001	
Std Err of Coef.	0.00001	

Interactions and Environmental Carrying Capacity Limitations of Natural and Artificial Stocks of Salmonids

P. M. Washington

Artificial propagation of salmonids has been practiced for more than a century. In theory, this practice allows the production of almost unlimited amounts of fish. The practice was developed and used to mitigate losses of smolts formerly produced in natural habitats, and evolved to reduce the high mortality during the early freshwater life of anadromous salmonids. Stocks used in hatcheries were homogenized to produce more easily handled fish. Short pulsed hatchery runs currently provide the basis for many coastal net fisheries.

Artificial facility releases can produce yields of salmonids up to ocean carrying capacity. Oceanic salmonid yield potential is limited by both density-dependent and -independent factors. Monoculture has produced localized density limiting production, but actual production limitation may not be approached until the use of all niches and niche subsets approaches maximum.

Fisheries precluding individual stock management should be terminated before extinctions of wild stocks result. Harvest policies can no longer be to the detriment of wild stocks. Artificial propagation based policy has reduced genetic diversity, manipulated adult size and age downward, and had profoundly negative impacts upon wild stocks.

C.
MANAGEMENT

Overview of Salmon Enhancement Programs in Southeast Alaska

D. F. Amend

All five of the Pacific salmon species are being enhanced by hatcheries in southeast Alaska. Non-hatchery enhancement is not included in this report. Hatcheries are operated by the FRED Division of the Alaska Department of Fish and Game, the Northern and Southern Southeast Regional Aquaculture Associations, and private non-profit corporation. Hatcheries played a minor role in the commercial harvest prior to 1985. Since 1985, the average annual harvest of enhanced chum salmon has been 695,700 (31.2%), chinook 19,590 (10.2%), coho 195,650 (8.1%), sockeye 58,480 (2.4%), and pink 475,000 (2.1%). At full production the percentage of enhanced salmon in the commercial harvest is expected to be about 66.4% chum, 32.5% chinook, 18.2% sockeye, 16.2% coho, and 5.8% pinks. The annual value to the commercial fleet has averaged $8.4 million annually and at full production is expected to average $36.8 million annually. The annual 3% enhancement tax paid by fishermen has averaged $2.39 million. Cost recovery is conducted only by the two regional aquaculture associations and the private non-profit corporations. The annual revenue generated from cost recovery is estimated to be about $2 million.

The Perpetual Oversight of Hatchery Programs

E. L. Brannon

A major concern of fisheries biologists and managers has been the perception that hatchery fish are inferior to wild fish, and the belief that hatchery fish tend to degrade natural populations. These perceptions are not without foundation, but the problems are the fault of how we have managed hatcheries, and not with either concept or the potential which hatcheries can offer. The perpetual oversight that we have demonstrated consistently throughout our history of fisheries management has been to ignore the fact that fish populations are an integral component in a complex environmental system. If we neglect the requirements that populations have, and hence the traits they possess to synchronize their life history with specific environmental constraints, failure is guaranteed. Although appropriate technology is the key in producing healthy fish, the absolute critical component for success of the hatchery concept is the seed stock used for propagation. Synchrony between stock characteristics and the environment cannot be sacrificed, which means that every possible effort must be extended on working with the native gene pool and avoiding contamination from other brood sources. Adherence must be given to the stock concept in the use and management of hatcheries.

Trends in Abundance of Hatchery and Wild Stocks of Pink Salmon in Cook Inlet, Prince William Sound, and Kodiak, Alaska

D. M. Eggers, L. R. Peltz, B. G. Bue, and T. M. Willette

Trends in pink salmon (*Oncorhynchus gorbuscha*) abundance, production, and average weight of hatchery and wild stock catches, were examined for the years 1960 through 1990 for the lower Cook Inlet, Prince William Sound, and Kodiak Island areas. The abundance of wild pink salmon was the sum of wild stock catches and escapement, which were aerial survey index counts expanded by estimates of stream life. Abundance of hatchery stock was the sum of the estimated contribution of hatchery stocks to catches and the returns to the hatchery. Production estimates were based on hatchery stock returns from fry released at the hatchery and wild stock returns from parent escapement. Hatchery runs have increased greatly since the late 1970s and currently exceed wild stock runs. The total central Gulf of Alaska runs of pink salmon have increased and average weights have decreased since the early 1970s. Since the construction of hatcheries, wild pink salmon runs in Kodiak and Cook Inlet have not declined; however, in Prince William Sound a marked decrease in wild stock runs has coincided with the increase in hatchery runs. Return per spawner for wild stocks and survival of releases for hatchery stocks were similarly affected by ocean temperatures. The recent decline in Prince William Sound wild pink salmon runs is believed to be the result of lower wild stock escapement levels due to the heavy exploitation of weak to moderate wild stock runs.

Gene Frequencies, Risk Assessment, and the Management of Hatchery Production of Pacific Salmon

J. E. Seeb

The legislative mandate of the Alaska Department of Fish and Game (ADFG) is the "enhancement and development of all aspects of the state's fisheries for the perpetual use, benefit and enjoyment of all citizens" (Alaska Statutes Title 16). The legislature accompanied this mandate with the requirement that enhancement of crucial native stocks should only be undertaken if careful consideration indicated that they can be conserved in the presence of hatchery management (Title 16; ADFG Genetics Policy).

Native stocks of salmon are important because they not only are the mainstay of the Alaska fisheries economy, but they also represent thousands of years of adaptive evolution. Reproductive isolation, through homing, leads to between-population genetic differences. This component of genetic variation is responsible for adaptive fitness to diverse environments, a factor which permits different stocks of salmonids to thrive under different environmental regimes; and it is the factor that provides for optimal sustained production of wild stocks given the vagaries of environmental variation.

Hatchery production of enhanced fish can relax many of the pressures of selection on a population. While such a stock may thrive in a hatchery and produce fish for harvest, after several generations it may lose some of the genetic traits that made it optimally fit for response to the natural environment. Thus it is important that hatchery fish only be used to truly enhance harvests, and they must be kept from replacing the important wild stocks from which they were derived.

Of paramount concern (this symposium) is the loss of genetic integrity of the isolated salmon populations that can result if hatchery practices lead to increased straying of hatchery fish (and their interbreeding with the native populations). As a part of its effort to protect wild stocks, ADFG is conducting (and proposing) genetic research such as: (1) genetic stock identification (GSI)—genetic screening to determine stock boundaries, provide GSI data to identify hatchery and wild stocks in mixed stock fisheries, genetic marking to monitor straying of hatchery fish; (2) risk assessment and genetic monitoring—evaluation of the genetic consequences of new or increased hatchery production during phased-in expansion, monitoring of changes in fitness and possible effects on wild stocks, conducting long-term monitoring of hatchery and wild stock genetic diversity, modifying hatchery strategies if called for; and (3) use of best possible breeding practices to maintain fitness and genetic variability.

The ADFG believes that this recommendation of a conservative hatchery management strategy incorporating genetic monitoring will facilitate responsible development of the fishery resource. Strict adherence to this strategy will help ensure that hatchery enhancement does not cause any genetic alteration resulting in the loss of these important wild stocks.

Population Genetic Structure of Chum Salmon: Identification of Wild and Hatchery Fish in Mixed Fisheries

L. W. Seeb

The control and management of mixed-stock harvest of chum salmon is one of the most difficult problems facing salmon managers today. Interception of chum salmon exacerbates allocation issues and may contribute to conservation problems in certain areas. Genetic stock identification (GSI) is the primary tool which is being implemented to address these mixed-stock interception issues. Through GSI analyses, scientists can identify the origin and amounts of the different stocks harvested in mixed-stock areas. These values can be used both in-season and post-season to insure conformance to international treaties, to allocate future harvests by nation and user group, or to separate hatchery from wild stocks. They can also be used to adjust harvest areas or times to protect important depleted stocks, the extinction of which would represent an irreversible loss of distinct population segments of the species.

Genetic data from chum salmon have been collected for over a decade by many state, federal, and provincial agencies along the Pacific Rim. These data show that chum salmon subdivide genetically not only into large regional groups, but also one a finer scale into local genetic races. Federal and state agencies have invested considerable resources in the collection of data from stocks originating from Washington, southeast Alaska, Russia, and Japan; the Canadians have likewise gathered extensive data from British Columbia populations. Yet, with the exception of stocks inhabiting the Yukon River and Bristol Bay, no database currently exists for the remaining Alaskan stocks which comprise approximately 40% of the chum salmon production of North America. Many of these stocks have not been sampled because they inhabit remote areas difficult to access. The Alaska Department of Fish and Game has placed a high priority on obtaining genetic data from these stocks.

Further development of the Prince William Sound chum salmon genetic database would allow for identification of wild stocks adjacent to hatchery installations. The current chum salmon broodstock in Prince William Sound is a heterogenous group originating from multiple sources and timings. The effect of hatchery stocks on the wild stocks within Prince William Sound could be monitored through GSI techniques to insure the continued health of these important wild stocks.

D.
Atlantic Salmon

Status of Wild and Hatchery-Propagated Swedish Salmon Stocks After 40 Years of Hatchery Releases in the Baltic

T. Eriksson and L-O. Eriksson

The Baltic stocks of Atlantic salmon have been exploited by humans for many centuries. Especially during the last century, salmon populations have been subjected to dramatic changes in spawning stream access, fishing patterns, and fishing pressure.

At the end of the 19th century salmon spawned in 60–70 rivers in the Baltic proper. From 1940 onward, many of the large salmon rivers were dammed, most of them below the lowest spawning rapids for salmon. Methods for rearing salmon up to the smolt stage were developed and the first smolt releases were around 1950. The number of smolts released in Swedish rivers gradually increased to between 2 and 2.5 million by the middle of the 1980s. During the last 10 years other countries have started salmon release programs, resulting in an annual release of about 3 million smolts. The smolt releases have been successful, showing high survival rates of stocked fish. Today, only about 20 rivers, most of them in Sweden, are attainable for natural spawning runs. The runs are very weak.

Before the second world war the Baltic salmon fishery mainly consisted of coastal and river catches of spawning migrators ascending the rivers. After the war an offshore drift gillnet fishery developed, nowadays making up the major part of the total catch. As a consequence, the spawning runs of wild salmon have decreased dramatically. One hundred years ago the natural production of salmon smolts from the Baltic salmon rivers was around 7–8 million smolts annually. In the early 1970s the wild smolt run to the Baltic was about 2 million. At present, only about 0.5 million wild smolts are produced to the whole Baltic proper, which is only about 20% of still remaining smolt production capacity of the rivers.

The offshore fishery on mixed populations in the central areas of the Baltic proper leads to an extremely high fishing pressure on the Baltic salmon stocks. Wild stocks are unable to cope with the present exploitation rate. As a result, the number of wild spawners in natural streams gradually diminishes. In the absence of a compensatory program, a reduction in stock size of the magnitude shown by wild salmon in the Baltic would decrease catch per unit effort to such a degree that a salmon fishery would be meaningless. At present, however, about 90% of the salmon smolts leaving Baltic rivers are of hatchery origin. Depending on extremely high egg-to-smolt survival rates the reared stocks can withstand this high exploitation. It is concluded that the success of hatchery enhancement programs in combination with the lack of effective regulations allowing a high catch per unit effort in the offshore fishery, explains a major part of the sad fate of the remaining wild salmon stocks in the Baltic.

A biologically sound management program for the Baltic salmon is bound to include a stop (or strict regulation) of the offshore fishery on mixed stocks. Salmon stocks should be exploited in relation to the carrying capacity of individual populations, by a more terminal fishery at the coast, or in rivers.

However, an established offshore fishery in the main Baltic, including (at least) seven nations, has so far made any kind of regulations difficult. A recent and, hopefully, more accessible management program is a compromise, suggesting a ban on salmon fishing outside 24 nautical miles form the coast. The fishery closer to the coast will be supported by net-pen delayed releases of salmon at selected areas along the coast of the Baltic main basin. The proposed offshore fishery regulation would increase escapement considerably, while total catch (in tons) would remain unchanged. If the proposal is accepted, we estimate that most wild salmon stocks would have a possibility to recover within 3–4 generations. If not, we believe that the fate of all the wild salmon stocks in the Baltic is extinction within a few additional salmon generations.

Interactions Between Wild and Cultured Atlantic Salmon: A Review of the Experience in Norway

T. Heggberget

About 500 streams in Norway support Atlantic salmon. Most of the Norwegian salmon populations are characterized by small numbers of fish. Physical conditions, for instance water flow and temperature regimes, vary significantly along the Norwegian coast. Analyses of age and size at maturity, timing of spawning, and timing of smolt migrations clearly support the hypothesis of ecological adaptation to different physical environments. The differences in life history patterns are results of different selection pressures on salmon under varying physical conditions.

Proportions of cultured salmon have increased together with the rapid growth of the Norwegian salmon farming industry, and a maximum of 80% cultured fish in spawning populations have been observed. The sources of cultured salmon in Norwegian streams are fish released for general enhancements of stocks, ocean ranching, and escapees from the fish farming industry. Escapees from closed pen operations are the main source of cultured fish in nature.

The most striking effect of the increasing numbers of cultured fish so far has been the introduction of parasites and diseases. In recent years more than 30 populations of salmon have been completely wiped out by the monogean *Gyrodactylus*, and high mortality of adult salmon due to furunculosis has been observed in some streams. The long-term effects of genetic interbreeding might result in extra mortality of wild fish due to erosion of local adaptations.

VI.
ACKNOWLEDGMENTS

This workshop was sponsored by the Prince William Sound Science Center (PWSSC) and the School of Fisheries and Ocean Sciences (SFOS), University of Alaska Fairbanks. Co-chairpersons were Dr. Ole A. Mathisen, SFOS, and Dr. Gary L. Thomas, PWSSC. The list of contributors includes Pew Charitable Trust, University of Alaska Fairbanks, Alaska Department of Fish and Game, Pacific Seafood Processors Association, Prince William Sound Aquaculture Association, and Sealaska Corporation. We want to extend special thanks to Ms. Nancy Bird and Ms. Penelope Oswalt for their efforts to make the workshop a success.

VII.
AGENDA
Workshop on the Biological Interactions of Natural and Enhanced Stocks of Salmon in Alaska

Saturday, November 9

Participants arrive during the day.

Sunday, November 10 *Open to the public*
First Morning Session - 8:30-10:00 a.m.

Opening remarks:

1. Gary L. Thomas, Director Prince William Sound Science Center

2. Goals of the Conference - Ole A. Mathisen, Univ. of Alaska-Juneau

3. Prince William Sound Aquaculture Corporation - John McMullen, President

4. State Genetic Policy - James E. Seeb, Alaska Dept. of Fish & Game

Session 1 -- Ocean carrying capacity
10:30-12:00

1. *A theoretical evaluation of the carrying capacity of Prince William Sound, Alaska for juvenile Pacific salmon.* R. Ted Cooney, School of Fisheries and Ocean Sciences, University of Alaska, Fairbanks

2. *Density dependent changes in chum salmon, Oncorhynchus keta, returning to Iwate Prefecture, Japan.* Hitoshi Ida, Kitasato University School of Fisheries Sciences, Sanriku-cho, Kesen-gun, Japan

3. *Factors affecting marine growth of Bristol Bay sockeye salmon.* Donald E. Rogers, Fisheries Research Institute, University of Washington, Seattle, Washington

4. *Interaction in natural carrying capacity limitations for natural and enhanced stocks of salmon.* Percy M. Washington, GAIA NW, Inc., Seattle, Washington

5. *The carrying capacity of the North Pacific Ocean.* William G. Pearcy, Oregon State University, Corvallis (Summary)

Session 2 -- *Management of mixed stocks*
1:30-3:00 p.m.

1. *Trends in abundance of hatchery and wild stocks of pink salmon in Cook Inlet, Prince William Sound and Kodiak, Alaska.* Doug M. Eggers, Chief Fisheries Scientist, Alaska Department of Fish & Game, Juneau, Alaska

2. *Management of mixed enhanced and wild salmonids in British Columbia.* Don D. Bailey, Salmon Enhancement Division, Department of Fisheries and Ocean, Vancouver, Canada

3. *Gene frequencies, risk assessment and the management of hatchery production of Pacific Salmon.* James E. Seeb, Alaska Department of Fish & Game, Anchorage, Alaska

Session 3 -- Summary and general discussion
3:30-4:30 p.m.

Monday, November 11 *Open to the public*

Session 4 -- Basic Genetic Structure
8:30-10 am Session Chair: James E. Seeb

1. *Conservation of genetic diversity in salmonid fishes: why, what and how.* Fred W. Allendorf, Division of Biological Sciences, Missoula, Montana

2. *The predictive value of stream distances for estimating genetic relationship in salmonid species.* Fred M. Utter, National Oceanic and Atmospheric Administration (NOAA), Seattle, Washington

3. *Population genetic structure of chum salmon: identification of wild and hatchery fish in mixed fisheries.* Lisa W. Seeb, Alaska Department of Fish & Game, Anchorage, Alaska

4. *The importance of fine genetic structures in natural populations.* Anthony Gharrett, School of Fisheries and Ocean Science, University of Alaska, Juneau, Alaska

Session 4 continued
10:30-12:00

5. *Quantitative genetic variation of life history traits in pink salmon.* William Smoker, School of Fisheries and Ocean Science, University of Alaska, Juneau, Alaska

6. *Genetic stock identification of Yukon River chum and chinook salmon.* Richard L. Wilmot, U.S. Fish & Wildlife Service, Anchorage, Alaska

7. *Genetic relationships among Pacific salmon of the Bristol Bay area of Alaska.* Rebecca J. Everett, U.S. Fish & Wildlife Service, Anchorage, Alaska

Session 5 -- Straying
1:30 - 2:00 pm

1. *Homing, straying and the interaction between wild and enhanced stocks of salmon.* Thomas P. Quinn, Fisheries Research Institute, University of Washington, Seattle, Washington

2. *Do culture conditions of hatchery reared salmon affect return and straying of adults?* Sven Ebbesson (abstract only)

Session 6 -- Long Term Case Histories
2:00-3:00 pm

1. *Interactions between wild and cultured Atlantic salmon -- A review of the experience in Norway.* Tor G. Heggberget, NINA, Norsk Institutt for Naturforskning, Trondheim, Norway

2. *The status of wild and hatchery propagated Swedish salmon stocks after 40 years of hatchery releases in the Baltic rivers.* Torleif Eriksson, Swedish University of Agricultural Sciences, Department of Aquaculture, Umea, Sweden

Session 6 continued
3:30-5 pm

3. *The perpetual oversight of hatchery programs.* Ernest Brannon, University of Idaho, Moscow, Idaho

4. *The Soviet experience in the field of salmon interactions.* Mikhail Glubokovsky, Institute of Marine Biology, Far East Branch, Vladivostok, USSR

5. General discussion

<u>Tuesday, November 12</u>

Field trip to Wally Norenberg Hatchery at Esther Island (western Prince William Sound) --

<u>Wednesday, November 13</u>

Session 7 -- Interactions in Prince William Sound
8:30-10 am

1. *Overview of Ocean Ranching in Prince William Sound,* Jeff Olsen, Operations Manager, Prince William Sound Aquaculture Corporation, Cordova, Alaska

Session 7 continued
10:30-12 noon -- *Interactions in Prince William Sound*

Session 8 -- Interactions in Southeast Alaska
1:30-3 pm Session Chair: Ole Mathisen

1. *Southeast Alaska Chinook; Fisheries, management, enhancement, wild stocks and treaties.* William R. Heard, National Marine Fisheries Service, Auke Bay Laboratory, Auke Bay, Alaska

2. *An Overview of the Pink, Chum and Coho Enhancement programs in Southeast Alaska.* Donald F. Amend, Southern Southeast Aquaculture Association, Ketchikan, Alaska

Session 8 continued
3:30-5 pm -- ***Interactions - General discussion***

Thursday, November 14

Session 9 -- ***Interactions regarding other species, especially sockeye***
8:30-10 am

Session 9 continued
10:30-12 Noon

Session 10 -- ***The Working Party: Writing sessions divided into sub-groups***
1:30-5:00 pm Session Chairs in charge of each group

Friday, November 15 *Open to the public*
Session 11 ***Concluding Session***
Session Chair: Gary Thomas

8:30-10 am Session leaders will present a short discussion of the findings of their working group followed by an open discussion session and approval of reports and documents.

10:30-noon Open discussion session continues.

Afternoon Departures

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VIII.
LIST OF MANUSCRIPTS SUBMITTED

R. T. Cooney
A Theoretical Evaluation of the Carrying Capacity of Prince William Sound, Alaska, for Juvenile Pacific Salmon

T. Eriksson and L-O. Eriksson
Status of Wild and Hatchery-Propagated Swedish Salmon Stocks after 40 Years of Hatchery Releases in Baltic Rivers

A. J. Gharrett and W. W. Smoker
Adaptive Importance of Genetic Infrastructure in Salmon Populations

T. G. Heggberget
Interactions Between Wild and Cultured Atlantic Salmon: A Review of the Experience in Norway

T. P. Quinn
Homing and Straying of Wild and Hatchery-Produced Pacific Salmon

D. E. Rogers and G. T. Ruggerone
Factors Affecting Marine Growth of Bristol Bay Sockeye Salmon

F. M. Utter, J. E. Seeb, and L. W. Seeb
The Predictive Value of Stream Distance for Estimating Genetic Relationship in Salmonid Species

P. M. Washington
The Interactions and Environmental Carrying Capacity Limitations of Natural and Artificial Stocks of Salmonids

VIII.
LIST OF MANUSCRIPTS SUBMITTED

E.L. Brannon
The Perpetual Oversight of Hatchery Programs

R.T. Cooney
A Theoretical Evaluation of the Carrying Capacity of Prince William Sound, Alaska, for Juvenile Pacific Salmon

T. Eriksson and L.O. Eriksson
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The Interactions and Environmental Carrying Capacity Limitations of Natural and Artificial Stocks of Salmonids

IX.
LIST OF PARTICIPANTS

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(REFERENCE COPY)

The Use of Supplementation to Aid in Natural Stock Restoration

MICHAEL L. CUENCO, THOMAS W.H. BACKMAN, and PHILLIP R. MUNDY

1. Introduction

Supplementation is one of the strategies that may be used for restoring natural production of anadromous salmonid populations in the Columbia River Basin. Depending on the particular circumstances, supplementation may be used by itself or in conjunction with other management strategies for restoring natural production such as habitat restoration and maintenance, improvement of tributary and mainstem river passage survival, improvement of estuarine and ocean survival, and harvest management by escapement objectives to allow the population to optimally seed available habitat. Above mainstem dams, all measures may need to be employed simultaneously to achieve success.

1.1. Ecological Complexity and Degradation

Efforts to restore naturally reproducing salmonid fish populations in the Columbia River Basin must begin with an understanding of the diverse and complex biology and life history of these populations. Not only are many species and races involved, but these fishes use diverse freshwater, estuarine, and marine habitats during the different stages of their life cycles (Davidson and Hutchinson, 1938; Northcote, 1969; Ricker, 1972; Howell et al., 1985).

Superimposed upon this natural complexity is man's intervention in the form of timber harvest and removal of riparian vegetation (Chamberlain, 1982), forest roads (Yee and Roelofs, 1980), water transportation of logs (Sedell and Duval, 1985), agriculture and irrigation withdrawals (NPPC, 1986), livestock grazing on riparian areas (Platts, 1981), mining (Martin and Platts, 1981), urban development (NPPC, 1986), fishing (NPPC, 1986), and hydroelectric development (Raymond, 1979; NPPC, 1986). Numerous studies have been conducted to quantify the detrimental effects of these activities on anadromous populations and their habitat.

1.2. Systems Approach to Restoration

Because the Columbia River Basin is a complex system with many interacting components, an improvement in one component will not necessarily result in improvement of the system as a whole. Thus, the function of any component and its manipulation can only be

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properly assessed in relation to the system of which it is a part. In the Columbia Basin, this approach has been called "gravel-to-gravel" management.

A first step in restoration of natural fish populations is an assessment of population "health," the stock's biological characteristics, the difference between the quality and quantity of present and former habitat, analysis of the factors limiting abundance, and modes of interaction of these factors (RASP, 1992). Understanding the physical and biological requirements for each life history stage of all stocks of concern, as well as the ways in which they use the habitat, is key. Although there will be common factors affecting many fish populations, detailed restoration plans should be based on a case-by-case analysis.

Supplementation efforts described in this paper are based on restoring anadromous salmonid populations to their historical localities and levels of production. Natural fish stock rehabilitation activities facilitated by the use of the hatchery system are commonly known in the Columbia Basin as supplementation, although the specific practices envisioned have varied among the proponents. A holistic rehabilitation plan, given the constraints imposed upon the Columbia River Basin fish production system by human activities, requires the effective use of supplementation in conjunction with improved habitat, water quality and flow, and fishery management. Wherever possible, the plan envisions actions to make it possible for anadromous salmonid stocks to be returned to their ancestral habitats through a variety of actions, including supplementation.

2. Definition of Supplementation

For the purpose of this document, *supplementation is defined as the stocking of fish into the natural habitat to increase the abundance of naturally reproducing fish populations.* Maintaining the long-term genetic fitness of the target population, while keeping the ecological and genetic impacts on nontarget populations within acceptable limits, is inherent in this working definition. This definition is consistent with efforts by other groups, such as the Regional Assessment of Supplementation Programs, to define elements of supplementation.

Supplementation includes activities where fish are stocked into barren habitats (currently unoccupied by the species). This activity is commonly referred to in the literature as transplantation or introduction (Withler, 1982; Fedorenko and Shepherd, 1986). In the Columbia Basin, supplementation activities will, in most cases, involve stocking fish into habitats that contain depressed, but existing natural fish populations.

Although artificial propagation has a central role in most supplementation activities, the definition of supplementation used here does not preclude the use of fish that have not been reared in a hatchery or other man-made propagation facility. The choice of a wild or natural stock for direct transfer should follow the genetically and ecologically sound guidelines presented as "similarity criteria" in Kapuscinski et al. (1992). However, unlike many "traditional" hatchery programs, the objective of supplementation is to increase the abundance of a naturally reproducing fish population and therefore, is oriented toward maintaining the natural biological characteristics of the population and reliance on the rearing capabilities of the natural habitat. In contrast, many traditional hatchery programs were designed to augment harvest by the development of hatchery fish populations that rely entirely on artificial spawning and rearing in the hatchery. These hatchery fish populations were not intended to contribute, and most likely have not contributed, to the abundance of naturally spawning fish populations. Typically, the juvenile fish are released into streams adjacent to the hatchery and the returning adults are guided back to the hatchery through the use of barriers and fishways.

The increase in the abundance of a naturally reproducing fish population may be self-sustaining after an initial but finite period of supplementation or it may be sustained through continual assistance from supplementation depending on the specific spawner-recruit relationship under given environmental conditions and management objectives. Supplementation measures will not obviate the need to concurrently pursue other necessary actions such as improvement of mainstem passage, habitat protection, and harvest management to rebuild stocks.

3. Uses of Supplementation

Supplementation is considered a tool for rebuilding natural fish populations, not a panacea. It can be used to assist in rebuilding natural stocks, to replace extirpated stocks, or to introduce and establish a stock in a barren habitat (Withler, 1982; Fedorenko and Shepherd, 1986)

3.1. Seeding Barren Habitat

For barren habitats that historically produced salmon or steelhead but are currently unoccupied, it is necessary to stock fish into the habitat to re-establish a desired fish population. The fish should be stocked at densities that do not exceed the carrying capacity of the habitat for the limiting life history stage of the fish being stocked. The carrying capacity of a damaged habitat will need to be re-evaluated as rehabilitation is undertaken. In evaluating carrying capacity, the potential for interspecific interactions and risks to non-candidate species must be addressed. In currently unoccupied habitat, it is essential to choose a fish population that has adaptive traits that are as similar as possible to those of the extirpated population. It is also desirable to match their genetic lineages if such information is available.

3.2. Provide Survival Advantage for Depressed Stocks

For "sparsely populated" habitats where there is an existing damaged salmonid population, the objective is to boost the population density above a certain minimum viable population size as quickly as possible (Thomas, 1990). For example, the minimum viable spawning escapement size for each stock may be calculated from the minimum effective breeding number by a transfer function, whose elements include the amount of spawning and rearing habitat available and the average total mortality. The concept is to employ a supplementation program to a level that minimizes risk of extirpation.

The primary role of supplementation in this case is to increase the survival rate of the population during its early life history (egg through smolt) relative to its survival rate under natural conditions. It is anticipated that this effort will result in increased adult returns to seed sparsely populated habitats.

For depressed stocks, the question of how many and what proportion of the natural stock to intercept for hatchery broodstock must address the need to maintain an effective breeding number in the natural and hatchery broodstocks. In practice such questions can only be resolved by carefully evaluating the impact of programs that initially take moderate fractions of the depressed population for broodstock.

3.3. Speed Rebuilding to Carrying Capacity

For a rebuilding, lightly damaged stock in healthy habitats, a potential but unresolved role of supplementation is to increase the rate at which the population rebuilds. Supplementation may be unnecessary in the long term if other factors limiting populations in the basin are corrected.

4. When to Use Supplementation

4.1. Life Cycle Analysis of Limiting Factors

A sound analysis of the population status (such as depressed or healthy), population trend (such as decreasing, stable or increasing), and the factors limiting population abundance are necessary to address the policy question of whether it is appropriate to use supplementation as a tool in increasing natural production. When a stock is considered to be at some high level of risk (nonviable status or declining numbers) and a policy decision is reached on the need to reverse the slide toward extirpation and implement restorative measures, and the physical and biological constraints on the natural stock (such as habitat conditions, passage and water quality) make its restoration feasible, supplementation should be considered as a chief form of biological support for the natural population.

Other support must aim at reducing or eliminating the original causes of decline. All available conservation actions such as reducing passage mortalities, reducing harvest mortalities, and rehabilitating spawning and rearing habitat need to be identified and prioritized to be used singly or in various combinations in concert with a supplementation program. Supplementation measures do not obviate the need to correct other factors limiting stock productivity.

4.2. Prerequisites for Supplementation

For supplementation to be part of the solution to increase the abundance of a natural fish population, the following prerequisites must also be met. In reading the text that follows, care must be taken in interpreting terms such as "carrying capacity" and "maximum escapement level." These terms are defined in the context of an undamaged environment in which the various species of anadromous salmonids complete their life cycles.

4.3. Decisions Regarding the Use of Supplementation

The potential need for and efficacy of use of supplementation depend both upon stock status and management objectives for a particular stock as well as potential impacts on other stocks and species. The decision to initiate a new supplementation program or to modify an ongoing program must be determined on a case-by-case basis. The following are eight criteria that the fishery agencies and tribes consider in determining whether to initiate or revise a supplementation program:

I. Extirpated Stock: Average spawning escapement is effectively zero. When data permit, the average spawning escapement is to be based on a period of years equal to three times the age class that represents the largest proportion of the run.
   - A. Stock in the most effective manner with the most similar available genetic, phenotypic and ecotypic stock.
   - B. Emphasize the use of returning adults for broodstock while allowing for escapement to the original spawing grounds.
   - C. Cease stocking when average return of spawners exceeds the lesser of the minimum viable population size, MVP, (see Thomas, 1990) or 85% of carrying capacity for three generations. If successful after one or two generations, stocking can be reduced.

II. Damaged Stock:
   - A. Badly damaged; average spawning escapements fall far below MVP and are be-

low the number of adults needed to produce 50% of the carrying capacity of the freshwater environment for the limiting life history stage.

1. Decreasing; the trend in average spawning escapements is declining or indeterminate for three life cycles.
   a. Take as few spawners as necessary to cross with the most similar available genetic, phenotypic and ecotypic stock (Kapuscinski et al., 1992, for some guidelines).
   b. Preserve unique characteristics of damaged stock; the ratio of donor to damaged stock should be approximately 1:1 in parental generations, leaving at least 50% F1 to spawn naturally, if survivals permit. Use the other returnees for broodstock in a 1:1 ratio with the damaged stock if survivals permit it to continue supplementation. The specific breeding protocol must be worked out with the advice of a professional geneticist on a case-by-case basis. Return (supplement) all production to the habitat from which the damaged stock was taken at an appropriate life history stage.
2. Stable or increasing; the trend in average spawning escapements is stable or increasing for three life cycles.
   a. Various proportions of native stock up to 50% may be taken for broodstock in the breeding program designed with the advice of a professional geneticist. All progeny will be returned to the stream from which broodstock was taken.
   b. As supplementation continues, use varying proportions of hatchery-reared and natural returns for broodstock for both artificial rearing and natural spawning in a professionally designed breeding program.

B. Moderately damaged; average spawning escapements fall between MVP and the number of adults needed to produce 50% of the carrying capacity of the freshwater environment for the limiting life history stage.
   1. Decreasing; the trend in average spawning escapements is declining or indeterminate for three life cycles.
      a. As a first approximation, annually take no more than 25% of natural spawners over a period of two life cycles to produce offspring that are reared in isolation and returned to the spawning habitat of their parents.
      b. After evaluating one life cycle of returns, if the average rate of returns of artificially reared fish is equal to or better than returns from natural spawners, increase the percentage of natural spawners taken to no more than 50%, taking no artificially reared fish for broodstock. If the rate of returns is not better than returns from natural spawners continue at the 25% level.
   2. Stable or increasing; the trend in average spawning escapements is stable or increasing for three life cycles.
      a. Supplementation is a lower priority than cases indicated above.
      b. Monitor survival and age-sex structured escapements and if population begins decreasing over one life cycle proceed as in II.B.1.

C. Lightly Damaged; average spawning escapement levels fall between the number of adults needed to produce 50% and 85% of the carrying capacity of the freshwater environment for the limiting freshwater life history stage.
   1. Decreasing; the trend in average spawning escapements is declining or indeterminate for three life cycles.

a. Monitor survival and age-sex structured escapements while determining the trend in escapements, and/or the proximate cause of decline.
b. If stock is actually decreasing after one life cycle;
   i. other remedies being available, apply them until the escapements increase for one life cycle.
   ii. if the escapements continue to decline after two life cycles, if the average population levels fall below 50% of the carrying capacity, or if other remedies are not available, then evaluate the need for supplementation and make a decision whether to proceed as in II.B.

2. Stable or increasing; the trend in average spawning escapements is stable or increasing for three life cycles.
   No supplementation action is necessary, but careful monitoring of escapements and survivals is essential.

III. Undamaged Stock: No supplementation is necessary to achieve basic conservation purposes when average escapement deficits are within 0% to 15% of the maximum in undamaged habitat. Such population levels still require monitoring to evaluate survival and to obtain age and sex structured escapements.

4.2.1. Sufficient Natural Habitat Exists

The present or rehabilitated habitat should be judged capable of supporting a viable, self-perpetuating population in the face of natural stochastic events (such as floods, droughts, earthquakes) demographic factors (ability to find a mate, sex ratio, age structure) and genetic considerations (such as maintenance of an effective population size to prevent serious loss of genetic variation). This is important to ensure that the carrying capacity of the habitat does not become a limiting factor in the population's rebound. The actual numbers of fish that constitute a) minimum viable population size, b) proportions withdrawn for broodstock, and c) carrying capacity of the environment would have to be determined on a case by case basis.

Salmon need different types of habitat during various stages of their life cycle (Reiser and Bjornn, 1979). Sufficient pre-spawning habitats (deep, cool, calm pools) should be available for spring chinook, summer chinook, and summer steelhead adults that have to hold several months before proceeding to their spawning habitat. Adequate spawning habitat should be presently or potentially available. Anadromous salmonid habitat requirements for spawning include sufficient gravel of the right size, suitable water temperatures, flow conditions, and water quality.

Adequate rearing habitat for feeding and growth should be available to support the juveniles produced during the season (spring, summer, fall) that they occupy the habitat. For juveniles that have to overwinter in fresh water, adequate habitat for this purpose must be present. In streams having high juvenile production followed by a large downstream displacement in fall, the lack of sufficient overwinter rearing habitat in downstream areas would negate production increases in headwaters. Thus, an important consideration is a periodic evaluation of habitat suitability and sufficiency on a seasonal and basinwide scale.

4.2.2. A Suitable Stock Is Available for Supplementation

The biological requirements of the stock to be used for supplementation must be carefully matched to the proposed habitat such that survival, growth and reproduction are successful. Thus, it is important to obtain knowledge of the biology, life histories, habitat use, genetic lineages and genetic diversity of candidate stocks insofar as this knowledge is obtainable. Su[illegible]ientation can involve stocking of fish that [illegible]nded from the natural population being supplemented or can involve the use of fish that have varying degrees of genetic distance from the supplemented population. In many cases, action on the basis of the best available information will be necessary. To maximize the chances for success, the indigenous stock should serve as the broodstock in its own enhancement program. If this is not possible, a stock with the greatest likelihood of being closely related to the potential recipient stock, or fish from environments that closely resemble the proposed recipient site, should be evaluated for their potential effectiveness as alternative broodstocks.

Among important biological traits, spawning, incubation and emergence times (temperature-dependent) must be synchronized with favorable environmental conditions such as suitable flows, temperatures, and food availability. To ensure migration success, imprinting of juveniles, migration to the ocean, and subsequent homing as adults to their natal stream must occur (Hasler and Wisby, 1951; Jensen and Duncan, 1971; Madison et al., 1973; Scholz et al., 1975; Cooper et al., 1976; Cooper and Scholz, 1976; Nordeng, 1977; Cooper and Hirsch, 1982; Hasler and Scholz, 1983; Brannon et al., 1984; Slatick et al., 1988). Because adults do not feed during their reproductive migration, they must possess sufficient energy reserves and physical stamina to travel back to their natal stream. Thus, fish from a lower Columbia Basin watershed may successfully imprint and attempt to home to an upper basin watershed, but the migrant may not have the physical stamina and energy to complete its journey.

4.2.3. Appropriate Technology

For supplementation to be successful, the artificial propagation technology must be adequate to rear and release fish that are biologically, genetically and ecologically suited to their receiving environments. The technology must provide a survival advantage sufficient to bring the spawner-recruit relation of the combined natural and hatchery-reared segments of the fish population above the replacement level. A life cycle analysis of the components of fecundity and mortality of the fish population both with and without supplementation should be conducted to compare the results under given environmental and management conditions.

5. Approach to a Supplementation Program

5.1. Phased Implementation and Adaptive Management

Although the fishery agencies and Indian tribes of the Columbia River Basin consider supplementation to have potential as a tool for increasing natural fish production, there is not yet a detailed understanding of which techniques work best under which circumstances. These uncertainties will necessitate undertaking a program of phased, experimentally designed supplementation studies as part of ongoing implementation of the supplementation program. Supplementation should proceed cautiously so that productivity of supplemented stocks can be tested. Past achievements have left concerns about meeting productivity. Procedures and techniques identified in this chapter are intended to improve supplementation practices. These procedures apply the concept of adaptive management, which relies heavily upon monitoring and evaluation.

Representative pilot sites will be identified for initial supplementation by the process described above. As knowledge and confidence are gained and natural production is increased, supplementation technology will be improved and more sites will be phased in for supplementation.

Within a given project site, the level of supplementation will also be phased in, commensurate with the number of spawners available for broodstock. For example, for a site with an estimated capacity of 200,000 juveniles, the level of effort could be increased in quarters: Phase 1, 25% of target capacity; Phase 2, 50%; Phase 3, 75%; Phase 4, 100%. As experience is gained, succeeding phases will be adjusted or the entire project aborted as warranted.

5.2. Monitoring and Evaluation

Because supplementation technology is nascent and uncertainties exist about its effectiveness and safety, it is important to incorporate a monitoring and evaluation program to assess performance of each supplementation project. Knowledge and experience gained should be incorporated into the design and operation of future supplementation projects. Kapuscinski and Lannan (1986) describe a conceptual phenotypic model to ensure the long-term reproductive fitness of stocks. Essential elements of monitoring include escapement data by sex and age, estimates of survival at each life stage, and the ability to distinguish supplemented from natural spawners visually, or by some other rapid method that does not harm the animal.

Two levels of monitoring and evaluation are envisioned. The first level is to determine the degree of success of the supplementation project. The second level is to try to answer why the project was successful or not successful and provide ways to adjust the program and to apply the results to guide other proposed supplementation projects. The procedure for monitoring and evaluation should include the following elements.

1. Clearly define supplementation objectives.
2. Identify performance measure(s) for each supplementation objective.
3. Develop experimental and sampling design.
4. Collect and analyze data.
5. Interpret results.
6. Adjust or correct the parts of the supplementation plan that are ineffective or inefficient in meeting the objective(s). Alternatively, if objective(s) are unclear, too general, conflicting or too ambitious, modify them so that the existing plan can achieve them.
7. Review the adequacy of the monitoring and evaluation plan and modify accordingly.

6. Supplementation Technology

Previous sections presented a working definition of supplementation, discussed its potential role in a comprehensive effort to address the physical and biological constraints on natural fish production, and provided general guidelines of when supplementation is appropriate. The following sections discuss some key considerations and general guidelines to provide a logical starting point in crafting the specifics of how to conduct the supplementation program. Each of the following considerations needs to be evaluated and tailored to the specific supplementation program.

6.1. Level of Technology

Since supplementation in the Columbia River Basin will most likely involve some type of artificial propagation, one of the considerations is to determine an appropriate level of technology to a specific situation. Artificial propagation encompasses a wide range of technology, from small-scale facilities (such as streamside incubators) located at tributaries to large-scale, alized hatchery facilities. Thus, it may be us consider the availability, ecological a... ..onomic advantages and disadvantages of small-scale facilities and large-scale facilities.

6.1.1. Large-Scale Facility

A total of 85 hatcheries and satellite facilities in the Columbia River Basin rear an average of 7.7 million pounds of anadromous fish per year (Delarm and Smith, 1990). One approach is to consider whether some of these existing hatchery facilities, with some modifications, would be appropriate to use in a supplementation program since these facilities are already in place and operational.

In general, some key changes would have to be made for some of these facilities to be used in supplementation. It is envisioned that incubation and rearing will continue to be done in the central hatchery. However, if two or more stocks will be reared in the hatchery, provisions must be made to keep them separate. Moreover, to ensure genetic compatibility, hatchery broodstock should be collected from the natural population targeted for supplementation if possible. Thus, provisions must be made to collect adults at or near their home stream. Also, juvenile acclimation facilities should be considered for the purpose of allowing the fish to imprint and adjust gradually to the natural environment before their eventual release into their home stream. Care would be taken that the selection of rearing water not interfere with the ability of stocked fish to return home to the point where they were released.

An example that applies this approach is the East Bank central hatchery facility located near Rocky Reach Dam in the Columbia River (Rock Island Project Settlement Agreement). The central hatchery was designed with incubation and juvenile rearing facilities, but no facilities for adult collection and release of juvenile fish. Instead, satellite facilities located near the streams targeted for supplementation were designed for broodstock collection and juvenile acclimation and release.

The potential advantages of using the large-scale approach must be weighed against some potential disadvantages. Large-scale hatcheries literally put all one's eggs in one basket with all that is implied about risk taking (Larkin, 1981). Should there be a failure, human error or accident in the hatchery, large numbers of fish may be lost. The fish will not be reared in the same water into which they will be released except for the final period before release when acclimation ponds are used. Thus, imprinting may not be as complete and unequivocal. This approach may also entail more handling and transporting of adult fish from the supplemented streams to the hatchery and of juvenile fish from the hatchery to the supplemented streams. Thus, there is greater potential for stress, health impairment, fish mortality, and straying.

6.1.2. Small-Scale Facility

Another approach envisions the use of small-scale facilities that are located alongside the streams targeted for supplementation. The size of these facilities are relatively small (600 to 10,000 pounds of juveniles) and would depend on the capacity of the streams targeted for supplementation. Adult collection and juvenile release facilities would be located on site, thus eliminating or greatly reducing fish handling and transportation which may lead to stress, impaired health and mortality. This approach would include incubation and rearing facilities located on site and would use the stream water for its water supply. Because the fish would be reared using the same water where they would be released throughout their residence in the hatchery, acclimation facilities would not be necessary and imprinting of juveniles should be more compl d unequivocal. This, in turn, should improve coming back to the stream and reduce ...ng.

The use of small-scale facilities allows for considerable flexibility in managing many smaller units, so that when deemed appropriate, a project can be abandoned with limited potential ecological damage and loss in investment. Smaller releases of juveniles commensurate with the capacity of the stream should reduce potential effects from "ecological swamping." This approach is readily adaptable to individual drainages, enabling the conservation of gene pools. Because the fish would be reared in artificial conditions more similar to their natural environment, domestication selection should be reduced.

The disadvantages with the small-scale hatchery approach include potentially greater cost in constructing and operating many small facilities located in the tributary streams. Logistics for many scattered facilities may also prove difficult. Moreover, some of these potential sites may not be readily accessible (no roads).

Most of the sites in the Columbia River Basin containing large quantities of water required by large hatcheries (100,000 pounds of fish or more capacity) have already been developed (Senn et al., 1984). However, there are many potential sites still available for developing small-scale hatcheries to produce smaller quantities of fish.

An example of this approach is the streamside chinook salmon spawning and rearing facility of the U.S. Forest Service at Horse Linto Creek, a tributary to the Trinity River in northern California. The facility consists of an adult migrant trap, two hatch boxes, a filter system, two fiberglass raceways, and an earthen rearing pond. The adult migrant trap and the juvenile release facility are located on site and adjacent to the stream. This arrangement minimizes fish handling and transportation. Juvenile releases from the facility started with 5,000 fish in 1984 and have increased to 57,000 in 1989. Before the restoration project began, less than 10 spawning pairs were counted (1979-1981) in a 2.5 mile index. By 1988 and 1989, the number of spawning pairs counted had increased to 50 and 55, respectively. Forest Service biologists are confident that the project can rebuild the chinook population to the estimated stream capacity.

Another example is a Swedish program to preserve native runs of Atlantic salmon in tributaries to the Baltic Sea after they were blocked by dams (Behnke, 1986). Instead of constructing a few large centralized hatcheries, Sweden opted for constructing a smaller hatchery in each major river (17 in all). This approach was chosen to propagate the native runs of each river and to preserve the original genetic diversity. The smolt-to-adult survival rates have typically ranged from 10% to 20%.

6.2. Spawning Protocol

The goal is to conserve genetic resources and maintain the ability of the stock to survive and reproduce in the natural environment. Relevant broodstock management principles and spawning guidelines (Hershberger and Iwamoto, 1981; Kreuger et al., 1981; Kincaid, 1983; Seidel, 1983; Tave, 1986, Kapuscinski et al.,1992) should be carefully considered. Special considerations will be necessary to supplement remnant (endangered or threatened) wild stocks (Meffe, 1986; Kapuscinski and Phillip, 1988). The main points of these guidelines include:

1. Maintenance of a large effective breeding size (Ne) for each generation to minimize inbreeding and genetic drift. To protect against inbreeding depression, the following information is required: the level of inbreeding at which inbreeding depression occurs and the number of generations you wish to incorporate in a breeding program before inbreeding reaches the critical value. For example, an Ne of 250 would keep the level of inbreeding below 10% through 50 generations (Tave,

1986). T rd against genetic drift, the following inform is required: the value of the rare alleles (how rare an allele would you try to save), and the probability level of saving rare alleles through the course of a given number of generations. For example, an Ne of 424 would provide a 99% probability of saving a rare allele with a frequency of 0.01 through 50 generations.

2. Insurance that the broodstock selected is representative of the natural population targeted for supplementation. To achieve this objective, a large sample size should be selected at random from the entire spectrum of the fish population (over all age groups and sizes and over the entire spawning season).
3. Implementation of a "no selection" protocol (Tave, 1986). For example, fish with poor secondary sexual characteristics, slow growth, etc. will not be culled out. This is designed to conserve the gene pool and ensure survival and reproduction in the wild.
4. Use of equal numbers of males and females as much as possible or at least keep the sex ratio within the bounds 60:40 to 40:60. This is designed to maintain a high Ne.
5. Monitoring of the wild and hatchery-reared fish for genetic and phenotypic information.
6. Consideration of the ratio of wild/natural to hatchery spawners in the natural habitat that minimizes potential genetic risks to the wild/natural spawners.
7. Consideration of the proportion of wild/natural fish used as hatchery broodstock to maintain the genetic integrity of the wild/natural stock and minimize adaptation to the hatchery.

6.3. Rearing Protocol

The basic approach is to provide more natural rearing conditions to promote the success of the fish after release to the natural environment. The objective is to mimic important natural rearing conditions (such as temperature) as much as possible but while providing a more abundant food supply and eliminating predation. Thus, the use of rearing units (earthen ponds and raceways) that provide more natural rearing conditions should be considered.

Stocking densities should more closely mimic densities in the stream at full seeding. Crowding should be reduced to help prevent stress, disease outbreaks, and disruption of territorial and other behaviors that are adaptive in the natural environment. Should territorial behavior be disrupted, it may be possible to restore it by behavioral conditioning (NFA, 1989) of the fish for two to four weeks before release (Shustov et al., 1980).

Hatchery-reared fish can exhibit diminished behavior to avoid predation in the natural environment (Bams, 1967; Mead and Woodall, 1968) and consequently result in increased mortality (MacCrimmon, 1954; Piggins, 1959; Kanid'yev, 1966; Larsson, 1985). To improve the chances of escaping predators after the fish are released, the use of predator avoidance conditioning should be considered (Thompson, 1966; Kanayama, 1968; Olla and Davis, 1989).

6.4. Disease Prevention

Disease prevention must be emphasized. For many diseases, the causative agent is almost always present in the fish's environment. Despite the presence of the pathogen, as long as the environment is not stressful to the fish, disease outbreaks are unlikely (Wood, 1974; Meyer et al., 1983). Disease prevention is based on the proper understanding and management of the interactions between the pathogen, the host, and the environment (Sniezko, 1973,1974; Wedemeyer et al., 1977; Meyer et al., 1983; Rohovec, 1988,1990). Primary attention must be given to role of the environment in increasing the se resistance of the fish and decreasing the virulence of the pathogen (minimizing crowding, handling, and stress; providing proper nutrition and water quality; and providing proper hygiene and sanitation).

6.5. Release Strategy

6.5.1. Level of Seeding

Sufficient numbers of fish should be stocked and matched to the biological productivity of the habitat to ensure an adequate, but not excessive level of seeding with respect to carrying capacity of the suite of natural environments encountered by the fish. As the natural stock rebuilds to higher seeding levels, higher egg-to-smolt mortality is expected due to density dependence (Major and Mighell, 1969; Bjornn, 1978; Jonasson and Lindsay, 1983; Knox et al., 1984). However, the total number of smolts produced should increase at higher seeding levels up to the carrying capacity of the habitat.

6.5.2. Life Stage to Stock

There are at least two considerations that would affect the choice of life stage to outplant. First, we want to ensure that successful imprinting to the distinctive chemical cues in the habitat and subsequent homing occur. The existence of a "sensitive" period for olfactory imprinting (SPOI) in early ontogeny in Atlantic salmon has been demonstrated (Morin et al., 1989). In salmonid species that undergo smoltification (Hoar, 1988), the SPOI appears to correspond to the smoltification period (Cooper and Hirsch, 1982; Hasler and Scholz, 1983; Smith, 1985; Hara, 1986). The SPOI was evident between three to four weeks after the onset of smoltification (the total smoltification period was eight weeks) in Atlantic salmon (Morin et al., 1989). During SPOI, the fish's capacity to store information in memory is optimal, implying that some of this capacity may persist beyond the sensitive period.

Second, we want to increase the survival rates for the hatchery-reared fish (during the time period from the egg stage through the smolt stage) compared to the corresponding survival rates typical of these life stages in the natural environment.

Stocking adults or eggs should provide better imprinting to the stream compared to stocking fry and smolts. However, stocking adults or eggs would not provide a survival advantage. Most of the mortality in the time period from the egg stage through the smolt stage occurs soon after the fish emerge from the gravel. For example, fry-to-smolt survival rates are on the order of 20% for spring chinook and 1.5% to 3.8% for steelhead in Big Springs Creek, Idaho; 2.2% to 6.7% for steelhead in Snow Creek, Washington; 5.7% for coho in Speelyai Creek, Washington; and 7.7% for coho in White Salmon River, Washington (Smith et al., 1985). In comparison, egg-to-emergent fry survival rates using streamside incubators in Oregon were on the order of 73.5% to 88.5% for spring chinook, 79.3% to 89.4% for fall chinook, 85.6% to 93% for summer steelhead, about 89% for winter steelhead, and 78% to 83.1% for coho (Smith et al., 1985). Rearing the fish in the same water as the stream where they would be released (the small-scale approach) would allow the flexibility of releasing the fish at any life stage while providing for imprinting.

6.5.3. Size and Age of Fish at Release

It is recommended that fish be released at a size and age that is compatible with those of the natural f eing supplemented to minimize potential adv ecological interactions (such as pred between the hatchery fish and the natural , unequal competitive advantage) and alteration of the age composition of returning adults (increased jack returns with release of larger juveniles). To accomplish this objective, the two primary factors affecting growth (temperature, and ration levels) should reference natural rearing conditions. Since reduced rations or starvation have adverse consequences on an actively growing fish (Ivlev, 1961; Rondorf et al., 1985), primary attention should be directed at mimicking the natural water temperature in the stream.

6.5.4. Acclimation for Stress Reduction

Acclimation is a technique used to prepare fish for release in the natural habitat. It is used to provide the fish time to adjust gradually to the natural stream conditions and reduce transportation-induced stress. This is important when fish are not reared in the same kind of water in which they will be released. In contrast, acclimation would not be necessary when the small-scale approach is used because the fish would be reared in the same water as the receiving stream. Care must be exercised to minimize stress from physical handling, confinement of large numbers of fish in small containers, and sudden changes in water quality parameters (such as temperature) when the fish are transferred from one water to another. Such stress can lead to mortality and can also impair a fish's ability to learn for up to several weeks (Sandoval, 1979; Olla and Davis, 1989). This could block imprinting processes needed for subsequent adult homing.

6.5.5. Timing of Release

Timing of release of juveniles into the natural habitat from hatcheries is a major determinant of survival success. This timing involves the coincidence of various biologic factors (fish size, readiness of fish to migrate and adapt to ocean conditions, outmigration of other hatchery and natural stocks, and estuarine and marine conditions such as food availability, predator abundance, competition for food from other fish stocks) and physical factors (migration flows, operation of mainstem dams, mainstem and tributary water temperature patterns and estuarine and marine conditions such as temperature and upwelling). Volitional release (allowing the fish to exit the rearing facility when they want to) is favored over forced release. Releasing fish at the proper time of day can also reduce initial predation losses and facilitate the adaptation of the fish to a new environment.

6.5.6. Dispersal

Past supplementation programs commonly released the fish at a single location in the stream (Steward and Bjornn, 1990). This practice may lead to limited dispersal and poor utilization of the habitat. The relative effectiveness of scattered and point releases should be considered in a supplementation program.

7. Risk Analysis

This section will address only the potential risks of the kind of supplementation as proposed in this chapter, not any other kind of supplementation or hatchery program.

7.1. Risk ‍xtirpation or Reduction of Natural Stock

7.1.1. No Supplementation Action

The risk of contributing to the further decline of a fish population through the use of supplementation must be weighed against the risk of continued decline and eventual extirpation when no further action, of any kind, is taken to restore the population.

7.1.2. Partial or Total Failure in the Hatchery

Possible loss of a significant portion of the natural stock through partial or complete failure in the hatchery (loss of electric power, pump failure, loss of rearing water through leakage, human error and accidents) is a risk that must be minimized. Efforts to reduce this risk include building fail-safe features in critical hatchery components, reducing the proportion of natural fish that are brought into the hatchery, rearing the fish in two or more facilities to avoid the risk of failure at one facility, and the use of small-scale facilities.

7.1.3. Predation

Increased or decreased predation on wild fish may occur due to large point-source stocking of hatchery-reared fish in the stream (Steward and Bjornn, 1990). To minimize the impact of predators on young salmon, it would be necessary to understand which predators are present and their capability to consume salmon prey. Different predators respond differently to increased prey abundance. Birds have been shown to have a nonlinear and depensatory functional response (Mace, 1983), whereas predator fish can show a compensatory response at low prey densities, but depensatory at higher densities (Peterman, 1987). This risk can be minimized by avoiding large point-source releases. Instead, the stocked fish should be dispersed throughout the target stream area. In addition, because we are attempting to restore the natural population to historic levels, an increase in predation should be no more than what the population sustained when it was at abundant levels.

Another concern is potential predation between stocked fish and the supplemented natural fish. If there are significant size differences, predation between hatchery-reared fish and the supplemented fish cannot be ruled out. Thus, this risk can be avoided by stocking fish at a size consistent with that of the natural fish.

7.1.4. Competition

Competition for food and space between the natural fish being supplemented and the stocked fish is influenced by the capacity of available rearing habitat. There is a paucity of information on the potential competition between the supplemented salmon population and other fish populations inhabiting the target stream (Steward and Bjornn, 1990). Since the goal is to restore the natural population to historic levels commensurate with the carrying capacity of the habitat, the adverse effects of competition should be no more than those experienced by the population when it was at higher abundance levels. The supplementation strategies described in this chapter seek to minimize or eliminate any differences between the stocked fish and the wild fish so that they are a single population.

7.1.5. Disease

Not much is known about the role of disease in natural fish populations. There is little evidence that hatchery-reared fish cause widespread transmission of disease to natural fish (Steward and Bjornn, 1990). Fish can carry pathogens and not show any outward signs of the disease. As a consequence, subclinically infected fish are probably released into natural waters more often than is realized (Marnell, 1986). In any case, it is desirable to avoid introduction of pathogens and disease to the supplemented stock. This precaution includes introduction of exotic pathogens and also endemic ones that present a threat to the healthy naturally spawning population.

7.2. Loss of Genetic Variability between Populations

Hybridization between different populations typically increases gene diversity (heterozygosity) within the hybridizing populations at the expense of a loss of gene diversity between populations. The concern is that a variety of locally adapted populations will be replaced with a smaller number of relatively homogeneous populations (Allendorf and Leary, 1988). This consolidation will tend to limit the potential of the species to adapt to new environmental conditions and reduce its capacity to buffer total productivity of the resource against periodic or unpredictable changes (Riggs, 1990).

7.2.1. Outbreeding Depression

Outbreeding is the mating of unrelated or distantly related individuals. The potential for outbreeding depression, specifically when hatchery fish mate with wild fish, is a concern related to supplementation in the Columbia Basin. Depending on the specific mating and on the genetic distance between the hatchery and wild fish, the hybrids may display increased fitness (heterosis or hybrid vigor) or decreased fitness (outbreeding depression) (Waples, 1991). Heterosis is more likely when the hybridizing gene pools are inbred and not too different genetically (Waples, 1991). As genetic distance between the parental stocks increases, however, genetic incompatibilities become more likely and the fitness of the hybrids may decline (outbreeding depression). Current genetic theory on hybridization indicates that the potential effects of hybridization result from genetic variance due to the interactions among alleles (Tave, 1986). Because this form of genetic variance depends on interactions, it is disrupted during meiosis and cannot be transmitted from parent to offspring. This genetic variance is created anew and, in different combinations each generation, its effects are basically those based on chance.

A series of studies carried out during the last 30 years showed that crossbreeds between wild and domestic stocks are superior to domestic stocks and may eqaul or even surpass wild stocks in performance in the wild (Wohlfarth, 1991, this symposium). A few studies have indicated the potential for outbreeding depression when hatchery fish are mated with wild fish. Those studies did not look at outbreeding depression per se, but rather compared the performance of hatchery fish with wild fish in the natural environment. A study in the Deschutes River in Oregon compared the progeny from hatchery, wild, and hatchery-wild parents in the natural environment (Reisenbicher and McIntyre, 1977). The authors concluded that wild eggs survived better than hatchery-wild eggs and hatchery eggs. Juvenile fish differed in size among the treatments. Hybrid juveniles were larger than the non-hybrid juveniles. This suggests that there w fferences between the hatchery fish and th d stocks. This study may not support the conclusion that outbreeding depression occurs when wild and hatchery stocks are mated. It is unclear whether or not the hatchery stock originated from a stock different than that of the wild stock. If genetic lineages of the hatchery and wild stocks were different, the likelihood of outbreeding depression or heterosis would increase independently of potential hatchery effects on genetic makeup and performance (Kapuscinski and Miller, 1992). In a study in Washington, the reproductive success of a Skamania Hatchery steelhead stock was compared with the reproductive success of wild Kalama River steelhead stock in the natural environment of the Kalama River (Chilcote et al., 1986). The success of hatchery fish in producing smolt offspring was only 28% of that for wild fish. The failure of the hatchery fish to produce as many offspring as the wild fish can be attributed to the use of a hatchery stock that was genetically and ecologically poorly matched to the natural environment of the Kalama River. The Skamania Hatchery stock originated from wild stock indigenous to the Klickitat and Washougal rivers (a different drainage) and has been subjected to artificial selection for hatchery production traits for many years (Leider et al., 1990). The hatchery fish were subjected to more unfavorable flooding conditions in the Kalama River because they spawned earlier than the indigenous wild fish.

The effectiveness of using hatchery fish to rebuild wild populations was evaluated in 15 supplemented and 15 control streams in the Oregon coast (Nickelson et al., 1986; Solazzi et al., 1990). Although the summer density of hatchery and wild juveniles increased in the supplemented streams, the density of only the wild juveniles was reduced. Adult returns to the supplemented streams were not significantly different from returns to the control streams and the hatchery fish produced juveniles at a lower rate than wild fish. The failure of this program can be attributed to the use of a hatchery stock that was incompatible with the wild population and genetically and ecologically poorly matched to the natural environment. The hatchery fish were subjected to more unfavorable conditions because they spawned earlier than the wild fish. Also, the hatchery fish outcompeted the wild fish because they were released at a much larger size than the wild fish.

All these studies indicate the fundamental importance of selecting a stock that is compatible with the target stock and releasing fish at life stages and with biological features that are adaptive in the target stream environment. Since the level of outbreeding that causes outbreeding depression is not known, it is impossible to predict whether a particular hatchery and wild cross will result in outbreeding depression. In addition, the variable (hatchery fish) being tested is quite undefined and imprecise, which results in a variety of effects given the same variable. Hatchery fish are spawned, incubated, and reared in many different hatchery environments using many different hatchery practices. A comparison between hatchery fish and wild fish lumps too many complicating factors that cannot be separated from each other. Thus, it is not known exactly what is being tested.

There is no clear evidence that a well-managed supplementation program, as described here, would pose a serious genetic risk to the natural population through outbreeding depression. The supplementation program described here attempts to eliminate or minimize any serious divergence between the hatchery broodstock and the target stock by ensuring that the hatchery broodstock is representative of the natural stock and by minimizing divergent natural selection by minimizing important differences between the hatchery and wild environments.

7.3. Loss of Genetic Variability within Populations

7.3.1. Inbreeding Depression

Inbreeding is the mating of related individuals (Tave, 1986). Genetically, all inbreeding does is inc the homozygotes at the expense of the heter ›tes. Because almost every organism c...s deleterious recessive alleles that are hidden in the heterozygous state, increasing homozygosity increases the likelihood that deleterious recessive alleles will be paired and expressed. The pairing of detrimental recessive alleles produces a general trend toward lowered viability, survival, growth, egg production and increased abnormalities (Ryman and Stahl, 1980; Allendorf and Phelps, 1980; Gall, 1983; Allendorf and Ryman, 1987). This phenomenon is called inbreeding depression.

To protect against inbreeding depression, a basic approach is to maintain a large, effective population size (Ne). To calculate the Ne that is needed to prevent inbreeding from reaching levels that decrease productivity, two pieces of information are required: the critical level of inbreeding at which inbreeding depression occurs, and the number of generations to incorporate in a breeding program before inbreeding reaches the critical level (Tave, 1986). For example, an Ne of 250 fish would keep the level of inbreeding below 10% through 50 generations.

Thus, an integrated approach, to guard against both outbreeding and inbreeding depressions, must travel the middle road. If we move too far to one side (mating closely related individuals), we risk falling into the inbreeding depression ditch. If we move too far to the opposite side (mating distantly related individuals), we risk falling into the outbreeding depression ditch.

7.3.2. Genetic Drift

Genetic drift refers to random changes in gene frequency caused by sampling error between generations (Tave, 1986). The effect of genetic drift is the loss of some alleles and the fixation of others (inbreeding). Rare alleles are easily lost, but more common alleles can also be lost via genetic drift. The loss of alleles (reduction in genetic variability) will limit the potential of a population to adapt to changes in environmental conditions and compromise its ability to exploit new environments.

A narrow genetic variability in a fish population would not necessarily result in low productivity or fitness to a particular environment. It would depend on the degree of adaptation of the population to the given environment and the magnitude and rate of change in the environment. Introduced chinook, coho, and pink salmon in the Great Lakes are examples of fish populations that were initiated from very small founding populations. Despite this narrow genetic variability, these fish have been thriving well for the past 20 to 40 years (Tanner, 1988).

To guard against genetic drift, the basic approach is to maintain a large Ne. The Ne that is needed depends on the following pieces of information: how rare an allele you would try to save and the desired probability level of saving rare alleles through the course of a given number of generations. For example, an Ne of 424 fish would provide a 99% probability of saving a rare allele with a frequency of 0.01 through 50 generations.

7.3.3. Selection

Anadromous salmonids are reared in a hatchery environment for only a portion of their life cycle. For the majority of their life cycle, hatchery fish are exposed to the same natural environment and subjected to the same natural selection process as wild fish. However, this does not mean that the selection (artificial and natural) that may occur in the hatchery is not important as far as the abilily of the fish to survive and reproduce successfully in the natural environment.

Artificial selection in the hatchery might select for hatchery production traits that are not adaptive in the natural environment. For example, broodstock might be selected from only the early … f the run because the egg-take quota has bee… d or to produce fish that are larger at r… or can be released earlier. Only large spawners or spawners that are ripe when the hatchery manager wants to spawn fish might be spawned. Also, throughout the rearing period slow-growing fish may be culled out.

Moreover, the natural selection process that occurs in the hatchery is most likely different from that which occurs in the wild by virtue of the difference between the hatchery and wild environments. Egg-to-smolt survival rates are typically 5% to 15% in the natural environment while the corresponding rates under artificial propagation are about 60% to 80% (Howell et al., 1985). This difference represents a reduced intensity of selection than occurs in the wild (i.e., most of the fish that would have died in the wild survive in the hatchery). Conversely, a higher percentage of wild smolts may typically survive to return as adults than will hatchery smolts. The high post-release mortality for hatchery fish allows ample opportunity for selection against traits that are adaptive for hatchery conditions, but not for the wild, thus counteracting, to some extent, adaptation to the hatchery environment. Thus, the degree to which the hatchery fish would diverge from the wild fish will depend on the degree to which the wild smolts are genetically representative of the hatchery smolts.

The supplementation scheme described in this chapter seeks to eliminate any divergence between the hatchery fish and the wild fish by using representative samples of the wild population as hatchery broodstock, by avoiding any artificial selection, and by minimizing the difference between the natural and the hatchery environments. Although one can hypothesize that exposure to the hatchery environment, for even a small portion of the fish's life cycle, allows some genetic divergence from the natural genome, the degree and consequences of the change remain unknown.

7.3.4. Hatchery versus Natural Environment

The kind of supplementation described in this chapter is based on the underlying principle that the fish population must be adapted to its environment to thrive. Since genetic fitness is partially a function of the environment, it is important to evaluate the hatchery environment vis-à-vis the natural environment with respect to those parameters that are related to performance and genetic fitness traits. A complicating factor that must be taken into account is that the natural environment and, to a lesser extent, the hatchery environment change daily, seasonally, and from year to year. In general, the quantity and diversity of salmonid habitats in the Columbia Basin have been greatly reduced (NPPC, 1986). For example, over one-third of the spawning and rearing habitat has been eliminated by impassable dams. Thus, any program of supplementation that emphasizes restoration of natural stocks and maintenance of their genetic diversity must be accompanied by an equal emphasis on restoration of habitat quality and quantity to which these stocks have adapted.

7.4. Genetic Risk of Other Activities

The genetic concern associated with supplementation must not preclude needed attention on other equally important genetic risks associated with habitat loss and degradation, alteration of the migrational environment, and harvest. Habitat loss and degradation can affect the genetics of wild populations by depressing the Ne of the population and by natural selection for increased fitness in the new environment, which may decrease the value of the resource (Kapuscinski and Jacobson, 1987). Harvest management can affect the genetics of wild fish in at least two ways (Kapuscinski and Jacobson, 1987). First, high exploitation rates can reduce the Ne of a stock so that rates of genetic drift and inbreeding are increased. Second, fishing methods and re ions can act as artificial selection programs tl n cause genetic change in the stock ove e (Handford et al., 1977; Favro et al., 1979; Ricker, 1981). The migrational environment of Columbia Basin anadromous salmonids has been drastically transformed from fast flowing streams to slow-moving reservoirs. Flow allocations and spill at dams favor juvenile fish whose outmigration timing coincides with the flow.

8. Research Needs

1. How different is a hatchery-reared fish population from its wild counterparts in terms of important performance traits such as survival, growth, reproduction, migration? How are these traits affected by the hatchery environment and by the natural environment?
2. In a natural fish population, which genotypes and gene frequencies comprise the typical 5% to 15% of the fish eggs that survive to smolt stage in the natural environment? Do the survivors represent a random sample of the total eggs deposited or are they a result of natural selection in the wild?
3. In a hatchery-reared fish population, which genotypes and gene frequencies comprise the typical 60% to 80% of the fish eggs that survive to smolt stage in the hatchery environment? Do the survivors represent a random sample of the total eggs spawned or are they a result of natural selection in the hatchery?
4. Assuming that the fish spawned in a hatchery were derived from and are genetically representative of a given wild fish population, are the hatchery smolts that survive in the hatchery environment genetically similar to the wild smolts from the same wild fish population that survive in the natural environment?
5. What is the level of inbreeding that causes inbreeding depression? How do we measure inbreeding? How do we measure inbreeding depression? Is there a qualitative aspect to inbreeding (i.e., one population with the same level of inbreeding as another population exhibits inbreeding depression where the other will not)?
6. What is the level of outbreeding that causes outbreeding depression? How do we measure outbreeding? How do we measure outbreeding depression? Is there a qualitative aspect to level of outbreeding (i.e., will one population with the same level of outbreeding as another population exhibit outbreeding depression where the other will not)?
7. Does natural selection reduce genetic variability within a population; between populations?
8. What are the most effective means of ensuring no artificial selection in hatcheries?
9. What are we doing in the hatchery that renders fish less fit when released into the natural environment? Does the hatchery environment influence the expression of traits or behaviors that are not adaptive in the wild environment? For example, hatchery reared fish are not exposed to predators nor provided natural food. Hence, many fish that would have died in the wild due to predation or starvation survive in the hatchery. In the wild, the juveniles learn to avoid predators and learn to capture prey, but in the process incur mortalities through predation and starvation.
10. Evaluate food availability during different life stages in terms of survival, growth, and reproduction.
11. Compare levels and variability in important parameters (such as temperature) in natural stream environments with those in hatchery environments. Look at temporal variability (diel, seasonal, interannual) and spatial variability (location of

hat(; or stream, locations within hatchery or strea( )ols, riffles, different reac...). Is there more seasonal variability in a given location than between locations (streams) for a given season?

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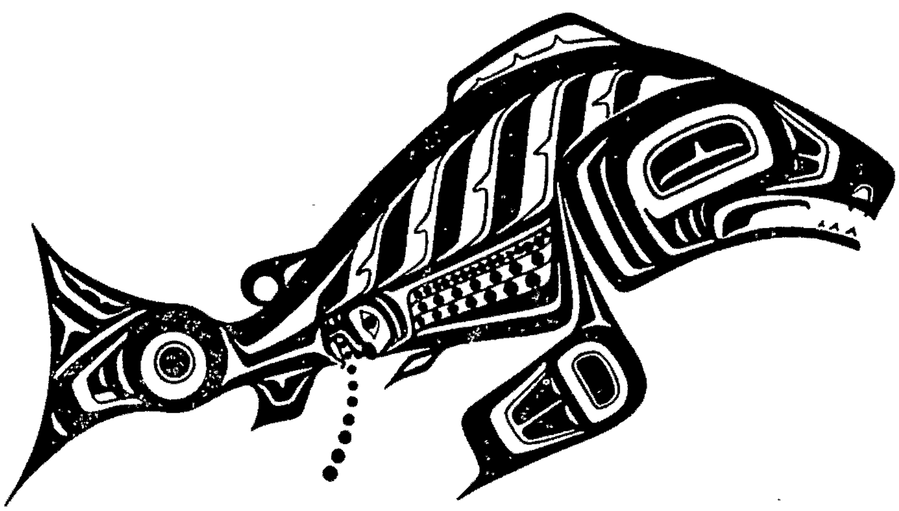
(REFERENCE COPY)

International Symposium on Biological Interactions of Enhanced and Wild Salmonids

Hosted by the Department of Fisheries and Oceans, Biological Sciences Branch/ Salmonid Enhancement Program, Pacific Region

June 17 - 20, 1991
Coast Bastion Inn
Nanaimo, British Columbia
Canada



Fisheries and Oceans Pêches et Océans

Canada

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International Symposium on Biological Interactions of Enhanced and Wild Salmonids

P R O G R A M

June 16	Arrival in Nanaimo
1700-2100	Registration Coast Bastion Inn - Foyer
1900-2100	Welcoming Reception (Ballroom) - hosted by the Biological Sciences Branch (B.S.B.), and the Salmonid Enhancement Program (S.E.P.)
June 17	
0900-0930	Introductions and Opening Remarks, Dr. John C. Davis, Regional Director, Science, Institute of Ocean Sciences, Sidney, B.C., Canada, and Mr. David Griggs, Director, Salmonid Enhancement Program, Vancouver, B.C., Canada

SESSION ONE - PRODUCTION TRENDS

Chairman - Dr. F. Keith Sandercock, Salmonid Enhancement Program, Vancouver, B.C., Canada

0930-1015	Khorevin, L.D., F.N. Rukhlov, and A.P. Shershnev. TINRO Sakhalin Region, USSR. Abundance dynamics of mixed (natural and enhanced) origin salmon of Sakhalin-Kurile area.
1015-1100	Kaeriyama, M. Hokkaido Salmon Hatchery, Fisheries Agency of Japan, Sapporo, Japan. Production trends of salmon enhancement in Japan.
1100-1130	Break

1130-1215	Peltz, L., et al. Alaska Department of Fish and Game, Cordova, Alaska, U.S.A. [Presented by D.M. Eggers]. Trends in abundance of hatchery and wild stocks of pink salmon (Oncorhynchus gorbuscha) in Kodiak Island, lower Cook Inlet, and Prince William Sound, Alaska.
1215-1330	Lunch
1330-1415	Steer, G., et al. Department of Fisheries and Oceans, Vancouver, B.C., Canada. Trends in biological characteristics and survival rates of wild and enhanced salmonids in British Columbia.
1415-1500	Hilborn, R., R. Francis, and S. Hare. Fisheries Research Institute, University of Washington, Seattle, Washington, U.S.A. Hatchery and wild fish production on the Columbia River.
1500-1530	Break
1530-1615	Whelan, K.F., and P. M^cGinnity. The Salmon Research Agency of Ireland Incorporated, County Mayo, Ireland. A comparative biological and genetic profile of wild and ranched Atlantic salmon (Salmo salar L.) stocks from the Burrishoole system, Co. Mayo, Western Ireland.
1615-1700	Karlsson, L., T. Eriksson, and C. Eriksson. Swedish Salmon Research Institute, Älvkarleby, Sweden. Production trends in reared Swedish stocks of Baltic salmon.
1845-2100	**POSTER SESSION RECEPTION** (Ballroom) - hosted by the Oak Bay Marine Group, April Point Lodge, Province of British Columbia, Rhys Davis Ltd., B.C. Packers Ltd., and Canadian Fishing Company.

June 18

SESSION TWO - GENETIC CONCERNS

Pop. geneticist

Chairman - Ms. Ruth Withler, Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada

0830-0915	Allendorf, F.W. University of Montana, Missoula, Montana, U.S.A. Effects of genetic changes in enhanced stocks on productivity of wild and enhanced salmonid populations.
0915-0945	Crandell, P.A. University Alaska Fairbanks, Juneau, Alaska, U.S.A. Genetics of domestic California rainbow trout (*Oncorhynchus mykiss*): implications for wild stocks.
0945-1015	Chebanov, N.A. TINRO, Kamchatka Region, USSR. Experimental assessment of genetic aberrations in hatchery salmon and the possibilities of their reduction.
1015-1045	Break
1045-1115	Gharrett, A.J., et al. University of Alaska Fairbanks, Juneau, Alaska, U.S.A. Use of a genetic marker to examine genetic interaction among subpopulations of pink salmon (*Oncorhynchus gorbuscha*).
1115-1145	Zhivotovsky, L.A. National Academy of Sciences, Moscow, USSR. Population dynamics of pink salmon.
1145-1330	Lunch

Chairman - Dr. A. J. (Tony) Gharrett, University of Alaska Fairbanks, Juneau, Alaska, U.S.A.

1330-1400	Skaala, Ø., K.E. Jørstad, and R. Borgstrøm. Institute of Marine Research, Bergen, Norway. Genetic impact on wild populations from fish farming: experiments with genetically tagged brown trout (*Salmo trutta* L.).

1400-1430	Smoker, W.W., A.J. Gharrett, and M.S. Stekoll. University of Alaska Fairbanks, Juneau, Alaska, U.S.A. Genetic variation in seasonal timing of anadromous migration in a population of pink salmon.
1430-1500	Kawamura, H. Makkari Branch of Hokkaido Fish Hatchery, Hokkaido, Japan. Stock enhancement of masu salmon (Oncorhynchus masou) with hatchery-reared fish and difference in timing of smolting between hatchery and wild populations in Hokkaido, Japan.
1500-1530	Break
1530-1600	Leary, R.F., and F.W. Allendorf. University of Montana, Missoula, Montana, U.S.A. Use of meristic variation to monitor the health of salmonid fish populations.
1600-1630	Gritsenko, O.F., and A.A. Kovtun. VNIRO, Moscow, USSR. Interaction between wild and reared parts of chum salmon populations from the Tym' River.
1830-2200	**BANQUET** (Ballroom) - Invited speaker: Mr. Ike Baart, Vice-President, Export Sales, British Columbia Packers Ltd., Vancouver, B.C., Canada. Marketing aspects of salmon production.

June 19

SESSION THREE - FACTORS AFFECTING FRESHWATER AND MARINE PRODUCTION

Chairman - Dr. Doug M. Eggers, Director of Research, Commercial Fisheries Division, Alaska Department of Fish and Game, Juneau, Alaska, U.S.A.

0900-0945	Kitchell, J.F. Center for Limnology, University of Wisconsin, Madison, Wisconsin, U.S.A. Salmon in the Great Lakes: a compromised miracle.
0945-1015	Karpenko, V.I. TINRO, Kamchatka Region, Petropavlovsk, Kamchatka, USSR. The role of early marine life in forming Pacific salmon production.

1015-1045	Beamish, R.J., and B.L. Thomson. Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada. Survival of hatchery-reared salmon in the Strait of Georgia.
1045-1115	Break
1115-1145	Wood, C., et al. Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada. Testing for ecological interactions between wild and hatchery-reared salmonids as an explanation for declining smolt-to-adult survival in sockeye salmon (Oncorhynchus nerka) populations of Barkley Sound, Vancouver Island.
1145-1215	McAllister, C.D., and C.D. Levings. Biological Sciences Branch, Department of Fisheries and Oceans, Pacific Biological Station, Nanaimo, B.C., Canada. Evidence of habitat limitations for hatchery and wild chinook salmon (Oncorhynchus tschawytscha) in two British Columbia estuaries.
1215-1330	Lunch
	Chairman - Dr. Blair Holtby, Department of Fisheries and Oceans, Biological Sciences Branch, Pacific Biological Station, Nanaimo, B.C., Canada
1330-1400	Beall, E., and M. Héland. INRA, Unite Ecologie des Poissons, Station d'Hydobiologie, Saint-Pee-sur-Nivelle, France. The influence of introduced coho salmon (Oncorhynchus kisutch) juveniles on the survival, growth, distribution, and production of Atlantic salmon (Salmo salar) fry and parr.
1400-1430	Seiler, D., et al. Washington Department of Fisheries, Olympia, Washington, U.S.A. Supplementation of wild coho salmon (Oncorhynchus kisutch) with hatchery-produced fry in Washington coastal streams.

1430-1500	Cramer, S.P. S. P. Cramer & Associates, Fisheries Consultants, Corvallis, Oregon, U.S.A. Dynamics of the decline in wild coho (*Oncorhynchus kisutch*) populations in the lower Columbia River.
1500-1530	Break
1530-1600	Labelle, M., C.J. Walters, and B.E. Riddell. University of British Columbia, Vancouver, B.C., Canada. [Presented by C. Walters]. Ocean survival and exploitation patterns of hatchery and wild stocks of coho salmon (*Oncorhynchus kisutch*) from southeast Vancouver Island, British Columbia.
1600-1630	Francis, R.C., and R.D. Brodeur. Fisheries Research Institute, University of Washington, Seattle, Washington, U.S.A. Production and management of coho salmon (*Oncorhynchus kisutch*): a simulation model incorporating environmental variability.
1700-2200	**TOUR** - Choice of tour to Big Qualicum River Project or Robertson Creek Hatchery/Somass River. (Dinner not included in registration.)

June 20

SESSION THREE - (continued)
FACTORS AFFECTING FRESHWATER AND MARINE PRODUCTION

Chairman - Dr. Robert C. Francis, Fisheries Research Institute, University of Washington, Seattle, Washington, U.S.A.

0900-0930	Ward, B.R., F.A. Slaney, and A.F. Tautz. Ministry of Fisheries, Province of British Columbia, University of B.C., Vancouver, B.C., Canada. Differential survival and synchronous return from the sea in Keogh River wild and hatchery steelhead (*Oncorhynchus mykiss*).
0930-1000	Leskelä, A., et al. Merenkurkku Fisheries Research Station, Vaada, Finland. Variations in the relative year-class strength and growth of anadromous whitefish (*Coregonus lavaretus s. str.* L.) in the rivers flowing into the Gulf of Bothnia.

1000-1030	Evans, D.O. Ontario Ministry of Natural Resources, Fisheries Branch, Maple, Ontario, Canada. Factors affecting angling yields of wild, self-sustaining, and hatchery-supplemented stocks of lake trout, Salvelinus namaycush, in eastern Canada.
1030-1100	Break
1100-1130	Hayashizaki, K., and I. Hitoshi. School of Fisheries Science, Kitasako University, Japan. Size decrease of chum salmon, Oncorhynchus keta, in Tohoku districts, Japan.
1130-1200	Koenings, J.P., et al. Alaska Department of Fish and Game, Soldotna, Alaska, U.S.A. [Presented by G. Kyle]. Collapsed populations and delayed recovery of zooplankton in response to intense juvenile sockeye salmon (Oncorhynchus nerka) foraging.
1200-1330	Lunch

June 20

SESSION FOUR - FISHERIES MANAGEMENT

Chairman - Mr. Paul E. Sprout, Division Manager, South Coast Division, Fisheries Branch, Department of Fisheries and Oceans, Nanaimo, B.C., Canada.

1330-1415	Geiger, H.J., et al. Department of Fish and Game, Division of Commercial Fisheries, Juneau, Alaska, U.S.A. The management of the Alaskan salmon hatchery commercial harvest.
1415-1500	Riddell, B.E., P.E. Sprout, and A. Cass. Department of Fisheries and Oceans, Nanaimo, B.C., Canada. Managing wild and enhanced salmonids: a review of three British Columbia fisheries.
1500-1530	Coffee

1530-1615	Lichatowich, J.A., and J.W. Nicholas. Jamestown Klallam Tribe, Sequim, Washington, U.S.A. The use of hatcheries in the management of Oregon's chinook (Oncorhychus tschawytscha) and coho (O. kisutch) salmon stocks: case histories and general observations.
1615	Chairmen's Concluding Comments
	Concluding Remarks - B. E. Riddell, Organizing Committee Chairman

ABSTRACTS

INVITED AND CONTRIBUTED PAPERS

(Abstracts listed in order according to program sequence;

A comparative biological and genetic profile of wild and ranched Atlantic salmon (*Salmo salar* L.) stocks from the Burrishoole system, Co. Mayo, Western Ireland

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The Salmon Research Agency of Ireland Inc.
Farran Laboratory
Newport, County Mayo
Ireland

Comparative data are available from returns of over 10,000 reared and 20,000 wild grilse and salmon, since 1966. Wild smolt survival has been greater by a factor of 3.7. Survival from egg to smolt has averaged 0.5% in the wild population, while survival in the reared population has been 80 times better to the S1 smolt stage. Since 1975 the average weight of wild grilse has dropped from 2.39 kg to 1.90 kg; the mean size of reared grilse has remained stable at 2.60 kg. Fecundity is similar, in terms of egg size and number. The number of wild grilse returning to the fishery has declined steadily, from an average of 924 during the 1970's to 470 during the past decade. Survival to the coast averaged 13% (range 3-33%) for reared grilse during the period 1980 to 1990. Survival to the traps averaged 2.4% (range 0.4-4.9%) for reared and 8% (range 4.0-12.0%) for wild grilse. Exploitation by the offshore driftnet fishery on reared grilse has averaged 78% (range 52-90%) during the same period. The Burrishoole reared stock has also become genetically distinct from the indigenous wild source population. A comparison of allelic frequencies between Burrishoole wild and hatchery populations has revealed significant overall differentiation (chi square = 22.329, $df=_5$, P<0.001). This was particularly evident at the Idh-3 locus (chi square = 11.281, $df=_1$, P<0.001) and to a lesser extent at the Me-2 (chi square = 5,433, $df=_1$, P<0.05) and the Sdh-1 (chi square = 4.421, $df=_1$, P<0.05) loci. Examination of allelic heterogeneity among three year classes of wild Burrishoole salmon has confirmed a remarkable degree of temporal genetic stability. In contrast, an assessment of allele frequency stability among four separate year classes of reared stock revealed highly significant variation (chi square = 102.857, $df=_{12}$, P<0.01). Allelic variation was observed at all diagnostic loci in the wild population. However, in the hatchery-reared population no allelic segregation was observed at the Mdh-3 locus and at the Aat-2 locus; it would appear that the rare (Z5) allele has been lost.

Experimental assessment of genetic aberrations in hatchery salmon and recommended procedures for reducing their occurrence

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USSR

Genetic processes in hatchery salmon populations are poorly understood, particularly those resulting in genetic aberrations. Knowledge of those processes may improve procedures for salmon culturing. One approach to this problem is to compare the mating strategies characteristic of spawners in wild versus hatchery populations. The fact that pink salmon mate assortatively according to body size was discovered relatively recently. This means that in the wild, mating tends to occur between fish of similar sizes (Chebanov 1984). At present, hatchery salmon spawners are not sorted by size before artificial fertilization. The viability of progeny from experimental crosses has been found to be related to the size of the parents both in pink salmon and in other species (Chebanov 1984a); on average, viability was higher for progeny of matings between fish of similar sizes than between fish of very different sizes. This relationship indicates the adaptive significance of positive assortative mating in pink salmon populations. These results are strongly consistent with those from cytokaryological analysis of pink salmon embryos from experimental matings. The frequency of chromosome aberrations was closely correlated with the mortality rate of embryos during incubation. Differences in the viability of broods from different-sized spawners resulted from genetic features. Such differences in viability probably become even more significant after the embryonal stages, for example, during the marine period of life. These findings also suggest that the survival of hatchery populations could be increased by 6.6-9.4% by ensuring that crosses are made between fish of similar size.

The role of early marine life in the production of Pacific salmon

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Naberezhnaya str. 18 683602
USSR

The early marine life of pink, chum, sockeye, coho and chinook salmon has been studied rather thoroughly. Juvenile salmon from different populations inhabit coastal waters for different lengths of time: those from east and west Kamchatka spend about 3 months whereas those from southwestern Sakhalin and British Columbia spend up to 5-6 months in coastal waters. Downstream migration of salmon fry occurs from March-April through July-August and offshore migration is observed from the end of July to October. Older juveniles that have spent a year or more in fresh water migrate offshore more quickly than juveniles migrating at age 0+. The prevalence of age 0+ migrants is fairly high among all the Pacific salmon species, and in eastern Kamchatka can be as high as 60% for sockeye, 15% for chinook, and 10% for coho salmon. However, few of these survive to reach maturity.

The main factors limiting the survival of juveniles are the availability of food (determined in part by the overall abundance of juveniles), predation pressure, and the occurrence of abnormal hydrological conditions. It is extremely difficult to examine the effect of each of these factors separately because the influence is interrelated. The availability of food for age 0+ juveniles depends primarily on whether the time of outmigration coincides with the development of planktonic crustaceans. The availability of food for older juveniles depends on the abundance of larvae and fry of sand lance, smelt, capelin, and other fishes in the plankton. Food availability determines the rate of growth of juveniles which tends to be highest in the coastal waters of the Okhotsk and Bering seas, slightly lower off northern Sakhalin, close to average in the Strait of Georgia (Canada) and off southwestern Sakhalin, and lowest off Iturup. Juvenile salmon grow most quickly in coastal waters.

Mortality due to predation varies from 1.5 to 52% in the coastal waters of the different regions. At least 10 species of fish, birds, and marine mammals feed on juvenile salmon, but smelt, Arctic char, Siberian char, navaga and bullheads are the most significant predators. Predation pressure on salmon is highest during downstream migration during the peak period of outmigration for pink and chum salmon. To ensure efficient management, salmon stock assessments should take into account regional differences in environmental conditions experienced by juvenile salmon in their early marine life.

Survival of hatchery-reared salmon in the Strait of Georgia

R.J. Beamish and B.L. Thomson

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The average survival of coho (Oncorhynchus kisutch) and chinook salmon (O. tschawytscha) released from the Big Qualicum hatchery increased relative to historic wild salmon survival during the first 5 to 6 years of hatchery operation. Since the late 1970's, survival of hatchery-released coho and chinook salmon has declined to levels below the historic wild survival rates. The pattern of declining survival is common among hatcheries located in the Strait of Georgia. Predation may be the ultimate cause of mortality. Cyclic decreases in productivity may contribute to decreased abundance of alternate food sources for predators which results in increased predation mortality of hatchery salmon.

The influence of introduced coho salmon (*Oncorhynchus kisutch*) juveniles on the survival, growth, distribution, and production of Atlantic salmon (*Salmo salar*) fry and parr

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Development of coho salmon aquaculture in Europe has increased probabilities of accidental introduction of this species into natural stream systems, with the potential risk of an unfavourable influence upon indigenous anadromous species of the same family, particularly Atlantic salmon. We studied competition mechanisms between fry and parr of the two species in a large semi-natural stream channel and in laboratory artificial channels or aquaria.

Among Atlantic and coho salmon fry at emergence, survival, downstream movement pattern and residency are nearly identical in allopatric or sympatric situations. At this stage, micro-distribution is different, with Atlantic salmon found essentially in riffles and coho in pools. The superior size of coho associated with their pelagic and gregarious behaviour lead them to occupy and exploit the environment at the expense of the more substrate-bound Atlantic salmon. Feeding behaviours are different. Atlantic salmon fry assume subordinate behaviour to coho. If prey density is low, growth rate of Atlantic salmon fry is affected by competition. Because coho emerge sooner, Atlantic salmon emergence is delayed by coho presence. In the presence of coho, the density and biomass of Atlantic salmon fry is significantly lower in all microhabitats.

Direct aggressive interactions between the two species are seldom observed. However, Atlantic salmon parr exert a fairly heavy predation pressure on coho fry from emergence until a size of about 45 mm. Such predation is encouraged by the pelagic behaviour of coho fry.

Differential survival and synchronous return from the sea in Keogh River wild and hatchery steelhead (*Oncorhynchus mykiss*)

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Hatchery (pen-reared) steelhead smolts, originating from wild parents, were released into the lower Keogh River in coastal British Columbia, from 1979 to 1984, and their survival rate in the ocean and age-at-return were compared to wild smolts enumerated at a counting fence. The survival rate of wild fish (mean 16%) was 1.9 to 3.4-fold (mean 2.8) higher than hatchery fish (mean 6.6%) when adjusted for size differences and size-biased survival. However, survival trends were similar; high survival of wild fish corresponded with high survival of experimental releases of hatchery fish. The age composition of hatchery fish, based solely on years in the ocean, was more variable than in wild fish. Fifty-three percent (9.4 to 74.4%) of the hatchery returns were, on average, comprised of fish that spent 3 years at sea, whereas approximately 46% (19.5 to 67%) of the wild stock returns had scale patterns indicating 3 years were spent at sea. Shifts in return age were synchronous; when wild smolts returned predominantly after 3 versus 2 years at sea, hatchery fish displayed the same pattern, with one exception (1981 smolts). Differences observed between wild and hatchery returns and variation between years were associated with ongoing release experiments and possible broodstock selection. It is concluded that hatchery steelhead from native brood stock survive at much lower rates compared to their wild cohorts, yet both were affected similarly by factors which influence return time.

Variations in the relative year-class strength and growth of anadromous whitefish (*Coregonus lavaretus s. str.* L.) in the rivers flowing into the Gulf of Bothnia

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Relative year-class strength and growth of whitefish was studied in anadromous populations of nine rivers around the Gulf of Bothnia. Two of the studied rivers depend totally on the natural reproduction of whitefish. In others there are stocking programs with one-summer fingerlings and variable amounts of natural reproduction. By means of stocking, it is possible to maintain a spawning population of moderate size in rivers where natural spawning places have been almost totally lost. However, large stocking does not automatically result in a strong year-class in the spawning population, even if it is made in a river with low natural reproduction. Age-structure of the spawning population varies in all rivers, but is most stable in rivers with good natural reproduction supported with stocking. Growth of anadromous whitefish is faster in populations of the southern rivers than in the northern ones. Within geographic regions, growth is similar in naturally reproducing populations and populations based mainly on stocking.

Factors affecting angling yields of wild, self-sustaining, and hatchery-supplemented stocks of lake trout, *Salvelinus namaycush*, in eastern Canada

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Angling yields of lake trout were estimated from creel survey data for more than one hundred Ontario lakes. Fishing effort explained >50% of the variation in annual yield (kg ha^{-1}) among lakes. Total dissolved solids (TDS) and the lake volume at depths >30m together accounted for an additional 9.9 and 10.1% of the total variation, respectively, the former being negatively correlated and the latter positively correlated with yield. The lake volume >30m is a measure of the amount of summer nursery habitat for juvenile lake trout in thermally stratified lakes, while TDS is an index of lake productivity. Water quality of the deep nursery habitat is negatively correlated with lake productivity, which appears to explain the negative correlation between TDS and yield. Yields of self-sustaining, wild populations were as high or higher than hatchery supplemented populations, except for winter fisheries. Mean fishing intensities (hr ha^{-1}) were 4.6- and 3.1- times higher for supplemented than for wild populations during winter and open water seasons, respectively, but harvest per unit fishing effort (HUE) for the stocked populations was only about 50% of HUE for the wild populations. Several case histories revealed that in some lakes stocking enhanced production, especially in the presence of weakly recruiting wild stocks. The latter stocks, however, are the most vulnerable to replacement by hatchery stocks as exploitation intensifies. The potential of supplemental stocking to cause the loss of wild stocks, and the marginal benefits of stocking, in other cases, warrants more critical evaluation of lake trout enhancement programs.

Collapsed populations and delayed recovery of zooplankton in response to intense juvenile sockeye salmon (Oncorhynchus nerka) foraging

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Experimental manipulation of whole-lake ecosystems was used to establish knowledge about limnetic food-chain responses to variable grazing pressure by juvenile sockeye salmon. Before-and-after studies, with temporal controls, involved manipulating rearing sockeye densities and the nutrient levels of "barriered" lakes. Stocking numbers of juveniles at the upper end of fry recruitment expected from natural-stock escapement goals results in a 90% reduction in zooplankton biomass. Vulnerable zooplankters (larger cladocerans and herbviorous copepods) were eliminated, and the community changed to smaller (e.g. Bosmina) and more agile (e.g. Cyclops) forms. Following cessation of fry stocking, zooplankton populations remained severely depressed. Empirical and experimental results show that in rearing-limited lakes, smolt biomass is dependent on zooplankton biomass. Juvenile sockeye, foraging on a standing crop of zooplankton severely depressed by heavy juvenile grazing the previous season, had >3-fold lower fry-to-smolt survival and smolt biomass. Delayed recovery of zooplankton populations following over grazing may initiate a pattern of cyclic adult abundance as exemplified at both Frazer and Coghill lakes, which received successive escapements 2- to 3-fold their existing goals.

The management of the Alaskan salmon hatchery commercial harvest

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Since 1971, the State of Alaska has allowed the production of Pacific salmon by ocean ranching. Fish are released as juveniles, rear at sea, and are harvested in common property fisheries during ocean migrations. Commercial subsistence and sport fishermen capture the returning fish in a number of very different fisheries. Additionally, some hatcheries are allowed a special harvest of returning hatchery fish to fund their operations. Fishery managers are asked to maintain the biological health of the wild stocks and the economic health of the hatchery system, and are charged with conducting orderly fisheries, all while meeting allocation guidelines established by a separate body, the Alaska Board of Fisheries. The addition of hatchery stocks to the existing fisheries has made the job of fisheries managers more difficult. Hatchery operators have generally been successful at producing salmon. However, for a variety of reasons the management apparatus has not always matched these successes. We discuss Alaskan salmon management in an era of increased hatchery production. The Alaskan experience is illustrated with examples from the large-scale hatchery experience in Prince William Sound and the mixed-stock chinook troll fishery in Southeast Alaska. We conclude that large-scale, pioneering, hatchery programs have not resulted in policies or guiding principles that hatchery operators and fishery managers can use to direct and manage the future development of hatcheries in Alaska.

The use of hatcheries in the management of Oregon's chinook (*Oncorhynchus tschawytscha*) and coho (*O. kisutch*) salmon stocks: case histories and general observations

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Artificial propagation has been a major tool in the management of Oregon's chinook and coho salmon stocks for over 100 years. However, the role of hatcheries in the management of coastal stocks of the two species has differed. Coastal stocks of chinook salmon have been managed primarily for natural production whereas coastal stocks of coho salmon have been managed primarily for hatchery production. An overview and comparison of the two programs is presented. Specific case histories that provide greater understanding of the use of artificial propagation in fisheries management are discussed. The lessons obtained from Oregon's use of artificial propagation over the past century are summarized.

ABSTRACTS

POSTERS

(Abstracts listed alphabetically)

Are feral Atlantic salmon likely to have a quantitative genetic impact on wild populations?

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Allelic variation between isolated salmonid populations is often accepted as conclusive evidence that such populations are locally adapted and that the extant gene pools represent the "best" set of genotypic combinations for prevailing environmental conditions. Feral escapees from aquaculture are therefore implicated as a potential threat to the genetic integrity of wild populations. In other species, where interactions between feral and wild animals can occur, evidence of deleterious genetic impacts prove difficult to document. Management strategies to preserve the genetic resources of natural salmon populations are strongly influenced by studies which measure allelic variation. The evidence presented in this paper supports the contention that strategies based on such a theoretical basis are insufficient for effective management. Such an approach overlooks quantitative genetic theory which predicts that the genetic performance of an individual does not reflect a fixed, unique set of alleles but may occur as a result of a large number of different allele combinations.

Effects of environmental variation and hatchery release strategy on the population parameters of fall chinook salmon (*Oncorhynchus tschawytscha*) from the Sacramento River

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Age-specific straying, survival, harvest, and maturity rates of fall chinook released in the Sacramento River basin during 1973-1985 were estimated by cohort analysis of coded-wire tag (CWT) returns from 175 marked groups. Straying rates differed significantly ($P<0.05$) between broods and tended to increase as fish were released farther off station.

Survival rate to age 2 differed significantly ($P<0.05$) between groups released at different locations and between brood years. Survival rate of age 0+ smolts released in June from Feather River Hatchery was doubled by trucking fish 110 kilometres downstream for release and was doubled again by trucking them an additional 130 kilometres to the estuary. Survival of fish released in the estuary was positively correlated to fish weight, negatively to river temperature, and positively to ocean upwelling. For fish released above the estuary, survival was highly influenced by fish weight and river temperature, but not by ocean upwelling. Survival of fry released during winter was positively correlated to peak flow within 2 weeks after release.

Harvest and maturity rates at each age differed significantly ($P<0.05$) between broods, but generally not between hatcheries or release locations. The majority of fish were harvested or matured at age 3. The brood averages for harvest rate at age 3 varied from 0.414 in 1981 to 0.782 in 1977. The brood averages for maturity rate at age 3 varied from 0.262 in 1982 to 0.927 in 1976. Both harvest and maturity rates were significantly lower ($P<0.05$) for age 0+ fish released in the fall than those released in the spring.

Variation in habitat use by the native salmonids and the rainbow trout (*Oncorhynchus mykiss*) that have escaped from a fish farm in Loch Awe, Scotland

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Seasonal variation in the abundance and habitat use by the native salmonids, particularly brown trout (*Salmo trutta*), and rainbow trout (*O. mykiss*) that had escaped from two fish farms in Loch Awe, Scotland, was assessed by setting a series of gill nets in the main habitat types that were found in the loch.

Although rainbow trout were caught throughout the loch they were only caught in large numbers in the immediate vicinity of the fish farms, and it was only when they were present in very high numbers that the distribution of the native species was adversely affected. The brown trout showed distinct seasonal variation in their habitat use. In winter they occupied the littoral zone and in the summer the older females (2+) moved offshore. There was also some evidence suggesting that rainbow trout followed a similar pattern. The pelagic morph of Arctic charr (*Salvelinus alpinus*) was found in small numbers in each habitat throughout the year, and the benthic morph was predominantly caught in the benthic zone, except in November and December, when they migrated into the sub-littoral zone to spawn.

The impact of the introduction of the feral rainbow trout on the important brown trout fishery in Lock Awe, and the wider implications of stock losses from fish farms on native species, in the light of the large expansion of the aquaculture industry in Scotland, are also discussed.

Breeding competition and reproductive success in hatchery versus wild coho salmon (Oncorhynchus kisutch)

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There is concern that hatcheries will result in the developmental and evolutionary divergence of salmon away from their wild phenotypic norm. In hatcheries, adult fish no longer experience the intense competitive and reproductive interactions of natural populations. Any resulting divergence of hatchery from wild fish would likely make the former inferior under natural conditions. We report a 2-year experimental study, using tagged individuals, to compare the competitive and reproductive success of fourth-generation hatchery coho salmon in direct competition with wild coho salmon under semi-natural spawning conditions. Experimental enclosures were constructed in the Oyster River stream channel, Vancouver Island. The first series of experiments tested for differences in competitive and reproductive success of hatchery relative to wild fish under a single breeding density. We found that hatchery fish could breed successfully when introduced into a stream environment where wild fish are absent. However, when in competition with wild fish, hatchery fish were competitively inferior. The reproductive disadvantage of hatchery fish was sex biased, with hatchery males suffering more than hatchery females. The following fall, a second series of experiments were carried out to examine how this reproductive disadvantage of hatchery fish is manifested across three different breeding densities. The results suggest a clear density-dependent pattern in reproductive success, particularly among hatchery fish. Our findings provide useful insight into the potential impact of artificial propagation on natural fish populations.

Predation by northern squawfish (*Ptychocheilus oregonensis*) on hatchery and wild coho salmon juveniles (*Oncorhynchus kisutch*) in the Chehalis River, Washington

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During 1988 and 1989, we evaluated predation by northern squawfish (*Ptychocheilus oregonensis*) on artificially and naturally produced coho salmon smolts in the Chehalis River, Washington. When only wild smolts were present in the river, about 4% of the squawfish had smolts in their stomachs. When hatchery-produced fish were present, 11% to 38% of the squawfish consumed at least one smolt. The proportion of squawfish consuming smolts depended on when hatchery fish had been released and where in the river squawfish were captured. We developed a simple model to estimate the number of hatchery and wild smolts eaten by squawfish. The model employed such information as the estimated population size of squawfish, the amount of time coho were exposed to predators, digestion rate of smolts in squawfish, numbers of smolts consumed per predator, and proportion of squawfish consuming smolts. We determined that a maximum of 7.0% of the hatchery-produced smolts were consumed by squawfish while fewer than 0.5% of the wild smolts were eaten by squawfish. The difference in mortality of hatchery and wild coho smolts could have occurred because hatchery fish were more vulnerable to predators than wild fish. Alternatively, more hatchery smolts may have been eaten because they were the most abundant prey available to the squawfish.

Time trends in returns from sea coupled with genetic equilibrium in Atlantic salmon (*Salmo salar*)

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Smolts have been released annually at Chamcook Harbour on the Bay of Fundy beginning in 1976, with the exception of 1984, using diallel matings of stocks from different rivers in the early years. Matings of returnees, together with the addition of genes from some different river stocks, allowed the formation of two synthetic gene pools derived from five and seven river stocks by 1981 and 1982, respectively. Available pedigrees revealed that 50 to 60 percent of the genes in each of the synthetic stocks had come from one stock, Big Salmon River.

The return rates for the fish in 1981 and 1982 were .54 and .64 percent, respectively. The progeny of these matings returned at respective rates of .06 and .13 percent in 1985 and 1986. Random matings of contemporaries of those returnees, reared in sea cages, were made in 1985 and 1986. The resultant progeny returned at rates of .41 and 1.08 percent, successively, with standard errors all less than .09 percent. Although other factors are involved, the results depict a significant recovery in return rate after one generation of random mating. These improved return rates were realized despite decreased returns in Inner Bay of Fundy rivers, such as the Big Salmon.

Identification of hatchery and naturally spawning stocks of Columbia Basin spring chinook salmon (Oncorhynchus tshawytscha) using scale pattern analyses

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Scale pattern analysis was used to differentiate hatchery and natural origin stocks of age 1.2 Columbia Basin spring chinook salmon (O. tshawytscha) from the Snake, Wenatchee, and Deschutes subbasins. Linear discriminant analyses indicated that hatchery and natural origin stocks within each subbasin could be identified with a relatively high degree of accuracy. High classification accuracies were also obtained by comparing pooled hatchery stocks from the three Columbia River subbasins with pooled natural origin stocks from those subbasins. A composite mixed stock analysis was made using unknown origin samples obtained from Bonneville Dam. This analysis, using a classification model based on pooled hatchery and natural origin stocks, estimated that 71% of age 1.2 spring chinook salmon sampled at Bonneville Dam were of hatchery origin.

Population structure of Sakhalin pink salmon (*Oncorhynchus gorbuscha*)

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Pink salmon populations can be recognized at four different spatial scales: (1) the species as a whole; (2) populations from vast regions (e.g. from the Okhotsk Sea); (3) populations from extensive coastal areas within regions (e.g. from eastern Sakhalin, western Kamchatka, the South Kuril Islands, and others within the Okhotsk Sea); and (4) populations from groups of small rivers or from individual large rivers.

Populations at the second level have been distinguished by their different spawning times and their use of different feeding grounds at sea. Where their spawning areas overlap significantly, the populations are regarded as seasonal races. Populations from the third level are isolated by distance and their abundance is determined by regional differences in climate. Tagging data indicates that the exchange between populations from Sakhalin and the South Kuril Islands amounts to 0.11%. Spatial isolation and adaptation to specific local conditions is typical of populations belonging to the fourth level. Pink salmon which spawn in different rivers of Sakhalin (except for several of the largest ones) do not warrant separate population status. The exchange of spawners between rivers is considerable and the smaller the river, the higher the percentage of strays. The proportion of strays exceeds 90% in the smallest rivers during years of high pink salmon abundance.

A significant increase in the abundance of spawners owing to strays from large rivers was recorded along the Okhotsk Sea coast of Sakhalin where the area of spawning grounds is less than 25,000 m^2. These recent high spawning densities, frequently exceeding 1,000 spawners per 100 m^2 in small rivers, will probably result in poor survival of the progeny. Thus, these rivers resemble sterile zones which act as "traps" for spawners. Removal of excess spawners from small rivers can be regarded as an opportunity for additional catches of pink salmon. These observations indicate that large-scale propagation of pink salmon in one river will influence production in adjacent rivers. Cultured pink salmon will, in turn, be affected by wild stocks. Potential consequences of the exchange will depend on the situation and, in particular, on the selective pattern of fish culture.

Consequences of seawater acclimation on the survival of Atlantic salmon (Salmo salar L.) smolts in the presence of cod (Gadus morhua L.)

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Atlantic salmon (Salmo salar L.) smolts were acclimated to full-strength sea water for periods of different duration. Following seawater acclimation, groups of smolts were released in a tank together with cod (Gadus morhua L.) to study survival and behaviour. Corresponding groups were sacrificed for the determination of physiological status after seawater exposure.

The duration of the seawater acclimation period significantly affected the number of smolts surviving in the presence of cod. Behavioural observations indicate that the smolts were unable to escape the predators due to decreased scope for activity. Determination of plasma ion levels suggest a casual relationship between the stress imposed by sea water and the maladaptive behaviour observed.

The present results contribute to our understanding of factors affecting early marine survival of wild and reared salmon smolts, and demonstrate the importance of release technique on post-release performance of smolts used for stock enhancement.

Escapement estimation of Pacific salmon by video technology

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Time-lapse VHS video tape equipment was used to record salmon passage at the fish ladder viewing window in Tumwater Dam on the Wenatchee River, Washington. Salmon passage was recorded during 2 years of migration. Video recordings served as the basis for escapement estimates of sockeye salmon (Oncorhynchus nerka), chinook salmon (O. tshawytscha), and steelhead trout (O. mykiss). Tests of estimation accuracy, tape reviewer precision, and tape recording speed were conducted.

Video-based escapement estimates were within 2% of independent visual counts. Analysis of variance showed no significant difference ($P>0.05$) among five different tape reviewers using fish counts of three species. Paired Wilcoxon tests indicated that fish counts were not significantly different ($P=0.286$) between 48- and 72-hour time-lapse recording speed modes. A significant amount of daily fish passage was observed between the 0500 and 2100 hr time periods when mainstem Columbia River counting stations do not operate because significant passage is not believed to occur.

The use of time-lapse video technology appears to be an effective method for Pacific salmon escapement estimation. In many applications, this method has advantages over the more traditional method of in-person visual fish counts. Video-based methods are more cost effective in areas with low escapement and provide a permanent and independently verifiable passage record. Tape analysis may be automated by using a computerized image processing system.

Dynamics of downstream migration and survival of juvenile salmon during early marine life

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From 1985-1989 factors restricting the survival of juvenile salmon during their early marine life were studied near the southwest coast of Sakhalin. Survival was influenced both by the abundance and by the seasonal and daily dynamics of foraging by predators and competitors, as well as by hydrological factors. It is clear that the survival of hatchery-reared salmon is greatly influenced by stategies for releasing juveniles. May is considered the best month for releasing hatchery-reared juveniles near the coast. Accordingly, we recommend releasing juveniles from hatcheries near the end of April over a span of 3-5 days to ensure discharge from the rivers in the middle of May. A release of 60 million juveniles will result in peak daily out-migrations of 2-9 million juveniles. We conclude that the construction of small hatcheries over various parts of the southwest coast of Sakhalin appears feasible, and that the survival of hatchery-reared salmon during early marine life can be improved by releasing fish at a suitable time and size.

An analysis of factors limiting enhancement potential of sockeye (<u>Oncorhynchus nerka</u>) in transboundary lakes of the British Columbia and Alaska border area

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Appraisal of enhancement potential of sockeye salmon in nursery lakes in the British Columbia-Alaska border region is required in association with the International Salmon Treaty between Canada and the United States. Observations have been completed on variations in sockeye abundance, zooplankton community structure, and limnological conditions among 11 "transboundary" lakes over the past 4 years. Analysis of these results has been used to identify the relative merits of alternative models for (i) identification of the extent to which zooplankton community state currently limits production of wild sockeye, (ii) appraisal of the utility of information on zooplankton community structure for prediction of sockeye enhancement potential among lakes, and (iii) predictions of how and when food supply will mediate interactions between wild and enhanced sockeye. Analysis of differences in zooplankton community structure among lakes suggests significant enhancement potential exists, via fry outplants or lake fertilization, for sockeye in Tatsamenie, Tuya, Tahltan, Trapper, Kuthai and King Salmon lakes but not in Chutine, Christina, Little Trapper, Kennicott or Klukshu lakes.

Biological monitoring of artificially propagated chum populations of Sakhalin Island

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Artificially propagated chum salmon populations account for more than 80% of chum catches on Sakhalin Island. Long-term artificial propagation without natural reproduction of chum has had considerable impact on the biological structure of the populations being propagated. For example, the timing of the run has become earlier owing to the deliberate selection of broodstock from the initial phase of the spawning run and the selection of large males. In addition, the average size and age of the population has increased but the rate of reproduction has decreased. For these reasons, a system of biological monitoring was developed and introduced to assess the biological state of hatchery-reared populations and to reduce the negative impacts of enhancement on their biological structure. This system consists of the following:

1. Routine sampling of chum for abundance, sex, age, and size composition during their return migration to the hatcheries;

2. Centralized processing of biological samples to facilitate monitoring changes in stock characteristics;

3. Forecasting of run strength one year in advance;

4. Recommending spawning escapement goals for all components of the chum spawning run.

The implementation of this comprehensive biological monitoring system has proven to be effective for preserving the genetic diversity of the population and for improving the management of the fishery.

Management of summer steelhead (*Oncorhynchus mykiss*) in the Columbia River Treaty Indian commercial fishery

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The history of fall season (August-October) management in the Columbia River treaty Indian commercial fishery can be divided into three periods: (1) pre-U.S. vs Oregon, (2) 1977 plan, and (3) current Columbia River Fish Management Plan. Catches of steelhead in the fall season have increased due to changes in regulations as well as additional enhancement. Most enhancement is mitigation for severe habitat losses and hydroelectric development. Recent increases in hatchery production (now 70-80% of the returns) have occurred without proportional increases in natural production. This, coupled with large numbers of fall chinook available to the Indian commercial fishery, has led to classic mixed-stock fisheries problems. The outlawing of commercial sales of steelhead by non-Indians (1975) has led to social conflict between tribes and sport fishermen. Recent efforts to identify hatchery and natural stocks through scale pattern analysis have helped quantify stock-specific impacts. Other methodologies are being explored to further refine stock-specific information. For future enhancement to be successful, all aspects of the life cycle must be examined. Improvements in habitat management, downstream migration and upstream migration are vital to increasing returns of natural steelhead. Standard fish production practices should be reevaluated for their effects on natural production. Simply creating more fish under standard hatchery practices will only exacerbate the imbalance of hatchery and natural production.

Genetic characterization of native *Salmo salar* and divergence with Scottish stocked salmon in the Esva River (Northern Spain)

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Restocking programs have been applied in the rivers of Northern Spain for 20 years to supplement declining natural populations. In the Esva River, salmon are exploited every year by rod and line from March to July. The average catch for the last 3 years was 153 individuals. To assess the possibility of a different genetic structure between "native" salmon populations and restocked salmon, samples were examined for genetic variation using starch gel electrophoresis at the variable loci previously cited by other authors.

The samples analyzed were:

- Muscle samples from the majority of adults caught by anglers (1990).
- Muscle and liver samples from "dwarf" males (October 1990).
- Muscle and liver from parr hatched in the river (May 1990).
- Muscle and liver samples from stocked Scottish parr (0+) introduced to the river (July 1990).
- Muscle and liver samples from mixed (native + stocked) populations in the river (October 1990).

We found differences between foreign (stocked) and native salmon in allelic frequencies in some enzymatic systems. Variation observed at the *Pgm-1* locus and the high frequency of the *Me-3* x (100) allele can be considered the characteristic pattern of Spanish salmon as described by Verspoor et al. (1989).

Genetic divergence between native, returning adults and stocked salmon point out the need for reconsidering future stocking programs to preserve native genetic variation.

Changes in total catch, salmon-grilse ratios, and age at smolting of Atlantic salmon (<u>Salmo salar</u> L.) in four Cantabrian rivers (Northern Spain): assessment of stocking incidence

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Annual changes in total catch, age and size at maturity, and age at smolting of Atlantic salmon (<u>Salmo salar</u> L.) were analysed in relation to stocking intensity in four Cantabrian wild stocks. Data on biological traits were obtained from scale analysis and available catch records from four rivers from Asturias (Northern Spain). Between 1953 and 1990, a general declining trend of captures was noted for Cares, Sella, and Narcea rivers, although for the latter this decline was not statistically significant. This appears to be the result of a sharp decrease since 1970-73, rather than a progressive and continued decrease. Interannual fluctuations in total catch in these rivers are strongly synchronized. By contrast, in the Esva River, catches increased over the period 1953-1990, and are not synchronized with those of other rivers. The proportion of three sea-winter salmon decreased significantly in Cares, Sella, and Narcea rivers, whereas the proportion of grilse increased in Cares and Narcea rivers. Preliminary analyses revealed that stocking intensity (measured as the number of foreign 0+ salmon released) did not contribute substantially to the observed trends in age at maturity, nor to variation in total catch. A significant correlation was found between abundance of two-sea winter salmon in year t and three-sea winter salmon in year t+1, but not between grilse and two-sea winter salmon. The different pattern observed in the Esva River (age at smolting, catch trend) might be attributed to the particular history of this river, whose salmon stock was restored by the 1950s.

Realized heritability of size at maturity in coho (*Oncorhynchus kisutch*) salmon

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In the 1980 STOCS Symposium, Dr. W.E. Ricker reported that average weights of coho salmon caught in B.C. commercial fisheries had decreased 1130 g since 1951. Ricker concluded that "it is quantitatively possible that the coho (outside of the Strait of Georgia) decreased in size because of selection by the fishery." This reduction in size represents a significant loss in biomass yield and coho productivity.

To test the genetic selection hypothesis, a mass selection program to increase the size at maturity of coho salmon was initiated at Quinsam Hatchery. A Control line was drawn randomly from the 1983 coho return and a Selected line drawn from the upper 10% of the size distribution. Selection pressure in the F_1 generation was less than the 10% objective due to non-synchronous maturity within lines. In both F_1 (1986) and F_2 (1989) returns, the Selected line by sex was larger than the Control line but the size distributions overlapped substantially. Within lines, females were consistently larger on average than males ($P>0.001$). Age-2 males ("jacks") have been excluded from these size distributions. It is interesting that in both generations fewer jacks returned from the Selected line.

Response to selection was minimal in the first generation but increased in the second. Over the two generations, the estimates of realized heritability for size at maturity were 0.14 ± 0.063 for males and 0.12 ± 0.070 for females (preliminary estimates of standard deviations). These estimates are lower than hypothesized by Ricker but do indicate that selection could operate to change this trait. Most size distributions of coho returning to Quinsam Hatchery do indicate selective removal of larger fish. However, an alternative hypothesis is proposed that inbreeding depression of growth in coho hatchery populations could also account for the observed reductions in body size.

Interannual variability in biochemical parameters of pink (<u>Oncorhynchus gorbuscha</u>) and chum (<u>Oncorhynchus keta</u>) fry in coastal waters of Kamchatka

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Biochemical characteristics of pink and chum salmon fry rearing in the eastern part of the Okhotsk Sea and the southwestern part of the Bering Sea were examined in relation to fry abundance. Fat content was higher and protein-water content was lower in the bodies of pink and chum fry in years of low abundance than in years of high abundance. These differences persisted, and were found in fry captured in inshore as well as in open waters. In years of low abundance, fat accumulation in the bodies of pink fry averaged 4.13% of raw matter for the Okhotsk Sea and 3.60% for the Bering Sea; in years of high abundance, the average levels were 3.08% and 2.98%, respectively. The rate and level of fat accumulation for Bering Sea chum fry from consecutive generations differed by a similar amount. Correlation analysis revealed a close inverse relationship between fry abundance and the ratio of fat to protein and a direct relationship between fry abundance and water and ash index in both pink and chum salmon. These relationships suggest that such biochemical indices, considered together with other ichthyological and hydrobiological parameters, may be useful for improving forecasts of adult pink salmon returns to the fishery.

Osmoregulatory ability in sea water in smolting hatchery and wild coho salmon (*Oncorhynchus kisutch*)

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Osmoregulatory ability in salt water was compared between smolting wild and hatchery-reared coho salmon (*Oncorhynchus kisutch*). The brood stock for the hatchery came from the population that naturally spawn the river. The fish were challenged to 30 ppt salt water for up to 7 days. The osmoregulatory ability of wild fish exposed to salt water is greater than hatchery-reared fish. After 24 hours' exposure to salt water, hatchery coho showed a significantly higher plasma sodium concentration than their wild counterparts. After residence in salt water for 7 days, plasma sodium concentrations in wild coho were at a level not significantly different from the initial freshwater values, while the levels were still elevated in hatchery fish. Hatchery smolts also showed a reduction in haematocrit after saltwater exposure that was not seen in wild fish. Specific activities of the enzymes Na^+K^+-ATPase and citrate synthase were higher in wild smolts than hatchery smolts. Comparison of saltwater tolerance among the wild fish showed that the larger fish tended to exhibit a greater hypo-osmoregulatory ability. This trend was not seen in the hatchery fish and, in fact, the much larger hatchery fish showed a weaker ability to osmoregulate in salt water. Since wild and hatchery fish come from a common genetic stock, differences seen between wild and hatchery-reared smolts were likely phenotypic responses to rearing environment.

Physiological assessment of maturation in juvenile Pacific salmon in hatchery and wild populations

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Nowadays, the culture of marine fishes, especially Cyprinidae and Salmonidae, the most valuable commercial species, is of great interest. The release of hatchery-reared juveniles of anadromous salmon has proven to be effective. However, the success of hatchery rearing depends to a great extent on the normal functioning of the reproductive system in hatchery fish. Accordingly, studies of gametogenesis were conducted using juvenile coho, chinook, and sockeye salmon (species with prolonged freshwater life) which were incubated and reared at increased water temperatures and fed pelleted food. Under these conditions, juveniles reached sizes typical of age 2+ or 3+ smolts in the wild within 6-8 months of emergence.

Morphohistological analysis of gonads revealed that the rate of growth and development of gametes was also accelerated. There was no evidence of pathological changes in the structure of gametes or their membranes. A positive correlation was observed between the rate of growth of females and the rate of ovarian development. By the end of the juvenile rearing period, oocytes reached the third or fourth stage of protoplasmatic growth. Male gonads reached the first stage of maturity, and the gametes were represented by dark and light A-type spermatogonia. In both sexes, the gonads of accelerated juveniles were characteristic of age 2+ and 3+ smolts in wild populations.

The accumulation of nutrients in oocytes was also measured in females reared for more than one year at the increased temperature. In males, the same conditions induced the formation of cysts with B-type spermatogonia. A "wave" of spermatogenesis accompanied an increase in gonadosomatic index in 3% of coho salmon held at the hatchery for the additional year. This indicates that they would mature later the same season.

Trophoplasmatic growth of oocytes was promoted in salmon juveniles transferred from fresh water to sea water (12-14‰). This is characteristic of juveniles caught in the open sea.

Thus, the development and formation of the reproductive system in juveniles from hatchery populations is identical to that in juveniles from wild populations. However, faster growth and development in juvenile Pacific salmon can reduce the freshwater period by 1-2 years, thereby promoting the earlier return of spawners.

An evaluation of 25 years of production from an enhanced stock of coho salmon (*Oncorhynchus kisutch*) in Bear Lake, Alaska

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Coho salmon (*Oncorhynchus kisutch*) fingerlings have been stocked into Bear Lake since 1963. The emigration of smolts from these stockings have been monitored using a smolt weir. Adult returns from these stockings have been monitored using a creel survey and counting weir. These efforts have yielded estimates of total smolt and adult production from these stocking efforts. Trends in smolt and adult production are evaluated. In addition, factors that influence freshwater and marine production are evaluated.

SYMPOSIUM INFORMATION