FINAL Meeting Notes
Lewis River License Implementation
Aquatic Coordination Committee (ACC) Meeting
July 9, 2009
Conference Call

ACC Participants Present (16)

Clifford Casseseka, Yakama Nation
Michelle Day, NMFS
Pat Frazier, WDFW
Bernadette Graham-Hudson, LCFRB
Diana Gritten-MacDonald, Cowlitz PUD
LouEllyn Jones, US Fish and Wildlife Service
Eric Kinne, WDFW
George Lee, Yakama Nation
Erik Lesko, PacifiCorp Energy
Jim Malinowski, Fish First
Kimberly McCune, PacifiCorp Energy
Todd Olson, PacifiCorp Energy
Frank Shrier, PacifiCorp Energy
Rich Turner, NMFS
Neil Turner, WDFW
Richard Turner, NMFS

Calendar:

August 13, 2009	ACC Meeting	Conference Call
September 10, 2009	ACC Meeting	Merwin Hydro

Assignments from July 9, 2009 Meeting:	**Status:**
McCune: Email copies of the Eagle Cliff Trail Feasibility Study Report comment letters from WDFW and USFWS to Pat Frazier (WDFW).	**Complete – 7/9/09**

Assignments from June 11, 2009 Meeting:	**Status:**
Lesko/McCune: Email current version of the draft H&S Plan to the ACC.	**Complete – 6/17/09**
Wills: Search the Washington State University database for an article on the use of electro-anesthesia on Chinook salmon and email the entire article to the ACC.	**Complete – 6/16/09**
Rich Turner: Provide the link to the NW Fish Culture Conference abstract on electro-anesthesia to the ACC.	**Complete – 6/11/09**

Assignments from April 9, 2009 Meeting:	**Status:**
ACC: Further investigate WDFW carcass survey methods established in 1978 and determine "next step" regarding modifications needed, if	**Pending – Per Pat Frazier could take 1 – 2 months to put**

any, to the 1978 methods.	**together**

Opening, Review of Agenda and Meeting Notes

Frank Shrier (PacifiCorp Energy) called the meeting to order at 9:05am. Shrier reviewed the agenda for the day and requested any changes/additions. LouEllyn Jones (USFWS) requested the addition of the Eagle Cliff tour update.

Eagle Cliff Trail

Due to technical difficulty on the conference call Todd Olson (PacifiCorp Energy) provided the update and Jones confirmed that the update was accurate.

Olson informed the ACC that a tour of the Eagle Cliff Trail was conducted. Representatives from USFWS, PacifiCorp Energy and WDFW were present. PacifiCorp received comments from both USFWS and WDFW requesting not to build the trail due to potential threat to bull trout (Attachment A). In response to Pat Frazier's (WDFW) question about who represented WDFW on the tour Kimberly McCune (PacifiCorp Energy) will email copies of the letters to his attention. The outcome of the trail is pending a decision from the Federal Energy Regulatory Commission (FERC).

Michelle Day and Diana Gritten-MacDonald joined

Shrier requested comments and/or changes to the ACC Draft 6/11/09 meeting notes. Michelle Day (NMFS) requested the meeting notes review and approval be appended to the end of the meeting to provide additional time for her review.

Hatchery and Supplementation Plan (H & S Plan) Update

Erik Lesko (PacifiCorp Energy) informed the ACC attendees that the next H&S Plan Subgroup meeting will take place on July 14, 2009 at WDFW, Vancouver, WA to work on completing the Spring Chinook portion of the H&S plan and then move on to the Coho program. Lesko expressed that there are monitoring and evaluation (M&E) components within the Hatchery & Supplementation Plan (H&S), the Monitoring and Evaluation Plan (currently under ACC review) and the Hatchery & Genetic Management Plans (HGMP). So a focus at the July 14th meeting is to review the M&E sections of these plans to identify overlap and ensure consistency with the H&S Plan.

Lesko informed the ACC attendees that August 1, 2009 is the target date for release of the 30-day review version of the H&S Plan. He emphasized that the H&S plan is a general plan used to direct implementation activities and that the impending and related Annual Operating Plans for each species will be where the details of implantation are described. Therefore, the H&S plan will not have significant changes to it which should help with the review time.

The FERC is requiring submittal of the H&S Plan on or before December 26, 2009.

Release Point for Adults at Swift Discussion

Shrier provided a brief PowerPoint presentation (Attachment B) as a visual aid during discussions and consideration of options to get fish to the upper watershed.

Shrier informed the ACC attendees that the primary question is how we get adult fish into the upper Lewis if there is snow, road failure or if the elevation of Swift reservoir is too low. The Engineering subgroup is discussing a number of options, one of which is the use of a flume (approximately 150' x 12") from the corner of the Eagle Cliff parking lot into the river (see slides 3 & 4 in the PowerPoint). Day expressed that consideration should be given to the size of the flume and securing the end to discourage use by children. Shrier shares this concern but said that the intent is to not leave the flume up during recreation season as the design is meant to be portable and temporary.

Rich Turner joined

Wild vs. Hatchery Spawning Success related to Electro-anesthesia (EA) Discussion

Shrier communicated to the ACC attendees that after conducting some research he did not find anyone who has evaluated the effects of electro-anesthesia on spawning success.

Day expressed that she has completed a cursory review of the paper written by Gayle Zydlewski (Attachment C), as provided by Shannon Wills (Cowlitz Indian Tribe). Day noted that the Zydlewski article looked at immediate effects but not that of spawning success. She also saw that more injuries occurred with the use of EA than with MS-222.

Day expressed concern that EA could affect the outcome goal and the affect of our choices may be doing something that minimizes the outcome success. She also recognizes that more homework is needed. She also communicated that it is important for the ACC to be fully aware and to do the best thing to meet all our objectives regarding save and efficient fish passage.

Frazier communicated that a tagging study at the Cowlitz program this Fall could be considered.

General discussion took place regarding varying voltage setting for first and second phases, application of MS-222 and use of electroshock, number of hemorrhages per fish as a result of electroshock and necropsy on fish.

The ACC agreed to add this topic on the August ACC agenda so that the ACC can continue to look for more information and report back.

Bull Trout Concerns

Lesko informed the ACC attendees that Eagle Cliff and the IP Pool at times contain a lot of bull trout which can be very susceptible to anglers. Approximately ten angler fishermen were found recently fishing at these two locations. One angler had caught a bull trout and placed it in a bucket. Fortunately it was still alive so he was forced to place it back into the river. Lesko spoke with Sgt. Rick Webb, WDFW Enforcement Officer about placing regulation signs indicating, “Absolutely no fishing” and “Closed waters”. Signs are needed as soon as possible. Lesko also pointed out that these signs will be different than those planned as part of the Recreational Interpretation and Education Program. Informational signs required by the Settlement Agreement are not to be confused with regulation signs from the Washington Department of Fish & Wildlife.

Frazier said that he would meet with Sgt. Webb about the signs and talk about emphasis patrols to cover sensitive areas.

Study Updates

Shrier and Lesko provided the following study updates:

Swift Constructed Channel and Swift Upper Release – Excavation at the upstream site is ongoing. Gravel placement (upper release portion) will begin this week or next.

Hatchery Upgrades – Pond walls at Lewis River Pond #15 are complete; construction to begin for hatchery platform and building. The pescalator will be in place within the month.

Speelyai Burrows Pond project is waiting on one construction permit.

Stress Release Pond Design – The Design is out for a 30-day review and comment period. Comments due on July 27, 2009.

Acclimation Pond Plan – Consultants working on a conceptual design. The consultants and the ACC are counting on the Yakama Nation staff for input regarding location and design.

Water Quality Management Plan – Currently still under Washington Department of Ecology (DOE) review. DOE is developing a comment letter.

Monitoring and Evaluation Plan (ACC Review Draft) – The Plan is out for a 90-day review and comment period. Comments due September 21, 2009.

George Lee and Clifford Casseseka joined

Baseline Monitoring Plan – The next meeting is scheduled for in August to discuss findings of field work and samples.

Yale Spillway Modification – Submitted to the FERC on June 24, 2009.

Merwin 90% Design Submittal – Submitted to the ACC and the Services for a 45-day review and comment period. Comments are due August 10, 2009.

Swift 90% Design Submittal – Submitted to the ACC and the Services for a 45-day review and comment period. Comments are due August 10, 2009.

Stranding Study – The Study will be conducted by Stillwater Sciences and Interfluve. PacifiCorp requested the study be available to the ACC in August 2009 for a 30-day review and comment period. The Study is due on June 26, 2011 (year 3 of the License).

Review and comments on June 11, 2009 Meeting Notes

Day requested clarification in the notes when Bryan Nordlund (NMFS) is referenced as he was not present at the June 11, 2009 meeting. Kimberly McCune (PacifiCorp Energy) will add text where appropriate to clarify Nordlund's was not present at the ACC meeting.

The meeting notes were approved with the changes referenced above at 10:15am.

Public Comment
None

New Topics
None

Agenda items for August 13, 2009

- Review July 9, 2009 Meeting Notes
- Update from H&S Plan Subgroup
- Wild vs. Hatchery Spawning Success related to Electro-anesthesia (EA) Discussion
- Study/Work Product Updates

Next Scheduled Meetings

August 13, 2009	September 10, 2009
Conference Call	Merwin Hydro Control Center
	Ariel, WA
9:00am – 3:00pm	9:00am – 3:00pm

Meeting Adjourned at 10:30 a.m.

Handouts

- Final Agenda
- Draft ACC Meeting Notes 6/11/09
- Attachment A – Eagle Cliff Trail Feasibility Study Report, WDFW and USFWS Comments, dated June 19, 2009
- Attachment B – Release Point for Adults at Swift Power Point, dated July 9, 2009
- Attachment C – Use of Electroshock for Euthanizing and Immobilizing Adult Spring Chinook Salmon in a Hatchery, by Gayle Barbin Zydlewski

State of Washington
Department of Fish and Wildlife

Mailing Address: 600 Capitol Way N, Olympia WA 98501-1091, (360) 902-2200, TDD (360) 902-2207
Main Office Location: Natural Resources Building, 1111 Washington Street SE, Olympia WA

June 19th 2009

David Moore
Cultural Resources Coordinator, PacifiCorp
825 NE Multnomah, Suite 1500
Portland OR 97232

RE: Swift 1 Hydroelectric Project, FERC No. P-2111 – Eagle Cliff Trail Feasibility Study Report, May 2009

The Washington State Department of Fish and Wildlife (WDFW) appreciates the opportunity to review the Eagle Cliff Trail Feasibility Study submitted in May of 2009 associated with FERC Project Number 2111. We have reviewed the study and our comments are contained below.

WDFW continues to have concerns about the alignment options for the Eagle Cliff Trail. Conducting construction activities and/or locating the trail over the pool via a cantilevered system along the base of Eagle Cliff and will have an appreciable impact on the Bull Trout (*Salvelinus confluentus*) that utilize that specific area as a staging pool (trail section designated "B-C" in the Feasibility Study) prior to spawning up Pine Creek and other systems in the area. There is also evidence, through conversations with PacifiCorp biologist Erik Lesko, that surveys have shown Bull Trout utilizing the area year round for foraging. Although there are assurances in the plan that the impact from falling rocky debris from blasting would be "unlikely to be adversely affected" and "under normal conditions, the material will be widely distributed by high wintertime flows" (Page 20, paragraph 4 of report), WDFW believes that the potential for any impact to a Federally Threatened species and its associated habitat needs to be avoided at any reasonable cost.

The removal of streamside vegetation to accommodate this plan is also of concern, as maintaining stable water temperatures as well as providing vegetative cover are paramount for this species. In addition, the plan calls for removing several larger trees along the trail path near points B-C. This area of the trail in particular has shallow soils with a high potential for slides and material deposition into the Lewis River system. WDFW wants to ensure that bank stability is maintained in the area so that further slides and sedimentation does not occur, particularly in the pool at the base of Eagle Cliff.

There is also a concern about ongoing disturbance for this specific area from trail users, both purposeful and inadvertent. The threat of poaching is always a concern, and the placing of a trail above or adjacent to the pool combined with limited enforcement

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officers in the area, this risk is increased under the current suggested alignment. In addition, passerby's can inadvertently startle and stress the fish while staging to spawn. This, coupled with the potential for litter and additional sedimentation to the system from trail users (particularly equestrian), increases the risk to Bull Trout and their habitat. Because of this, WDFW echoes the United States Fish and Wildlife Service's (USFWS) concern and does not support construction of the Eagle Cliff Trail at this location. WDFW would be open to the possibility of a trail at another location within the project area that would not have the same type of risk to environmental resources.

Thank you for the opportunity to comment on this study. If you have any questions or comments, please feel free to contact me using the information provided below.

David Geroux
Habitat Biologist
Washington State Department of Fish and Wildlife
(360) 902 2539
David.geroux@dfw.gov.wa

CC: Travis Nelson and Curt Leigh of WDFW, and LouEllyn Jones USFWS

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Washington Fish and Wildlife Office
510 Desmond Dr. SE, Suite 102
Lacey, Washington 98503

JUN 19 2009

David Moore, Cultural Resources Coordinator
PacifiCorp Energy
825 NE Multnomah Suite 1500
Portland, Oregon 97232

Subject: Eagle Cliff Trail Feasibility Study Report

Dear Mr. Moore:

This letter is in response to your letter dated May 20, 2009, requesting comments on the feasibility study report for the Eagle Cliff Trail. The Lewis River Settlement Agreement Section 11.2.1.2 on the Eagle Cliff Trail, states:

> "Criteria to be used in this study include...avoiding potential impacts on bull trout, to the extent practicable, by locating the trail away from sensitive habitat areas. PacifiCorp shall coordinate with and obtain the approval of USFWS on the final designs and location of the trail to ensure that impacts on bull trout are acceptable."

Based on the description in the feasibility report, conversations with PacifiCorp and Washington State Department of Fish and Wildlife staff and our site visit on June 12, 2009, we believe that this trail could have significant impacts on bull trout.

Bull trout are documented in this reach of the Lewis River and are commonly found in the pool alongside Eagle Cliff from May through September. Bull trout are most likely using the cool water there as a thermal refugia during summer months and may also be using the pool as a staging area prior to beginning their spawning runs. Bull trout are also found in the confluence of the Lewis River with Pine Creek and the Muddy River upstream of Eagle Cliff.

Currently, bull trout in the Lewis River are at some risk from both legal and illegal fishing. The state allows catch and release fishing in the Lewis River alongside Eagle Cliff above the 90 bridge. Catch and release may result in some mortality even when anglers are careful. Bull trout are the largest fish in the area, and anglers do target them. Poaching of bull trout is also known to occur. Anglers can easily access the Lewis River and Eagle Cliff area from the I90 bridge parking lot. From the other side of the river, anglers can also access the confluences with Pine Creek and the Muddy River via trail and an old logging road, respectively, though the access to the Muddy River is somewhat difficult to find.

Building the Eagle Cliff Trail would increase ease of access to these pools, increasing the risk of mortality to adults. During the settlement agreement negotiations, our agency commented that this trail would pose much less risk to bull trout if it were designed further inland, however this option is apparently impracticable and has been eliminated from consideration.

During settlement negotiations, this trail was seen as a connector with a larger trail system in the Lewis River area. However, as time has passed, development of connecting trail systems has not gone forward. The Eagle Cliff Trail, therefore, is a "trail to nowhere" and does not appear as important for recreationists as was once understood.

Based on the increased risk to bull trout from increased fishing access and the decrease in justification for this trail, we do not support further consideration of this project. If you have any questions, please contact Lou Ellyn Jones 360-753-5822 or Jim Michaels 360-753-7767.

Sincerely,

James L. Michaels

Ken S. Berg, Manager
Washington Fish and Wildlife Office

cc:
C. Leigh, WDFW


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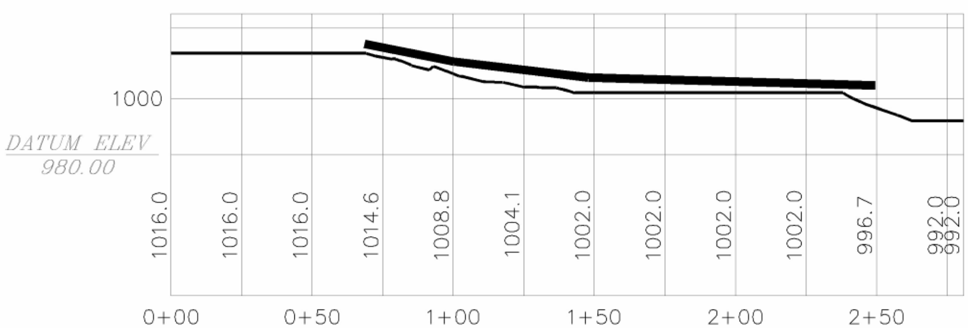
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ALIGNMENT 3

This message was sent with high importance.

van- docdel

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Cheers,
Shannon

Dear shannon wills,

A request you have placed:

North American journal of aquaculture
70 4 october 2008
Title: Use of Electroshock for Euthanizing and Immobilizing Adult Spring Chinook Salmon in a Hatchery
Author: Zydlewski GB, Gale W, Holmes J, et al.

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North American Journal of Aquaculture 70:415–424, 2008

DOI: 10.1577/A07-048.1

[Article]

Use of Electroshock for Euthanizing and Immobilizing Adult Spring Chinook Salmon in a Hatchery

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JEFFREY JOHNSON

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TROY BRIGHAM[3]

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U.S. Fish and Wildlife Service, Carson National Fish Hatchery, 14041 Wind River Highway, Carson, Washington 98610, USA

Abstract.—This study evaluated the use of electroshock as an alternative to traditional techniques for immobilizing and euthanizing hatchery fish. We used a commercially available electroanesthesia unit at the U.S. Fish and Wildlife Service's Carson National Fish Hatchery (Carson, Washington) to euthanize adult spring Chinook salmon *Oncorhynchus tshawytscha* and to sort and collect gametes of fish at maturation. During euthanization by electroshock, the response of each fish was observed, muscular and vertebral hemorrhaging was quantified, and electrical settings were optimized accordingly. During gamete collection, fish were either electroshocked or exposed to tricaine methanesulfonate (MS-222); hemorrhaging, egg viability, egg size and quantity, and resultant fry quality were examined for each treatment group. Electroshocked fish had a higher likelihood of injury during gamete collection than did fish exposed to MS-222. On average, each electroshocked fish had less than two hemorrhages on both fillets examined. The size of each hemorrhage was less than 0.10% of the fillet surface. Fecundity and egg and fry quality were not affected by either immobilization method. Electroshock was a viable and efficient means of euthanizing adult spring Chinook salmon or sorting the fish and collecting their gametes. However, equipment settings must be optimized based on site-specific (e.g., water conductivity) and species-specific (e.g., fish size and seasonal state of maturation) factors.

In most hatchery programs that produce spring Chinook salmon *Oncorhynchus tshawytscha*, the adults spend several months in the hatchery before they are mature and ready to spawn. At most facilities, adults are collected throughout the migratory season (April–August), so their progeny represent genetic contributions from all run times. Extended hatchery residence before gamete collection often makes it necessary to handle these fish on multiple occasions. For example, diseased or injured fish may have to be separated from other broodstock and fish health is often managed by prophylactic injection with antibiotics. It is imperative that handling operations minimize stress and physical impacts to the fish to ensure their survival and collection of gametes for hatchery purposes.

At times, the number of returning adults can greatly exceed hatchery goals and excess fish must be removed to prevent overcrowding. Under these circumstances, fish must be processed humanely while maximizing worker safety. To avoid wastage, excess fish are often given to tribal groups, food banks, and other entities (e.g., federal prison systems) for use as an additional food source. Euthanizing fish for consumption requires consideration of fish and human welfare as well as the effect of the procedure on fillet quality.

Current methods of fish preparation for consumption and gamete collection vary widely. It was beyond the scope of this project to review all such methods.

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Received May 24, 2007; accepted November 11, 2007
Published online October 30, 2008

However, two commonly used techniques—application of carbon dioxide (CO_2) and tricaine methanesulfonate (MS-222)—provide examples of limitations that are inherent to current technology. Application of CO_2 to holding tanks results in acute acidosis and spasms that are injurious to fish (G. K. Iwama, University of British Columbia, unpublished), therefore deviating from humane slaughter methods (Van de Vis 2003). For human consumption purposes, traditional chemical anesthetics are usually not permissible. For example, MS-222 requires a 21-d withdrawal period before consumption or release into the wild. In many cases, the application of CO_2 or MS-222 requires an additional blow to the head to kill the fish. This method is of increasing concern to animal protection groups and governments (Lambooij et al. 2007). Furthermore, results from tests on percussive stunning are inconclusive in terms of agreement with optimal slaughter methods, which require the fish to be rendered "unconscious until death without avoidable excitement. . ." (Van de Vis et al. 2003).

Electroshock has been used as a viable and humane means of processing large numbers of adult salmonids (Tipping and Gilhuly 1996; Tesch et al. 1999; Roth et al. 2002; Van de Vis et al. 2003). Evidence suggests that when electroshock is administered at carefully chosen levels, it renders the fish unconscious immediately (Van de Vis et al. 2003), causing minimal injury to adult fish and indiscernible effects on their progeny. Small-scale studies of northern pike *Esox lucius* and brook trout *Salvelinus fontinalis* (n = 1–3 fish/trial) have reported that egg viability and fry growth did not differ between parents treated with MS-222 and those treated with electroshock (Walker et al. 1994; Redman et al. 1998). Walker et al. (1994) also reported no physical damage to the adults when pulsed DC was used. However, deleterious effects of electroshock on individual parents (e.g., Arctic grayling *Thymallus arcticus* and cutthroat trout *O. clarkii*) have been associated with negative effects on progeny (Roach 1999; Dwyer et al. 2001). These conflicting results make it necessary to compare methods of immobilization and euthanization for each considered species and scale of operation.

The goal of this study was to examine whether electroshock is a viable and humane alternative for spring Chinook salmon immobilization (for up to 5 min; allowing subsequent recovery) and euthanization (humane death). First, we examined whether use of electroshock to euthanize excess adult fish affected fillet quality. Second, we examined whether electroshock could be used in place of MS-222 for sorting and gamete collection. Finally, we assessed how electroshock application to adults affected the survival and growth of progeny.

Methods

Adult spring Chinook salmon from the Wind River, Washington, ascend a fish ladder into adult holding ponds (662 m^3) at the U.S. Fish and Wildlife Service (USFWS) Carson National Fish Hatchery (CNFH), Carson. Throughout the season (May–August), predetermined numbers of males and females are maintained for gamete collection (in August). Fish in excess of the number needed for hatchery operations are kept in a separate holding pond to ensure that enough fish are available for gamete collection. Excess fish are euthanized as necessary.

A Model EA-1000 electroanesthesia (EA) unit (Smith-Root, Inc., Vancouver, Washington) was used for this study. The unit consists of an electronic pulse generator and fiberglass tank. The fiberglass tank has two braillers (1.02 m long × 0.63 m wide) for moving shocked fish up to a sorting table. Plate electrodes are located at the tank ends and in the middle between the two braillers. The design produces a predictable, homogeneous electrical field. The unit can be operated with the end electrodes as cathodes and the central electrode as the anode (normal polarity) or vice versa (reversed polarity).

The unit generates a pulsed-DC waveform and has a two-stage operation; the first stage uses lower voltage settings (3.5–35.5 V) than the second stage (12–235 V). Both stages produce a constant-DC pedestal and a pulsed-DC waveform on the pedestal. The pulsed-DC waveform is a burst of three pulses at 240 Hz and 50% duty cycle (2.08-ms pulse width). This pulse train is repeated 15 times/s. The constant-DC pedestal is 45% of peak voltage in stage 1 and 20–45% of peak voltage in stage 2. In stage 2, the higher percentage is at the lower peak voltage and decreases with increasing peak voltage settings. Voltage duration in the original configuration could be applied from 0 to 128 s for both stages. The design of this waveform is based upon two separate waveforms known to cause a low level of fish injury. Also, constant DC is less injurious than pulsed DC (McMichael 1993; Dalbey et al. 1996; Ainslie et al. 1998). The pulsed waveform used for anesthesia is similar to the patented complex pulse system (CPS) waveform developed by Coffelt Manufacturing, Inc. (Sharber et al. 1994). Studies comparing CPS with traditional pulsed-DC waveforms have shown significantly lower rates of injury when CPS is used (Sharber et al. 1994).

Preliminary tests were conducted to determine the minimum voltage levels, electroshock duration, and number of fish that could be processed at one time to achieve euthanization and immobilization while minimizing hemorrhaging. Immobilization was achieved when fish remained motionless on the sampling table for 5 min. Euthanization was achieved when fish did not recover from immobilization. Results from 31 individuals (11 single-fish trials and 3 multiple-fish trials) were used to establish methods for hatchery operations. Settings for euthanization were 19 V for 60 s and 298 V for 120 s. For sorting and gamete collection, settings were 19 V for 60 s and 130 V for 68 s. We did not optimize settings for other handling procedures, such as antibiotic injection. Control fish (i.e., those handled without EA or MS-222 treatment) were not used due to the impracticality of handling nonanesthetized animals. For purposes of this study, reported injury rates for MS-222-treated fish are considered to represent normal handling-related injury and any EA-related increase above the normal injury level represents the effect of electroshock treatment.

Euthanization of excess fish.—In 2002, 4,800 adult spring Chinook salmon were euthanized by CNFH staff over a 5-d period and 1 of every 100 fish ($n = 48$) was examined on each of the 5 d. In 2003, 5,800 fish were euthanized over 6 d and 15 fish were examined on each of 3 d.

All examined fish were measured postmortem, filleted (the entire length from operculum to tail), and sexed. The right and left fillets (and a metric scale) were photographed with a digital camera in lateral projection. Visual discrimination was used to separate fish into two mutually exclusive categories (modified from Reynolds 1996): (1) muscular injury (muscle hemorrhage that was not associated with the spinal column); and (2) vertebral injury (muscle hemorrhage that was associated with the spinal cord). Vertebral injury was measured as a hemorrhage that occurred near the vertebra, but actual vertebral injury was not assessed. In 2002, hemorrhages of euthanized fish were further analyzed using digital imaging software (Image J version 1.36b; Wayne Rasband, National Institute of Mental Health, Research Services Branch, Bethesda, Maryland). The area (in pixels) of each hemorrhage relative to the area of the fillet was determined ($n = 63$ hemorrhages from 17 fish [2 fillets/fish]).

Logistic regression was used to model the relationship between euthanization date, fish size, or fish sex and the likelihood of combined injury (presence–absence of either hemorrhage type) using a generalized linear model. Assessment of a date effect on combined injury was important, since physiological status of the muscular tissue changed during reproductive maturation (Figure 1; note the pale appearance of tissue in the lower photograph). Data were analyzed and reported for combined injury and vertebral injury (muscular injury alone was minimal and is not reported; however, it can be calculated by subtracting vertebral injury from combined injury). In the binary logit model, the response variable was likelihood of combined fish injury (hemorrhage present or absent), the explanatory value was size (fork length [FL]; size was correlated with response to electroshock in a study by Dalbey et al. [1996]), and the class variables were fish sex and euthanization date. All two-way interactions were considered in the initial model. We assessed the significance of the logistic regression models using a full–reduced-model likelihood ratio chi-square (χ^2) test. The likelihood of fish vertebral injury (presence or absence) was analyzed using the same logistic methods, explanatory variables, and class variables used for combined injury. A Kruskal–Wallis test was used to compare hemorrhage size (imaged from photographs) among sampling dates, as these data did not meet the assumptions of analysis of variance (ANOVA).

Immobilization of fish for gamete collection.—During two gamete collection days in 2002 and 2003, we compared the use of EA to the use of MS-222. Water temperature was approximately 10°C, and ambient conductivity was between 37 and 45 μS/cm. Adult Chinook salmon (n = 12–14) were crowded randomly from holding ponds and immobilized by use of either MS-222 or EA. The EA treatment was applied first, and then the treatment tank was filled with MS-222 (50 mg/L). The two treatments were alternated through the day, resulting in two MS-222 exposure groups and two EA exposure groups. The holding tank was drained and refilled with freshwater between treatments. Immobilized adults were sexed and checked for maturity. Ripe males were killed with a blow to the head. Ripe females were dispatched with a pneumatic guillotine and were allowed to bleed for approximately 3–5 min before egg collection. Approximately every other fish (males and females) was measured (FL) and filleted (operculum to tail). Both the right and left fillets were photographed, and blood vessel hemorrhaging was assessed as described previously. In 2002, photographs of individuals with hemorrhages were analyzed to estimate hemorrhage size relative to fillet surface area ($n = 155$ hemorrhages from 59 individuals). Adults that were not ripe were returned to the holding pond for future gamete collection. Unripe fish from each treatment group were marked with opercular punches (hole punches in the opercular plate); two punches were applied to MS-222-treated fish, and one punch was applied to EA-treated fish. On the second gamete collection date, males and females were paired within a treatment group (i.e., only EA × EA and MS-222 × MS-222 pairings were used).

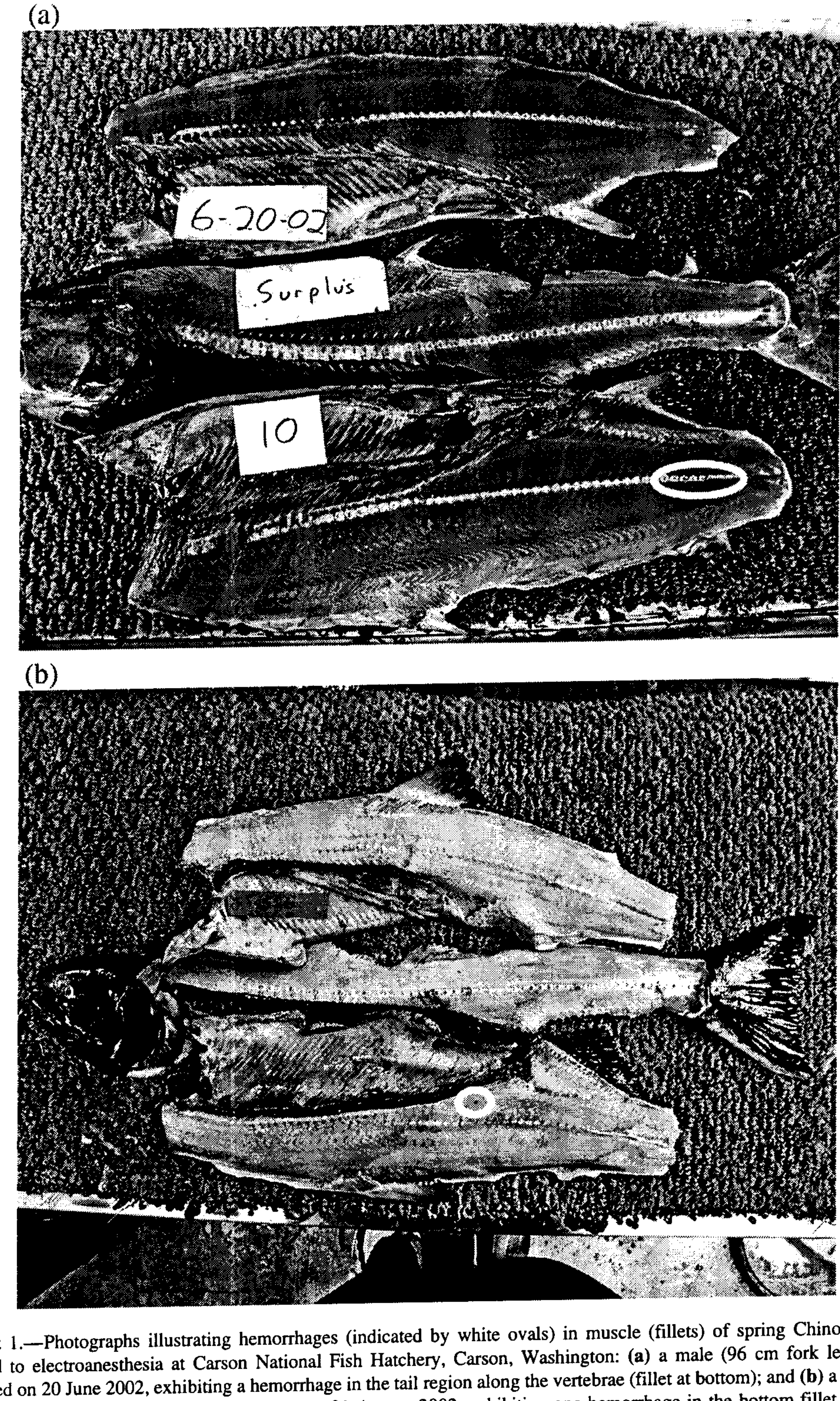

FIGURE 1.—Photographs illustrating hemorrhages (indicated by white ovals) in muscle (fillets) of spring Chinook salmon subjected to electroanesthesia at Carson National Fish Hatchery, Carson, Washington: **(a)** a male (96 cm fork length [FL]) euthanized on 20 June 2002, exhibiting a hemorrhage in the tail region along the vertebrae (fillet at bottom); and **(b)** a female (96 cm FL) anesthetized prior to gamete collection on 21 August 2002, exhibiting one hemorrhage in the bottom fillet.

Eggs were removed from females by abdominal incision, milt was collected from males, and fertilization was achieved using standard hatchery practices. A 1:1 random pairing of males to females was maintained. Eggs from an individual cross were placed in a plastic colander suspended in a bucket (7.6 L) supplied with single-pass spring water (7.6 L/min; 7°C). To prevent fungal growth, eggs were treated three times weekly with formalin (1,667 mg/L, 15-min exposure). Eggs from 60 females (30 fish/treatment group) were physically shocked via gentle transfer between two containers to reveal dead eggs (those that were white and opaque), which were counted and removed by hand. The total number of live eggs was calculated by weight based on a sample weight of 500 eggs/female. Fecundity was calculated as the sum of live and dead eggs for each female. In 2002, the eggs used for the sample weight for each female were transported to USFWS Abernathy Fish Technology Center (AFTC), Longview, Washington, to further track hatching and fry growth. Data on hatching and fry growth were not collected in 2003.

Logistic regression was used to model the relationship between immobilization treatment, gamete collection date, fish size, or fish sex and the likelihood of combined injury (presence–absence) using a generalized linear model. Treatment, fish sex, and date were class variables in the binary logit model. A model that incorporated all two-way interactions was used. Fish size was initially included as an explanatory variable but was removed from the final model due to its strong correlation with sex. The likelihood of vertebral injury (presence–absence) was analyzed using the same logistic methods and explanatory variables that were used for the combined injury analysis. A two-way ANOVA on ranked data (since data were not normally distributed and did not have equal variances) was used to determine date and treatment effects on hemorrhage size as determined from photographs.

Progeny growth and survival.—Upon arrival at AFTC, eggs were loaded into vertical tray incubators at a density of 500 eggs/tray (each tray contained eggs from a single female). Flow in the incubators was 11.4 L/min for eyed eggs and 18.9 L/ min for fry. During incubation, the water was 12.5°C and saturated with oxygen. To control fungus, formalin treatments (1,600 mg/L for 15 min) were performed daily until hatch. At the swim-up stage, fish from each egg take were divided randomly among six tanks (3 tanks/treatment). Fish were fed an ad libitum ration of BioDiet (BioOregon, Warrenton, Oregon) for 2 months to allow acclimation to the feeding process and tank environment.

After the growth trial was initiated, fish were fed BioDiet Starter 3 (first week of the trial) and BioDiet 1000 (remainder of the trial) in accordance with the manufacturer's feeding guidelines. Feeding rates (percent body weight per day) varied from 4.1% at the beginning of the trial to 2.6% at the end. The total tank biomass was determined every 2 weeks by weighing all individuals collectively, and ration amount was adjusted accordingly. The FL and weight of 30 randomly sampled fish from each tank were determined at the beginning and end of the trial. The absolute growth rate for each tank was calculated based on the following formula (Busacker et al. 1990): $(Y_2 - Y_1)/t$, where Y_2 is the individual mean weight at the end of the trial, Y_1 is the individual mean weight at the beginning of the trial, and t is the number of days in the trial.

Initial and final FLs, initial and final wet weights, and absolute growth rate were analyzed using a three-way ANOVA with tank, egg take, and treatment as the explanatory variables. When the ANOVA indicated significant differences, Tukey's multiple comparison technique was then used.

Results

Euthanization of Excess Fish

In 2002, 55 fish (36 males and 19 females) were sampled; mean (±SE) FL was 79.0 ± 3.1 cm for males ($n = 23$) and 76.0 ± 0.6 cm for females ($n = 11$). In 2003, 45 fish (17 males and 28 females) were sampled; mean FL was 81.20 ± 2.02 cm for males ($n = 16$) and 79.10 ± 1.26 cm for females ($n = 29$).

In 2002 and 2003, electroshock resulted in hemorrhage injury to 33–71% of euthanized fish (Table 1). Nearly all injured individuals had hemorrhages associated with the vertebrae (e.g., Figure 1a). The relation between likelihood of combined injury or vertebral injury and euthanization date, sex, or fish size was not significant in either year (logistic regression: all $P > 0.10$).

The number of hemorrhages per fish ranged from 0 to 8 (2002: 1.07 ± 0.27 hemorrhages/fish; 2003: 1.38 ± 0.16 hemorrhages/fish). In 2002, median hemorrhage size was 0.07% of the fillet surface area (minimum = 0.01%; maximum = 0.33%). Hemorrhage size did not vary with date ($P = 0.28$, $n = 63$ hemorrhages).

Immobilization of Fish for Gamete Collection

In 2002, 120 fish (55 males and 65 females) were sampled for injury assessment during the first egg take and 122 fish (61 males and 61 females) were sampled during the second egg take. Mean (±SE) FL was 79.0 ± 0.8 cm for males and 76.0 ± 0.4 cm for females. In 2003, 89 fish (45 males and 44 females) were sampled for injuries during the first egg take and 98 fish (49

TABLE 1.—Percentages of male, female, and all spring Chinook salmon (n = number of fish examined) that exhibited one or more hemorrhages in muscle after euthanization by electroshock at Carson National Fish Hatchery, Carson, Washington. Vertebral injury was hemorrhaging associated with the spinal cord; combined injury was any muscle hemorrhage regardless of association with the spinal cord (i.e., vertebral injury plus muscle injury, as defined in Methods).

	Male injury			Female injury			Total injury		
Date	Vertebral (%)	Combined (%)	n	Vertebral (%)	Combined (%)	n	Vertebral (%)	Combined (%)	n
2002									
6 Jun	57	57	7	50	50	8	53	53	15
12 Jun	44	56	9	50	50	4	46	54	13
19 Jun	50	58	12	40	40	5	47	53	17
26 Jun	50	50	2	80	80	5	71	71	7
8 Jul	NA	NA	NA	67	100	3	67	100	3
2003									
3 Jun	14	29	7	37	37	8	27	33	15
10 Jun	20	20	5	70	90	10	53	67	15
1 Jul	50	50	4	27	27	11	33	33	15

males and 49 females) were sampled during the second egg take. Mean FL was 84.0 ± 1.1 cm for males and 82.0 ± 0.8 cm for females.

In 2002 and 2003, EA resulted in combined injury (Figure 1b) or vertebral injury (Figure 1a) to 24–71% of all processed fish, regardless of sex or number of times shocked (Table 2). Most hemorrhage injuries were associated with vertebrae. The use of MS-222 resulted in a 2–16% combined injury rate that was also primarily related to vertebrae. Relations between combined injury or vertebral injury and gamete collection date, treatment, or sex were significant for 2002 but not for 2003 (Table 3). Fish exposed to EA had significantly higher levels of combined injury than those exposed to MS-222. Furthermore, combined or vertebral injury level was significantly higher on the second gamete collection date than on the first collection date; the gamete collection date × treatment interaction was significant for the combined injury data. In 2002, males had a higher rate of combined injury than females.

The number of hemorrhages (along the entire fillet surface) per fish ranged from 0 to 8 (EA: 1.33 ± 0.17 hemorrhages/fish in 2002, 1.61 ± 0.21 hemorrhages/fish in 2003; MS-222: 0.27 ± 0.09 hemorrhages/fish in 2002, 0.22 ± 0.16 hemorrhages/fish in 2003). In 2002, the median hemorrhage area was 0.06% (minimum = 0.01%; maximum = 0.48%) of the fillet surface area (e.g., Figure 1b). Hemorrhage size did not vary between dates or treatments (two-way ANOVA: date P = 0.45, treatment P = 0.356, date × treatment interaction P = 0.71; n = 151 hemorrhages). Fecundity, progeny survival to eye-up, and progeny survival from eye-up to swim-up did not differ between females that were immobilized with MS-222 and those immobilized with EA (Table 4).

TABLE 2.—Percentages of male, female, and all spring Chinook salmon (n = number of fish examined) that exhibited one or more hemorrhages in muscle after being immobilized with electroanesthesia (EA) or tricaine methanesulfonate (MS-222) during gamete collection at Carson National Fish Hatchery, Carson, Washington. Ripe fish were euthanized (males by a blow to the head; females by pneumatic guillotine), and fillets were examined for hemorrhages immediately after gamete collection. Vertebral injury was hemorrhaging associated with the spinal cord; combined injury was any muscle hemorrhage regardless of association with the spinal cord (i.e., vertebral injury plus muscle injury, as defined in Methods).

		Male injury			Female injury			Total injury		
Date	Method	Vertebral (%)	Combined (%)	n	Vertebral (%)	Combined (%)	n	Vertebral (%)	Combined (%)	n
2002										
14 Aug	EA	46	46	28	6	6	34	24	24	62
	MS-222	7	11	27	6	6	31	7	9	58
21 Aug	EA	70	87	30	50	53	30	60	70	60
	MS-222	19	19	31	10	13	31	15	16	62
2003										
14 Aug	EA	26	39	23	23	32	22	24	36	45
	MS-222	5	14	22	0	5	22	2	9	44
21 Aug	EA	61	68	31	74	74	31	68	71	62
	MS-222	6	6	18	6	6	18	6	6	36

TABLE 3.—Results (*P*-values of maximum likelihood ratio tests) of logistic regressions examining the effects of immobilization treatment method (electroanesthesia or tricaine methanesulfonate), collection date (14 or 21 August), and sex on the presence of vertebral injury (muscle hemorrhage associated with the spinal cord) or combined injury (any hemorrhage regardless of association with the spinal cord; i.e., vertebral injury plus muscle injury, as defined in Methods) in spring Chinook salmon used for gamete collection at Carson National Fish Hatchery, Carson, Washington, 2002–2003.

	Vertebral injury		Combined injury	
Explanatory variable	2002	2003	2002	2003
Date	<0.001	<0.024	<0.001	0.308
Treatment	<0.001	<0.001	<0.001	<0.001
Sex	0.002	0.592	<0.001	0.504
Date × treatment	0.308	0.581	0.034	0.047
Date × sex	0.199	0.265	0.47	0.341
Treatment × sex	0.277	0.402	0.045	0.519

Progeny Growth and Survival

Mean FL and body weight of fry at the time of transfer from trays to tanks did not differ between progeny of MS-222- and EA-treated broodstock (Table 5). Furthermore, the growth rate measured in the 57-d growth trial did not differ between progeny of the two immobilization treatment groups (Table 5). No relationship between egg take or tank and initial fish size or growth rate was apparent. Although initial size and absolute growth rate did not differ significantly, the progeny of the EA-treated group were slightly larger than the progeny of the MS-222-treated group at the end of the growth trial (weight: $P = 0.02$; FL: $P = 0.01$).

Discussion

Electroshock is a viable alternative to MS-222 for euthanizing and immobilizing adult spring Chinook salmon. When administered properly, electroshock can provide a safe and efficient means of euthanizing excess adult Chinook salmon while maintaining satisfactory flesh quality. We found no discernable effect of electroshock exposure (immobilization) on spring Chinook salmon reproductive performance (fecundity) or progeny (eggs and fry) survival and growth. Mortality rates for EA- and MS-222-treated fish did not differ between the first and second spawning dates, and there were no obvious EA effects during interim periods. Adults subjected to electroshock had a significantly higher likelihood of combined injury than adults receiving the MS-222 treatment. However, the median area of injury per fish was less than 0.06% of the representative viewed fillets.

Electroshocking excess fish for euthanization resulted in acceptable fillet quality and satisfactory working conditions. A Yakama Nation representative judged the excess electroshocked fish to be appropriate for both tribal consumption and ceremonial purposes (C. James, Yakama Nation, personal communication). By Alaska Seafood Marketing Institute standards, the fillets would

TABLE 4.—Mean (±SE) egg weight (calculated from a sample weight of 500 eggs/female), fecundity (total number of eggs [live or dead] per female), progeny survival to eye-up (%), and progeny survival from eye-up to swim-up (%) for female spring Chinook salmon subjected to immobilization with electroanesthesia (EA) or tricaine methanesulfonate (MS-222) during gamete collection at Carson National Fish Hatchery, Carson, Washington. Data on survival after eye-up were not collected in 2003.

Date	Method	Egg weight (g)	Fecundity (eggs/female)	Survival to eye-up (%)	Survival from eye-up to swim-up (%)	Number of females
2002						
14 Aug	EA	0.21 ± 0.004[a]	4,144 ± 155	80.5 ± 4.1[b]	95.2 ± 1.1	31
	MS-222	0.22 ± 0.007[b]	4,337 ± 170	81.1 ± 2.9	95.3 ± 1.1	31
21 Aug	EA	0.21 ± 0.005	4,425 ± 158	89.9 ± 3.3[a]	95.1 ± 1.1[c]	30
	MS-222	0.21 ± 0.005	4,236 ± 150	92.9 ± 2.1	95.7 ± 0.7	31
2003						
21 Aug	EA	0.24 ± 0.005	4,504 ± 119	93.2 ± 1.7		31
	MS-222	0.21 ± 0.006	5,106 ± 290	95.6 ± 1.1		17

[a] Calculated from the progeny of 29 females.
[b] Calculated from the progeny of 30 females.
[c] Calculated from the progeny of 28 females.

TABLE 5.—Mean (±SE) initial fry weight and fork length (FL), final weight and FL after a 57-d trial, absolute growth rate, and number of fish sampled (n) to examine growth performance in progeny of female spring Chinook salmon subjected to immobilization with electroanesthesia (EA) or tricaine methanesulfonate (MS-222) during gamete collection at Carson National Fish Hatchery, Carson, Washington, in 2002.

	Initial		Final			
Method	Weight (g)	FL (mm)	Weight (g)	FL (mm)	Growth rate (g/d)	n
EA	1.2 ± 0.02	52.2 ± 0.30	5.4 ± 0.08	77.8 ± 0.35	5.5 ± 0.60[a]	180
MS-222	1.2 ± 0.02	51.9 ± 0.30	5.1 ± 0.08	76.5 ± 0.40	4.9 ± 0.30[a]	180

[a] Calculated from six tanks.

be grade 2, defined as being acceptable for canning, mincing, or breading.

The EA device reduced labor requirements; previous operations at CNFH required a total of eight staff members, whereas electroshock required only three staff members. Electroshock eliminated the need to euthanize fish with a blow to the head, which is time consuming and physically demanding for personnel.

The effects of EA use in hatcheries on the long-term survival and injury rates of exposed fish have not been closely examined. However, a large body of evidence has accumulated that details the effects of electrofishing on individual injury and performance (Reynolds 1996; Snyder 2003). Several researchers have noted an alarmingly high rate of internal hemorrhaging and spinal injuries caused by both backpack (Hollender and Carline 1994) and boat (Sharber and Carothers 1988; Sharber et al. 1994; Thompson et al. 1997) electrofishing. Schill and Elle (2000) report that it can take up to 3–5 weeks for electrofishing-induced hemorrhages to heal and that the hemorrhage severity often increases through the first 2 weeks postexposure before declining. Furthermore, high mortality in eggs from backpack-electroshocked spring Chinook salmon females has been reported (Cho et al. 2002). The effects of electroshock on adult injury and on the progeny of treated fish in hatcheries have received little attention. Our study partly addresses this information gap by comparing hemorrhaging rates between EA and MS-222 groups and examining performance of the resultant progeny.

Our results are in agreement with previous findings that describe growth and survival of progeny from salmonids exposed to electroshock for purposes of gamete collection. For example, when EA is administered properly (i.e., when settings are systematically and carefully determined before production use), egg and fry survival is high and comparable with that associated with CO_2 use for adult steelhead *O. mykiss*, fall Chinook salmon (Tipping and Gilhuly 1996), and chum salmon *O. keta* (Tesch et al. 1999). Redman et al. (1998) also reported that progeny of brown trout *Salmo trutta* that were exposed to EA and MS-222 had equivalent survival and growth.

The long-term effects of electroshock on broodstock, especially fish that are maintained for long periods after treatment or that are handled multiple times, are not well documented. Tesch et al. (1999) reported survival rates of eggs from adult chum salmon exposed once to electrical shock, but they did not examine the effects of low DC voltage on the adults themselves. Redman et al. (1998) demonstrated that brown trout held for 6 months after EA treatment had a significantly higher mortality rate than fish treated with MS-222. In a study by Tipping and Gilhuly (1996), the recovery rate (hatchery returns) of EA-treated adult steelhead that were released into the wild was lower than the recovery rate of fish treated with CO_2. Those authors speculated that the lower recovery rate was due to an increased rate of delayed mortality for EA-treated fish.

Although our data show that EA resulted in more injuries than did MS-222, all hemorrhages (2002 data; regardless of treatment) were a small percentage of the fillet surface. However, when associated with vertebrae these hemorrhages could have an effect on subsequent performance. Injuries due to EA (i.e., those not visible upon external examination) could explain the negative results observed previously for this method (Tipping and Gilhuly 1996; Redman et al. 1998). Conversely, any increase in internal injury or stress during handling procedures could affect long-term survival of adult broodstock. These findings suggest that the use of electroshock must be carefully considered for broodstock programs in which repeated fish handling is necessary. However, due to the semelparous reproductive strategy of Pacific salmon, EA is a viable alternative for use in most hatchery programs for these species. The exception would be any steelhead program that attempts to recondition kelts for use as spawners in later years.

Optimal methods for immobilizing and euthanizing fish have been defined as those that cause the fish to become unconscious and remain so until death without avoidable excitement or pain (Van de Vis et al. 2003).

Many electroshocked individuals in this study exhibited some level of muscular hemorrhaging, but the method rendered fish immobile within seconds. While data suggest that electroshock is a useful tool for adult spring Chinook salmon immobilization and euthanization, fish pain perception is poorly understood and currently available studies are conflicting (UFR Committee 2004; Iwama 2007). Some evidence indicates that since pain is a psychological experience and fish lack the neurological structure associated with its perception, their detection of pain is a neurological impossibility (Rose 2002, 2007). Given the equivocal evidence of pain perception in fish, the best euthanization approach is to render fish unconscious (as with electrical stunning; Van de Vis et al. 2003) and prevent recovery. Our study concurs with previous studies showing that electrical stunning can be used to humanely slaughter salmon and other fish when conducted properly (Van de Vis et al. 2003; Lambooij et al. 2007). However, further research is needed to assess various methods of immobilization and euthanization to select the best technique for achieving hatchery goals.

An important aspect of EA application is the need to optimize the voltage and pulse settings based on site-specific differences in water conductivity, treatment chamber size, fish size, and species. Optimizing settings in the first year can be a significant commitment in labor and time. Settings must then be reviewed annually with established, relatively simple assessments, as optimal settings may change from year to year due to annual changes in fish size, condition, and water quality. Various authors have outlined the importance of identifying the best settings (voltage and pulse width) for individual hatchery situations. Tipping and Gilhuly (1996) advocated the use of electroshock, but they also emphasized the importance of using low voltage because of the notable damage to shocked adults at high voltages. Tesch et al. (1999) provided the caveat that each facility must optimize electrical settings based on water quality and proximity of the gamete collection area to the egg take area. Walker et al. (1994) outlined the importance of species specificity (particularly size at anesthesia) in electrical settings and the differences between AC and DC use. Roth et al. (2004) showed that a square AC wave inflicted more injury (spinal column and hemorrhaging) on Atlantic salmon *Salmo salar* than did a sinusoidal AC wave. Defined endpoints of fish health and quality are needed for all assessments. We suggest annual examination of internal hemorrhaging as a convenient and quantifiable method of monitoring EA effects on fish quality. Research focusing on the duration of EA-induced injury and the presence and severity of long-term effects is needed.

Acknowledgments

The findings and conclusions in this manuscript are those of the authors and do not necessarily represent the views of the USFWS. The use of commercially available equipment does not denote an endorsement by the authors or the USFWS. The authors gratefully acknowledge the CNFH staff, especially Randy Berge and Jeff Blaisdell, and AFTC staff members Jeff Poole and Megan Hill for their help with data collection and fish handling. We thank Yakama Nation tribal member and U.S. Bureau of Indian Affairs representative C. James, Jr., for assistance in examining the fillet quality of euthanized fish. Lastly, we are grateful to Rich Johnson from the USFWS Fishery Resources Pacific Region, who helped to secure funding for this project.

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