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Cormorant Harassment to Protect Juvenile Salmonids in Tillamook County, Oregon

2000

by Range D. Bayer

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EXECUTIVE SUMMARY

The goal of the Oregon Plan is to restore wild coho and wild steelhead runs. Under the federal Endangered Species Act, wild coho salmon along the Oregon Coast are listed as Threatened and wild Oregon Coast steelhead are a candidate for listing. Although cormorants have been hazed at the Nehalem Estuary for at least 10 years and at the Tillamook and Nestucca Estuaries for at least three years, spawning ground counts of wild coho salmon, winter steelhead, and fall chinook have averaged less since hazing began. Thus, hazing does not appear to be useful in recovering wild salmonids.

Hazing is not correlated with consistently improved hatchery returns. The survival of Coded Wire Tag marked coho smolts at the Nehalem was about the same whether hazing occurred or not, the percent return for coho smolts was not significantly greater at the hazed Nehalem than at the nonhazed Salmon River, and the number of returning adult coho salmon was significantly greater with hazing at the Nehalem hatchery but not at the Trask hatchery in the Tillamook Basin. For winter steelhead, the number of returning adults to the Nehalem and jacks to the Cedar Creek hatchery in the Nestucca Basin did not increase significantly with hazing, but the number of jacks returning to the Nehalem did.

Changes in fisheries subsequent to hazing are mixed. Coho catches increased with hazing at the Nehalem but not at the Tillamook Basin. Nehalem steelhead catches averaged less with hazing, but chinook fisheries have grown. However, the increase in chinook catches occurred as the number of wild chinook at spawning areas declined, so the larger catch may be a consequence of a greater harvest of wild chinook rather than hazing.

Returns may not have increased with hazing because it was ineffective in substantially reducing predation, because smolts saved by hazing died anyway, or because other factors such as unfavorable ocean conditions may have been much more important in affecting smolt survival than hazing.

In any case, hazing does not appear to be a panacea for salmonid recovery, and it has costs. During 1996-1999, the Oregon Legislature spent $100,000 for cormorant hazing, and a biological cost of hazing is the disturbance of wildlife other than cormorants.

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ACRONYMS

ADC	Animal Damage Control Program of U.S. Dept. of Agriculture, which is currently known as the Wildlife Services Agency of the U.S. Dept. of Agriculture
CWT	Coded Wire Tag
ESA	federal Endangered Species Act
NMFS	National Marine Fisheries Service
OAR	Oregon Administrative Rules
OCSRI	Oregon Coastal Salmon Restoration Initiative (1997a,b)
ODFW	Oregon Department of Fish and Wildlife
OSU	Oregon State University
PDT	Pacific Daylight Time
PFMC	Pacific Fishery Management Council
SPP	Smolt Protection Program, which is conducted by private individuals, under contract to the ODFW (see section C-1)
STEP	Salmon and Trout Enhancement Program of ODFW
USFWS	U.S. Fish and Wildlife Service

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A. INTRODUCTION

The purpose of the Oregon Coastal Salmon Restoration Initiative (OCSRI 1997a,b) is to recover populations of wild coastal coho salmon and wild coastal steelhead (common and scientific names are given in Appendix I). After the OCRSI was proposed, wild Oregon coastal coho salmon were listed as Threatened under the federal Endangered Species Act (ESA)(National Marine Fisheries Service [NMFS] 1998), and wild Oregon coastal steelhead are a candidate for listing under the federal ESA (Busby et al. 1996, Chilcote 1998; http://www.nwr.noaa.gov as of 12/11/1999). The OCRSI has been extended in the Oregon Plan to all at-risk wild salmonids throughout the state (Kitzhaber 1999). Thus, the primary state and federal goal is the recovery of wild salmonid populations.

Accordingly, actions that would increase the number of wild adult coho or steelhead to Oregon Coast spawning areas would be beneficial. Such actions could include cormorant harassment (hazing), which has been claimed in testimony before the Oregon Legislature and in newspaper and magazine articles to improve salmonid returns (Erickson 1989a,b,d; 1992, 1993, 1995a,b; Monroe 1995b, 1996a; Nokes 1995). Acting on these assertions, the Legislature has allowed and funded harassment (section C-1).

This paper has two purposes. First, to determine if cormorant hazing in Tillamook County is correlated with increased returns of wild salmonids, and thus possibly important in achieving the goal of the Oregon Plan and ESA. The second purpose is to see if hatchery salmonid returns and fishery catches have been enhanced with hazing.

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B. STUDY AREAS

Information about the estuarine area, drainage basin size, and average freshwater flow in April-June (when many coho and winter steelhead smolts migrate through tidewater; Appendix II) for estuaries included in this report are in Table 1, and their location is shown in Fig. 1. Note that estuaries differ markedly in these characteristics, and annual variation is to be expected.

Cormorant hazing has occurred in Tillamook County in tidewater portions of the Nehalem, Tillamook, and Nestucca basins (section C). Each basin (Fig. 1) has one hatchery: the North Fork of the Nehalem hatchery in the Nehalem Basin, the Trask hatchery in the Tillamook Basin, and the Cedar Creek hatchery in the Nestucca Basin.

The Salmon River, Siletz, and Alsea basins are most often used for comparison with the Nehalem (where most hazing has occurred, section C) because they are the nearest basins that are most like the Nehalem. For example, like the Nehalem, many hatchery coho and winter steelhead smolts have been released into each (Kostow 1995: Appendix A; Lewis 1997) and their sport fisheries are large enough to compare to the Nehalem (ODFW 1998b). However, they are 54-90 mi south of the Nehalem (Table 1), so human and environmental factors may affect them differently than the Nehalem. Other nonhazed basins (e.g., the Necanicum) are also included if spawning ground counts are available or if their coho or winter steelhead sports fisheries are substantial (ODFW 1998b). The Columbia is excluded because it has an estuary area of 147 sq mi (ODSL 1973), which is more than twice as large as all the rest of these estuaries combined, and it also differs politically and biologically from other coastal estuaries.

Compilations of information about salmonids in coastal basins exist for the Tillamook (Ellis 1998), Yaquina, Alsea, Salmon, Siletz, and other mid-coast stream basins (ODFW 1991,1997a-e); but fisheries management plans have not yet been prepared for the Nehalem, Tillamook, or Nestucca Basins (Rick Klumph, ODFW, pers. comm.).

FIGURE 1. Location of bays/estuaries (east of shoreline) that are mentioned in the text, with nearby large towns or landmarks listed west of the shoreline. The shoreline of Tillamook County is approximately from Cape Falcon to Cascade Head.

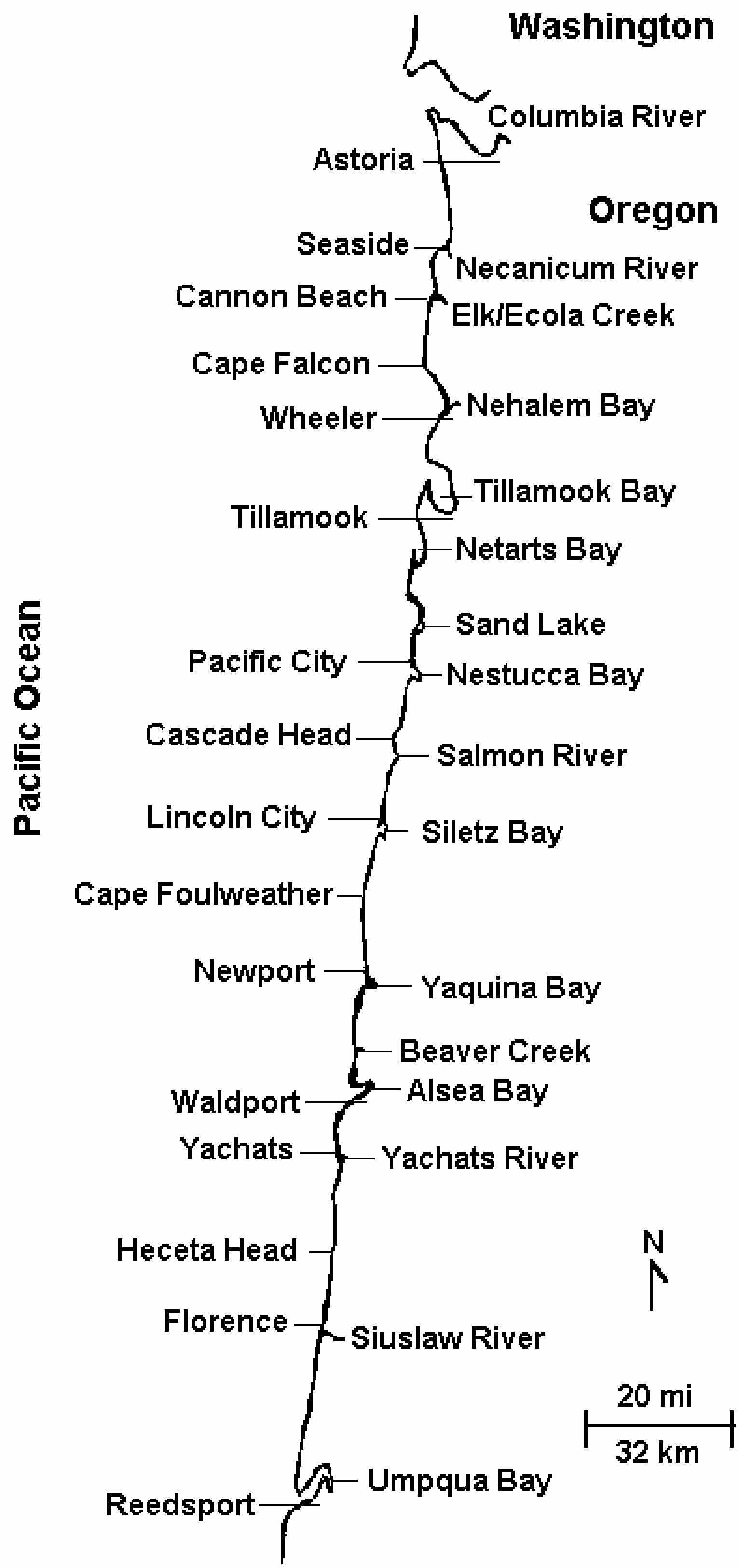

TABLE 1. Oregon estuaries included in analyses of cormorant hazing. ?=unknown.

Estuary	Estuary Area (sq mi)*	Drainage Basin*@ (sq mi)	Mean Freshwater Inflow @@ (1,000 cfs) APR	MAY	JUN	Distance & Direction from Nehalem** (mi)	Known Corm. Hazing
Necanicum	<1	87	?	?	?	21 north	no
Elk/Ecola Creek #	?	?	?	?	?	13 north	no
Nehalem	4	855	3.3	1.6	0.7	0	yes
Tillamook	13	540	3.8	2.1	1.1	9 south	yes
Nestucca	2	322	?	?	?	37 south	yes
Salmon River	<1	75	?	?	?	46 south	no
Siletz	2	373	2.7	1.5	0.9	54 south	no
Yaquina	6	253	1.2	0.5	0.3	76 south	no
Beaver Creek #	?	?	?	?	?	83 south	no
Alsea	3	474	2.1	1.3	0.6	90 south	no
Umpqua	11	4,560	?	?	?	137 south	no

Estuary so small that it is not included in ODSL (1973), Percy et al. (1974), or Shirzad et al. (1988).
* ODSL (1973) area in acres converted to sq miles.
*@ Percy et al. (1974:3).
@@ Shirzad et al. (1988); cfs=cubic feet per second.
** Straight line distance to the mouth of each estuary.

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C. HAZING METHODS

C-1. AUTHORIZATION OF HAZING

A state permit is required to legally harass migratory birds on public lands or waters of Oregon (Bayer 1989:10, ODFW 1998a:11, 13, 19, 22). Roy Lowe (U.S. Fish and Wildlife Service [USFWS], pers. comm.) thought that a federal permit might also be required if such harassment directly impacted nesting success.

In the spring of 1988, the Oregon Department of Fish and Wildlife (ODFW) Director, Randy Fisher, authorized the issuance of a series of state permits to allow private citizens to harass cormorants on public waters of Nehalem and Tillamook Bays (Bayer 1989:12). The harassers were not monitored by the ODFW (Bill Haight, ODFW, pers. comm.) or USFWS (Thomas Riley, USFWS Law Enforcement, pers. comm.). The Director can issue such permits by declaring an emergency and assuming the powers of the Oregon Fish and Wildlife Commission.

In 1989, the Oregon Fish and Wildlife Commission and the ODFW Director refused to issue any more permits, although petitioned to do so (e.g., Erickson 1989e, Bayer 1989:13-14, ODFW 1998a:22). Consequently, harassment proponents turned to the Oregon Legislature, and House Bill (HB) 3185 was introduced into the 1989 Session to allow cormorant harassment, but it did not pass (Bayer 1989:13-14, 55-58; ODFW 1998a:22). HB 2735 passed during the 1989 Session and directed the ODFW to study how to protect hatchery smolts; this resulted in Schaeffer's (1991) thorough literature review.

In 1995-1997, the Oregon Legislature passed bills directing the Commission to issue not more than three permits to private citizens to harass cormorants on public waters in Tillamook County and to allocate $25,000 of state funds per year to compensate the permittee's expenses in conducting cormorant harassment (1995 Senate Bill 707, 1996 [Special Session] House Bill 3483, and 1997 Senate Bill 5503; see http://www.leg.state.or.us). The 1995 bill was vetoed by Governor Kitzhaber (Monroe 1995b); however, the 1996 bill passed, so hazing is now authorized each year. But state funding of hazing must be approved each biennium by the Oregon Legislature; funding in the amount of $50,000/biennium was approved for 1996-1999. To obtain these funds, an annual report for hazing in these Smolt Protection Programs (SPP) is required for each bay; these reports are available from the ODFW (SPP 1996-1998). The permittees were not monitored by the ODFW (Kay Brown, ODFW, pers. comm.).

In 1997, Oregon Senate Bill 622 (see http://www.leg.state.or.us) was introduced that would have expanded cormorant harassment to all Oregon coastal streams and the main stem of the Columbia River and also would have removed a limit on the number of permits issued. A work session and public hearing were held, but it was not passed out of committee.

In 1999, the Legislature funded hazing for 2000-2001 (Charlie Bruce, ODFW, pers. comm.).

C-2. HAZING TECHNIQUES

C-2a. INTRODUCTION. Hazing methods need to be clearly stated, so that their effectiveness can be evaluated or others can use them in planning their own hazing program. Unfortunately, hazing methods in the SPP have not been adequately detailed.

C-2b. NEHALEM. Hazing was by cracker shells in 1988 and by a fast boat in following years (Table 2). Fast boats scared away cormorants by moving back and forth over schools of juvenile salmonids, while sometimes playing cormorant distress calls (Monroe 1995b, 1996a,b).

Scarecrows were also placed where smolts seemed to concentrate but seemed ineffective in keeping cormorants away after a day or so (SPP 1997-1998). A "Wytech" device (SPP 1996: April 18 and May 2-6, 16, 20) may have also been used (e.g., "Wytech seems to make birds nervous but very limited range. Will call and request long range unit"), but it is not explained what it is. Additionally, Monroe (1995b) wrote:

> "Smolt protectors tried a remote-control airplane one spring, but one of the operators wrecked it on the corner of a winding highway one afternoon while chasing a neighbor's truck. Volunteers went back to their boats."

C-2c. TILLAMOOK. In 1988, harassment was by cracker or screamer shells fired from firearms (Bayer 1989:12). In 1996 and 1998, the method is not given in SPP reports but was probably by using a fast boat like at the Nehalem. In 1997, a boat was used to patrol the upper and lower bay, and someone ran a hovercraft over Kilchis Flats during low tide on April 25 that disturbed cormorants in water too shallow for the hazing boat (SPP 1997). In 1997, a scarecrow at the mouth of the Wilson River was also used to deter cormorants (SPP 1997).

C-2d. NESTUCCA. Presumably, a boat was used to chase cormorants, and the use of a mannequin (scarecrow) or "dummy" was also mentioned (SPP 1996-1998).

C-3. YEARS OF HAZING

C-3a. NEHALEM. It is unclear if hazing occurred during 1985-1987. In 1985, hazing supplies were issued by the U.S. Dept. of Agriculture Animal Damage Control Program (ADC) to the President of the Nehalem Salmon and Trout Enhancement Program (STEP) group to be used by STEP volunteers to harass cormorants; these supplies may have included 12 gauge shotgun cracker shells and/or audio distress calls (Bayer 1989:11). In 1986, the ADC were contacted about hazing by staff from the ODFW North Fork Nehalem fish hatchery (Hoffman and Hall 1988). Hazing may have occurred in 1987 because Nokes (1995) indicated that there had been eight years of hazing at the Nehalem; since there was no hazing in 1995 (Monroe 1995b), backdating from 1994 suggests that hazing occurred in 1987. In any case, the interest in hazing was sufficient that by 1988, harassers were aware that they had to have permits to do so legally and went through the process of requesting these permits.

Hazing, with or without authorization, was reported during 1988-1994 (Table 2). This hazing was discussed during public testimony in the Oregon Legislature in 1989 (Parks 1989) and 1995 (Erickson 1995b), and there were also articles about it in fishing publications (e.g., Erickson 1992, 1993; Orcutt 1992), in the *Oregonian* (Oregon's largest newspaper)(Monroe 1995a,b; Nokes 1995), and in the Tillamook County newspaper (e.g., Erickson 1995a). Further, Roy Lowe (USFWS biologist, pers. comm.) notes that Erickson discussed his 1989-1992 Nehalem Bay hazing activities at the salmon predator workshop chaired by the Coastal Oregon Marine Experiment Station at the OSU Hatfield Marine Science Center on 28 September 1992, copies of Erickson's (1992) article about his hazing were available at the December 1992 Oregon Governor's Coastal Salmonid Restoration Initiative meeting at Otter Crest, and Lowe wrote the ODFW Director Randy Fisher about these unauthorized activities on 5 January 1993.

There was no hazing in 1995 (Monroe 1995b). This lapse may have been because hazers were no longer compensated for their expenses; Erickson (1995b) testified that a private individual had previously paid for the costs of gas and oil for hazing at the Nehalem, which was about $3,000 per year and that hazers had volunteered their time.

C-3b. TILLAMOOK AND NESTUCCA. State permits were given to allow hazing at Tillamook Bay in 1988 (section C-1). In 1993-1994, the boat used for hazing at Nehalem Bay was tested at Tillamook and Nestucca Bays during three days to see if it could haze cormorants (Erickson 1995b), but this test hazing would have been too brief to have a significant effect on reducing cormorant predation. In 1996-1998, hazing at Tillamook and Nestucca Bays occurred as part of the SPP (1996-1998).

C-4. SEASONAL TIMING OF HAZING

C-4a. NEHALEM. When documented, hazing occurred in spring from early or late April through early to mid-June (Table 2). In 1996 and 1998 SPP reports, there were notes for each day during this period, but it is not clear if hazing occurred daily; however, in 1996, there were at least three days without hazing and there were other days in which hazing probably did not occur because of bad weather. In the 1997 SPP report, the contractor was said to have hazed cormorants every day during the season.

Hatchery smolt releases occurred before hazing was authorized in at least 1996-1998 (Table 3), so cormorants may have been feeding on smolts prior to hazing. However, hazing occurred prior to authorization in at least 1998 (Monroe 1998).

C-4b. TILLAMOOK. Hazing was reported to have occurred during 21 April-20 June 1988, 15 April-7 June 1996, 8 April-15 June 1997, and 27 April-15 June 1998 (Bayer 1989:12, SPP 1996-1998), but hazing may also have occurred prior to authorization (Monroe 1998). In SPP (1996), there are daily records of the numbers of cormorants, but it is not clear if hazing occurred each day. In 1997 and 1998, there are no records of hazing during 12 and eight days of each season, respectively; six of these missed days in 1997 and one of the missed days in 1998 were before May 15.

C-4c. NESTUCCA. Harassment was recorded as starting on April 15, April 13, and April 14 in 1996-1998, respectively, and ended on June 15 each year (SPP 1996-1998). In SPP (1996), there are daily records, but it is not clear if hazing occurred each day. In 1997, there are no records during two days of the season, and, in 1998, there were no days without notes (SPP 1997-1998).

TABLE 2. Authorization, method, and duration of cormorant harassment at Nehalem during 1988-1998. The hazing dates are those given on permits, but hazing may have occurred earlier, as in 1998 (Monroe 1998). It is unclear if hazing occurred in 1985-1987. corm.=cormorants.

Yr	Hazing Permit Issued	Legal Species to Haze	Hazing.................... Method	Duration	Reference(s)
88	yes	corm.	shell A	4/8-6/6	B
89	no	none	boat	spring	C
90	no	none	boat	spring	D
91	no	none	boat	spring	D
92	no	none	boat	spring	D
93	no	none	boat	spring	D
94	no	none	boat	spring	D
95	no	none	no hazing	no hazing	Monroe 1995b
96	yes	corm.	boat & scarecrow	4/8-6/18	Monroe 1996a,b; SPP 1996
97	yes	corm.	boat & scarecrow	4/7-6/5	SPP 1997
98	yes	corm.	boat & scarecrow	4/24?-6/15	E

A Cracker or screamer shells shot from firearms.
B Hendrickson 1988, McAllister 1988, Bayer 1989:12, Erickson 1989d, 1992, 1993, 1995b; Monroe 1995b, Nokes 1995.
C Parks 1989, Bayer 1989:13, Erickson 1992, 1993, 1995b; Monroe 1995b, Nokes 1995.
D Erickson 1992, 1993, 1995a,b; Monroe 1995b, Nokes 1995.
E In 1998, authorization started on April 24, but hazing had already started (SPP 1998, Monroe 1998).

TABLE 3. Number of coho and winter steelhead fry, fingerlings, or smolts released into the Nehalem Basin during 1988-1998. These data were provided by John Leppink and Tracy Cabe of the ODFW. Dates of hazing are from Table 2. Hazing dates are from permits, but hazing in at least 1998 occurred before permits were issued (Monroe 1998). Thousands=thousands of fish released, Fr=fry, Fn=fingerling, Sm=smolt, WSte=winter steelhead. *=released at the North Fork of Nehalem hatchery; @=released elsewhere in the Nehalem Basin, *@=released both at the hatchery and also elsewhere in the Nehalem Basin on the same day.

	Juv Salmonid Release				
Yr	Date	Thousands	Age	Kind	Hazing Dates
88	3/2	67	Sm*	Coho	
	3/23	186	Sm*	Coho	
	3/28	487	Sm*	Coho	
	4/4	104	Sm*@	WSte	
	4/5	53	Sm*@	WSte	4/8-6/6
	6/8	124	Fn*	Coho	
89	1/31	206	Sm*	Coho	
	4/14	599	Sm*	Coho	?
	4/14	31	Sm*	WSte	
	4/19	123	Sm*@	WSte	
	4/28	53	Fn*	Coho	
	6/26	24	Fr*	WSte	
	6/29	24	Fr*	WSte	
	10/20	8	Fn*	WSte	
	10/26	4	Fn*	WSte	
90	2/2	65	Sm*	Coho	
	2/12	66	Sm*	Coho	
	2/22	67	Sm*	Coho	
	4/2	55	Sm*@	WSte	
	4/3	102	Sm*@	WSte	?
	4/16	632	Sm*	Coho	
	4/30	117	Fn*	Coho	
	6/20	2	Fr*	WSte	
	7/10	6	Fr*	WSte	
	10/30	6	Fn@	WSte	
91	2/25	57	Sm*	Coho	
	3/4	115	Sm*	Coho	
	4/2	20	Sm@	WSte	
	4/3	83	Sm*@	WSte	?
	4/4	7	Sm@	WSte	
	4/7	30	Sm*	WSte	
	4/11	564	Sm*	Coho	
92	1/24	69	Sm*	Coho	
	2/3	67	Sm*	Coho	
	2/14	70	Sm*	Coho	
	3/24	11	Sm*	WSte	
	3/30	63	Sm*@	WSte	
	3/31	70	Sm*@	WSte	
	4/13	626	Sm*	Coho	?
	4/20	54	Fn@	Coho	
	10/9	13	Sm@	WSte A	
93	2/8	65	Sm*	Coho	
	2/19	65	Sm*	Coho	
	3/3	65	Sm*	Coho	
	4/13	565	Sm*	Coho	?
	4/13	42	Sm*	WSte	
	4/15	48	Sm@	WSte	
	4/16	35	Sm*	WSte	
	9/29	26	Fn@	WSte	
94	2/28	213	Sm*	Coho	
	4/15	627	Sm*	Coho	?
	4/15	82	Sm*	WSte	
	4/27	51	Sm@	WSte	
	4/28	12	Sm*	WSte	
95	1/30	214	Sm*	Coho	
	4/10	7	Sm@	WSte	none
	4/14	576	Sm*	Coho	
	4/14	80	Sm*	WSte	
96	3/15	137	Sm*	Coho	4/8-6/18
	4/9	7	Sm@	WSte	
	4/12	83	Sm*	WSte	
	4/15	500	Sm*	Coho	
97	3/14	140	Sm*	Coho	
	4/2	15	Sm@	WSte	4/7-6/5
	4/15	489	Sm*	Coho	
	4/15	78	Sm*	WSte	
98	3/31	103	Sm*	Coho	
	4/13	15	Sm@	WSte	4/24?-6/15
	4/30	90	Sm*	Coho	
	4/30	63	Sm*	WSte	
	5/12	49	Fn@	Coho	

A 10/9/92 steelhead "smolts" weighed 13.8/lb, but smolts in spring weigh 5-7/lb, so these "smolts" were not as large as those in spring.

C-5. DAILY TIMING OF HAZING

C-5a. NEHALEM. During 1988-1994, it is unknown when hazing was done during the day. In 1996, hazing is recorded as occurring from about 7 AM Pacific Daylight Time (PDT) until early afternoon on some days; on other days, it is stated that hazing was done in the morning, but it is unclear if it was also done in the afternoon (SPP 1996). In 1997, it is stated that hazing occurred every day from 7 AM until 3 PM PDT (SPP 1997). In 1998, the daily duration of hazing is not specified (SPP 1998).

C-5b. TILLAMOOK. The duration of hazing during a day is not clearly recorded in 1996 and 1998 (SPP 1996, 1998). In 1997, the duration is not explicitly stated, but reports of hazing usually ranged from about 7 AM to 2 PM PDT; however, hazing in late May and early June was often only recorded in the afternoon and/or evening (SPP 1997).

C-5c. NESTUCCA. In 1996, the time of hazing was rarely recorded, but on three days when it was, patrolling occurred 11-14 hr/day (SPP 1996). In 1997, hazing was recorded as ending at 6:30-8 PM PDT on twelve days, but neither the starting time nor the ending time for other days was recorded (SPP 1997). In 1998, the starting and ending times were generally given, and hazing duration was usually about 11-14 hr/day (SPP 1998).

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D. METHODS OF COUNTING CORMORANTS IN 1996-1998

Descriptions of the methods of counting cormorants are essential but are insufficiently detailed in SPP (1996-1998). Examples of critical information include the starting and ending times of counts, the power of binoculars or telescope used for censusing, the area included in counts, the sites where censuses were made from, the methods of avoiding counting the same cormorants more than once during a census, and whether cormorant numbers were counted or estimated.

The census techniques that are described in SPP (1996-1998) raise questions about the accuracy of their cormorant counts for several reasons. First, it is essential that it is stated what bird species is being counted, but many counts (e.g., Nehalem Bay in 1996 and Nestucca Bay in 1996-1998) only give a number of "birds." Since only cormorants are supposed to be hazed, the reader could guess that the counts are of cormorants; however, other species were also disturbed (section F-3). Second, counts need to be of the entire area of concern, but only counts at Nehalem in 1998 state that they were for the "entire estuary"; other SPP counts appear to be point counts for where the hazer was at a particular time, not the whole bay. Third, counts need to be throughout the day to determine how cormorant abundance may change, but the 1998 Nehalem counts were just at 7 or 8 AM. Finally, a census should not include cormorants that have already been counted during that census. This can be difficult, especially if they are moving as they would be if they are being hazed, and it is not stated in any report how recounting the same birds was avoided.

Similar problems with cormorant counts in the 1999 SPP report are also described in Stahl et al. (2000:33-34).

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E. METHODS OF CORRELATING HAZING WITH SALMONID RETURNS

E-1. SALMONID SPECIES INCLUDED

Coho and steelhead are examined because hazing has been claimed to have greatly improved their returns (Erickson 1989a,b,d; 1993, 1995a; Monroe 1995b, 1996a; Nokes 1995). Further, smolts of both species are released (Table 3) or migrating to the ocean during spring (Appendix II-1 and II-2c), when hazing occurred. Chinook are included because juvenile chinook were observed at Nestucca Bay during early June 1996 hazing (SPP 1996) and may have been present at each bay during the time of hazing (Appendix II-3b), so hazing may have also affected their survival.

E-2. USE OF DATA WITH A TIME DELAY BETWEEN HAZING AND RETURNS

E-2a. INTRODUCTION. Stahl et al. (2000) used radiotracking to study the survival of hatchery coho smolts between release and their arrival at Fishery Point in Nehalem Estuary during the spring of 1999. Their short-term survival results suggest that there was substantial predation even with hazing and are discussed in section K-7. But adult return data are also essential in determining if hazing may be an important management tool because if hazing does not increase the number of adults returning to spawn or caught in fisheries, then its value is questionable, even if it may increase the survival of smolts migrating through an estuary (section K-3). Although jack and adult returns are affected by factors such as fisheries regulations and environmental conditions as well as hazing (Appendix V), proponents have claimed that hazing has improved jack and adult returns (Erickson 1989a,b,d; 1993, 1995a; Monroe 1995b, 1996a; Nokes 1995). Thus, correlating returns with hazing is appropriate.

E-2b. TIME DELAY OF RETURNS. Based on coho life history (Appendix II-1), any positive effects of hazing in improving survival of outmigrating smolts in the spring of one year may be correlated to increased jack returns during the fall of the same year or adult returns in the fall of the next calendar year. For example, hazing during the spring of 1988 may have affected returning jacks in the fall of 1988 and adults in the fall of 1989.

For winter steelhead, hazing in the spring of one year may affect jack (1-salt) returns after one summer in the ocean and adult returns after one or more additional summers in the ocean (Appendix II-2d). Because the percentage of adults coming back at a particular age can be variable (e.g., an average of 66-80% of adults returned after two summers in the ocean as 2-salts; Appendix II-2d), testing for the effects of hazing would be most robust for adults returning after at least two years and preferably 3-4 yr of hazing; this would be particularly true for wild adults because a higher percentage return as 3-salts and repeat spawners (Appendix II-2d).

Positive effects of hazing in the spring of one year on the survival of juvenile chinook may be correlated to jack returns during the following year and the returns of adults 2-6 years after hazing, when adults were 3-7 yrs old (Appendix II-3c). For example, hazing in the spring of 1988 may affect the returns of chinook jacks in 1989 and of adults mostly during 1990-1993. This large range and the yearly variation in the age of returning males or females (Appendix II-3c) make data analyses for determining the effects of hazing on chinook difficult. Hazing must occur for six consecutive years before it can be certain that all returning adults could have been affected by hazing when they migrated to the ocean as juveniles. The only bay where hazing has occurred that long is Nehalem.

E-3. TYPES OF JACK AND ADULT RETURN DATA

E-3a. SPAWNING GROUND COUNTS. The only long-term measure of wild coho, steelhead, and chinook abundance along the Oregon Coast is spawning ground surveys (Weber and Knispel 1977, Jacobs and Cooney 1997, Chilcote 1998). Although these surveys are only for portions of streams and consequently may not accurately estimate the total number of spawners for unsurveyed areas (Weber and Knispel 1977:52-53, Ellis 1998:3-6, Botkin et al. 1995 cited in Ellis 1998), these surveys are done consistently at the same areas, so these counts can be examined to see if changes in abundance are correlated with hazing.

E-3b. CODED WIRE TAGS (CWT) RETURNS. Some hatchery coho and chinook smolts were marked with CWT's for stock assessment (Lewis 1997). CWT recoveries are from ocean fisheries, hatcheries, and spawning ground surveys, but not freshwater fisheries (Lewis 1997:2, 13). For coho, only Nehalem returns are used for a basin with hazing because there are no CWT data available for the Cedar Creek hatchery (Nestucca Basin), and there are only two years of post-hazing data for the Trask or Trask Pond hatcheries (Tillamook Basin)(Lewis 1997). Chinook CWT data are not analyzed because there are no return data for the Nehalem (Lewis 1997) and hazing at the Tillamook Basin and Nestucca Basin only began consistently in 1996 and not all adults affected by this hazing would return until 2002. I did not find any steelhead CWT data.

E-3c. HATCHERY RETURNS. The number of fish returning to a hatchery can be affected by several factors (Appendix V), including the number of coho and steelhead smolts released (which has been variable at the Nehalem; Appendix III) and the season of counting returning fish (which has not been consistent, Table 4). However, correlating hatchery returns of coho and steelhead with hazing is appropriate because they have been reported as increasing as a consequence of hazing (Erickson 1989a,b,d; 1993, 1995a; Monroe 1995b, 1996a; Nokes 1995); for example, Monroe (1996a) wrote:

> "Strong hatchery returns of coho salmon and steelhead at the North Fork Nehalem fish hatchery have defied El Nino and other conditions blamed for flagging runs in most other streams. The hatchery's success coincided so closely with the local 'smolt protection program' that 1995 legislators finally approved this biennium's test for Nehalem, Tillamook and Nestucca bays."

Chinook hatchery releases into the Nehalem have been limited or discontinued (Nicholas and Hankin 1989: 253, Kostow 1995:A3-A4). Consequently, a maximum of 70 and generally less than a sum of 25 jack and adult chinook returned annually to the North Fork of Nehalem hatchery during 1984-1997 (John Leppink and Tracy Cabe, ODFW, unpubl. data); these are too few fish to test the effects of hazing.

Since hazing at the Tillamook Basin and Nestucca Basin only began consistently in 1996 and adult chinook can return at up to seven years old (Appendix II-3c), only returns of chinook jacks are tested at hatcheries in these basins to see if they have been affected by hazing.

TABLE 4. Number of winter steelhead jacks counted and season of counting returning steelhead at the North Fork of Nehalem River hatchery during the 1985-1986 and 1988-1989 Run-Years. Data are from Gary Yeager, John Leppink, Leslie Schaeffer, and Rick Klumph (ODFW, pers. comm.). -=counting ceased before any were counted.

	Steelhead Jacks/ Month		Season of Counting Steelhead Jacks.....			
				Steelhead Season.......		
	1985-1986	1988-1989	Run-Year	Begin	End	No. of Jacks
September	0	0	1985-1986	?	3/17	15
October	0	0	1986-1987	?	1/27	0
November	0	0	1987-1988	?	2/8	0
December	0	0	1988-1989	?	3/6	46
January	5	31	1989-1990	10/20	?	0
February	7	15	1990-1991	10/5	2/25	16
March	3	-	1991-1992	?	?	19
			1992-1993	?	3/26	2
SUM	15	46	1993-1994	12/1	2/24	2
			1994-1995	11/23	3/17	16
			1995-1996	11/17	3/5	30
			1996-1997	11/25	3/10	70

E-3d. PUNCHCARD DATA. The origin of salmonids caught in the ocean is unknown unless they have been marked with CWT's, but those caught in an estuary or stream probably originated in that basin, although some hatchery-reared salmonids can return to a basin other than the one into which they were released (Jacobs 1988, Lindsey et al. 1993-1995, Quinn 1997). Estuarine and freshwater fishery catch estimates are based on salmon/steelhead tags (punchcards) and are available through 1996 (ODFW 1998b). Although many factors other than hazing may have affected catches (Appendix V), examining catch data to see if it is correlated with hazing is important because maintaining or increasing fisheries is one goal of salmonid management.

E-4. METHODS OF DATA ANALYSIS

E-4a. COMPARING HAZING AND NONHAZING RETURNS. Testing the effects of hazing is not as simple as a laboratory exercise because there are no controls (Appendix IV). Returns within a basin can differ with time of release during a year and juvenile salmonids can linger in an estuary before or after hazing occurs, so it is not possible to compare hazed and nonhazed groups within a basin in the same year (Appendix IV). Because there is annual variation in returns for a basin and returns for a basin may differ from other basins, comparing results between a hazed and a nonhazed basin in the same year or between years with and without hazing at the same basin are also not rigorous (Appendix IV).

Nonetheless, such comparisons need to be done because of the interest in whether hazing may be an effective management tool in the recovery of salmonids and because hazing is supported by tax money. For example, proponents have stated that returns at the same basin (Nehalem) were greater for years with than without hazing and have sometimes suggested that returns for a hazed basin were greater than for nonhazed basin (Erickson 1989a,b,d; 1993, 1995a; Monroe 1995b, 1996a; Nokes 1995). Accordingly, comparisons are made at the same basin between years with and without hazing as well as between the Nehalem and nonhazed basins.

E-4b. DATA PRESENTATION. Graphical methods illustrate returns, abundance, and survival, so that the actual data can be examined to see if there are any consistent changes with hazing. Means are also often given because they can show whether returns are generally greater with hazing or not, and statistical analyses are used to determine if trends are significant. Together, these methods can help the reader evaluate the data with more insight than if only one type of data presentation is employed.

E-4c. STATISTICAL CHALLENGES. Tests are essential in determining if differences are statistically significant. However, there are challenges in using robust statistical methods in correlating returns with hazing because:

1) there are no controls to use in testing the survival of hazed vs. nonhazed smolts (Appendix IV)
2) there is a delay in measuring the effects of hazing on abundance or survival (section E-2), so that there are many variables other than hazing that could influence the survival of smolts from hazed or nonhazed estuaries (Appendix V)
3) the occurrence of hazing in 1985-1987 at Nehalem is uncertain (section C-3a), so these years should not be included in analyses.

In spite of these challenges, it is still possible to examine the data cautiously to determine if hazing has had as much of a positive effect on returns as has been claimed.

E-4d. STATISTICAL HYPOTHESIS: HAZING >NONHAZING. Proponents have stated that hazing improves the survival of juvenile salmonids (Erickson 1989a,b,d; 1993, 1995a; Monroe 1995b, 1996a; Nokes 1995). Accordingly, their hypothesis is that the survival of salmon and steelhead is greater when hazing occurs than when it does not, and this is the one-tailed hypothesis that will be usually tested in this paper. A significance level of 0.05 has been chosen because it is most commonly used (Sokal and Rohlf 1981:164, Zar 1984:44, 98); if the probability is greater than 0.05, the result is considered statistically nonsignificant. However, if it appears that nonhazing returns may be significantly greater than for hazing, this difference is also tested.

E-4e. SAMPLE SIZE. Without an adequate sample size, it may not be possible to determine if a statistically significant difference exists (e.g., see "sample size" in Zar 1984:714). A sample size of five is sometimes considered to be a minimum, but this may not always be true. In this paper, I footnote tests with sample sizes of less than five.

There are three reasons for small sample sizes. First, I have only used data through 1998, and during that time there have only been four years of hazing (1988 and 1996-1998) at Tillamook Bay and three years (1996-1998) at Nestucca Bay; this is not a problem at the Nehalem, where hazing is known to have occurred for at least 10 years (1988-1994 and 1996-1998). Second, sample size is also reduced if there is a time delay in compiling fishery data; for example, 1994 fishery catch data became available in October 1998 (ODFW 1998b). Third, there can be a small sample size because adult steelhead and chinook return at various ages, so it may take several years before all returns for a given release of juvenile salmonids can be calculated (Appendix II-2d and II-3c). Although sample size is an issue, the one-tailed hypothesis that hazing has improved salmonid returns reduces its importance because if hazing is as beneficial as has been suggested, this should still show up with small sample sizes.

E-4f. STATISTICAL TESTS. The nonparametric Mann-Whitney test is used to determine if catches, returns, or survival are greater with or without hazing at Nehalem, Tillamook, or Nestucca Bays because it is unclear if the assumptions used for parametric tests are violated (e.g., data are normally distributed and have equal variances).

A paired Mann-Whitney test is used to compare the differences in catches, returns, or survival each year between the Nehalem basin and a basin without hazing. The underlying assumption to this test is that changes in factors other than hazing affect all basins the same. Although this assumption is not robust because basins often differ in yearly trends of returns (Jacobs and Cooney 1997, Chilcote

1998:25-26, 43, 45), survival (Lewis 1997:5-6), and catches (ODFW 1987, 1998b); it is appropriate to cautiously do this test because of the importance of the hazing issue and the lack of alternative tests.

A paired-sample test was also once used (section I-1a), when a Mann-Whitney test was not appropriate.

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F. RESULTS AND DISCUSSION: SMOLT PREDATORS AND HAZING

F-1. CORMORANT REACTION TO HAZING

At Nehalem, "birds" became wary of the boat and would take off when the boat was about a mile away in 1996 (SPP 1996: April 17, April 21). In 1997, cormorants had become very wary of the boat by April 25 and scattered when the boat was a half mile or more away (SPP 1997).

At Tillamook, it is not reported how cormorants responded to hazing in 1996. The 1997 and 1998 SPP reports note if hazing was considered "successful" or not, but it is not explained what "successful" meant. Presumably, it meant that cormorants were chased from an area. The boat used for hazing could not chase cormorants from shallow waters at low tides, and once a hovercraft chased cormorants from such a situation at Kilchis Flats in 1997, but this did not seem to be a problem in 1998 (SPP 1997-1998).

At Nestucca, hazed "birds" would fly to another area to feed or roost on a sand bar, tree, or piling; sometimes they left the bay (SPP 1997-1998). It appears that some "birds" were often chased several times, and, on 11 May 1998, one hazer wrote: "Moved same birds all day."

F-2. SPECIES SUSPECTED OF SMOLT PREDATION DURING CORMORANT HAZING

Species other than cormorants identified as eating smolts in 1988 at Tillamook Bay included great blue herons, sea gulls, raccoons, mink, otters, and crows (Erickson 1995b). During 1996-1998, suspected predators included gulls at Nehalem (SPP 1996) and Nestucca Bays (SPP 1998), great blue herons at Nehalem (SPP 1996-1998) and Nestucca Bays (SPP 1998), Caspian terns at Nehalem (SPP 1996-1998) and Tillamook Bays (SPP 1997), green herons, crows, osprey, and mink at Nehalem (SPP 1996), and harbor seals at Tillamook (SPP 1997) and Nestucca Bays (SPP 1998).

Erickson (1989c, 1993, 1995b; Erickson in SPP 1996) considered cormorants to be the key smolt predator because he thought that they drove smolts up to the water surface or over to banks where other species could prey on smolts, and he indicated that if cormorants were driven away, then smolt predation by other predators would be insignificant. Jon Grigoraitis in SPP (1997) also thought that Caspian terns and great blue herons, but not harbor seals, were drawn to areas where cormorants had herded smolts, but he also reported that terns kept feeding after cormorants were chased away. Bob Rees at Tillamook Bay in 1997 (SPP 1997) noted that harbor seals were often not associated with cormorants. In 1999 at the Nehalem, Stahl et al. (2000:23) noted that double-crested cormorants, great blue herons, Caspian terns, and harbor seals sometimes foraged together and that cormorants seemed to attract other avian predators.

At Yaquina Bay, where I studied birds associated with hatchery releases of coho smolts (Bayer 1986), I often saw gulls, Caspian terns, and brown pelicans catching smolts independently of diving common murres (which were the predator of smolts of most concern there) or cormorants.

F-3. ANIMAL SPECIES HARASSED DURING CORMORANT HAZING

Animals other than cormorants were also disturbed during cormorant harassment. The cormorant hazing programs used cracker shells in 1988 and fast boats in later years (section C-2); this disturbance would not be specific to cormorants, especially if other animals were near the cormorants. For example, 25-150 waterfowl were often recorded as escaping the hazing at Nehalem during April-5 June 1997 (SPP 1997). Since black brant are particularly sensitive to human disturbance (e.g., Bayer 1996:743-744), they may have been disturbed by the cormorant hazing at Tillamook Bay, one of only three sites in Oregon where many overwinter (Bayer 1996), and where many are present in April when hazing occurs (Bayer 1989:44). Further, herons were noted as having been moved during cormorant hazing at Nestucca Bay (SPP 1998: April 24 [twice], May 23 [twice], and May 30), and for Nehalem in 1996, it is written: "Heron population is increasing and birds we saw very persistent in staying at Wheeler but got them to go out over state park" (SPP 1996: April 22). Hazers at Nestucca Bay may have sometimes attempted to chase wildlife other than cormorants; for example, the following comment was in SPP (1998:May 5): "3 loons can not move them."

F-4. OBSERVED PREDATION OF SMOLTS

On 27 April 1988, ADC personnel collected cormorants at Tillamook Bay that contained smolts (Hoffman and Hall 1988); this study has been used as evidence that cormorants were eating substantial numbers of smolts (Erickson 1988, 1995b; McAllister 1988). Unfortunately, this study was marred by faulty methods that make interpretation of their results tenuous (Bayer 1989:11, 25-26, 30).

During SPP (1996-1998), hazers sometimes observed cormorants eating smolts, and there were two reports of smolts recovered from cormorants. At Tillamook Bay on 28 April 1997, the contractor wrote that he had found three dead coho smolts in an area where he had hazed cormorants: two had their adipose fin clipped and were thus hatchery fish and one had all its fins intact and was thus probably a wild smolt (SPP 1997). Presumably, a cormorant had caught these smolts and regurgitated them when it was chased away. At Nestucca Bay on 23 April 1998, K. Delaney recovered and photographed five smolts that a cormorant regurgitated when it was chased (SPP 1998). Unfortunately, he did not identify the species of smolts or indicate if any had clipped fins and thus were hatchery fish, but one smolt (steelhead ?) was 8 inches (20 cm) and four smolts (coho ?) were 5-6 inches (13-15 cm)(SPP 1998).

In 1999 at the Nehalem, Stahl et al. (2000:28) reported that confirmed predators of radiotagged hatchery coho smolts were double-crested cormorants, harbor seals, and hooded mergansers; other species may have also preyed on these smolts. Prior to when hazing began on 1 April 1999, 30% of 10 radiotagged smolts were considered to have been preyed upon, and 55% of 20 smolts were thought to have been caught by predators after hazing began (Stahl et al. 2000:7, 28, 44).

F-5. ALTERNATE PREY OF CORMORANTS

In 1996 at Nehalem, cormorants started feeding on "pogeys" (sculpins ?) on May 3 and were reported to have switched over to feeding exclusively on "pink tailed perch babys" in the lower bay or "pogeys" in the upper bay around May 20 (SPP 1996). Alternate prey were not mentioned in SPP (1997), but, in 1998, cormorants were noted as feeding on nonsalmonid prey starting on June 9 (SPP 1998).

At Tillamook, the 1996 contractor observed that cormorants did not appear to be eating smolts after mid-May but were eating "sculpin, sandlance, shiners" (SPP 1996). In late May and June of 1997 and 1998, cormorants were noted as at least sometimes feeding on baitfish in the "lower estuary" (SPP 1997-1998).

At Nestucca, there were no notes of "birds" catching anything besides smolts.

F-6. DIURNAL VARIATION IN CORMORANT NUMBERS

From April through mid-June, there are about 13-15 hours of daylight between sunrise and sunset during which diurnal predators could prey on smolts. However, hazing does not appear to have occurred throughout the day at all three hazing sites (section C-5). At Nehalem, it is written that there was little cormorant activity after 3 PM in 1997, which is when the contractor stopped hazing (SPP 1997), and it is not expressed in the other reports if cormorant abundance decreased in the afternoon or increased again in the evening. At Tillamook, there does not appear to be enough counts throughout the day to determine if cormorant abundance changed during a day.

At Nestucca, the SPP (1996-1997) reports do not indicate changes in "bird" numbers during a day, but, in 1998, one of the three observers, J. Allen, recorded some details about his activities during six days from April 18 through May 3. His notes suggest that there were three periods of "bird" activity. Feeding "birds" were most abundant (usually 50-150) and consistent during 5:45-8 AM PDT. Later in the morning at 10-12 AM PDT, as many as 50 "birds" were also sometimes active, and, in the evening from 4-7 PM PDT, there was often another period of activity by up to 65 "birds" that was more consistent than in late morning but usually with fewer "birds" than in the early morning. Throughout the rest of the day, he sometimes noted that there was "light activity," or he would note that "birds" were inactive in trees or on sand bars, snags, or pilings. Since he was present and chased "birds" throughout these days, his presence presumably inhibited "birds" from feeding more often or more continuously throughout the day, but cormorants elsewhere have also been observed to feed primarily in the morning (Whitfield and Blaber 1978) or to have 2-3 feeding peaks during a day (Bowmaker 1963:15, Bayer 1986:282).

Since cormorants were at least sometimes feeding in the early evening at Nestucca Bay during 1998, hazing at Nehalem that ceased at 3 PM PDT or that did not occur in the early evening at Tillamook Bay may have allowed some cormorants to feed then.

F-7. SEASONAL CORMORANT ABUNDANCE

F-7a. INTRODUCTION. Because the methods of counting cormorants during SPP (1996-1998) are unclear (section D), it is speculative to interpret these counts and their accuracy. Nevertheless, these data are available, so they can be cautiously examined.

F-7b. NEHALEM. During 1996-1998, there was a similar pattern of high numbers of cormorants in April and much reduced abundance after about mid-May. In 1996, the high count was 400-500 "birds" (cormorants ?) on April 8 and 27, with 30 or less "birds" after May 20; apparently these counts were of "birds" at one location, and not the whole bay (SPP 1996). In 1997, the greatest number of cormorants seen in a single flock was 260, and no flocks with more than 100 cormorants were seen after May 15 (Table 5), but there were no counts of the whole bay. In 1998, a peak count of 640 cormorants in all of Nehalem Bay was noted in April, and 125 or fewer cormorants were found in May and early June (Table 5). This trend of a decline in cormorant abundance at the Nehalem after a week or so of hazing was also reported to have occurred during hazing prior to 1996 (Erickson 1995b).

In 1999, double-crested cormorant numbers were low in March and were much higher during April-May (Stahl et al. 2000:21, 49, 51).

TABLE 5. Daily counts of cormorants at Nehalem Bay in 1997-1998 from SPP (1997-1998). 1997 and 1998 counts were done differently. 1997 counts are of the largest flock seen during a day at one location and are not a census of all Nehalem Bay; a count of 80+ cormorants was included in the 50-99 category, and a count of 100+ cormorants was placed in the 100-149 category. 1998 counts are reported to be the total seen at 7 or 8 AM in all of Nehalem Bay. .=zero (used to increase readability). MAX=maximum number of cormorants seen in a flock in 1997 or in Nehalem Bay estuary in 1998.

1997	No. of Days with a MAX Corm. Count in a Flock of...											MAX
Time Period	1-10	11-49	50-99	100-149	150-199	200-299	300-399	400-499	500-599	600-699	700 or more	No. of Cormorants
April 7-30	.	3	10	4	4	3	.	.	.	.	.	260
May 1-15	.	9	4	1	1	.	.	.	.	.	.	165
May 16-31	7	8	1	.	.	.	.	.	.	.	.	90
June 1-5	5	.	.	.	.	.	.	.	.	.	.	4

1998	No. of Days with a Total Cormorant Count of.......											MAX
Time Period	1-10	11-49	50-99	100-149	150-199	200-299	300-399	400-499	500-599	600-699	700 or more	No. of Cormorants
April 24-30	.	.	.	.	4	1	1	.	.	1	.	640
May 1-15	.	10	4	1	.	.	.	.	.	.	.	125
May 16-31	.	7	7	2	.	.	.	.	.	.	.	125
June 1-15	1	12	2	.	.	.	.	.	.	.	.	75

F-7c. TILLAMOOK. In 1996, peak counts of up to 850 cormorants were reported in April in the Wilson, Trask, and Tillamook Rivers and Tillamook Bay, but in May and June there were 100 or less (SPP 1996). However, it is unclear if these are rough estimates rather than accurate counts since exactly the same numbers are given for many days in a row (e.g., 100 each day during May 18-June 2)(SPP 1996).

1997-1998 counts were by a different contractor, and again it is not known how cormorants were censused. But it is indicated that the number of cormorants is the number at an "active site" (SPP 1997), so counts are not for the whole bay. One estimate of abundance is the maximum number of cormorants counted during a day, as shown in Table 6. No more than 250 cormorants were censused in 1997 and 1998, although generally fewer than 100 cormorants were recorded in both years (Table 6).

In 1999, double-crested cormorant numbers were low in March and were much higher during April-May (Stahl et al. 2000:21, 49, 51).

TABLE 6. Daily peak counts of cormorants at portions of Tillamook Bay in 1997-1998. These counts are from SPP (1997-1998), were done by the same contractor, and were presumably done the same way; in 1997, counts were stated to be of the number of cormorants present at one site and thus not a census of all of Tillamook Bay. .=zero (used to increase readability). MAX=maximum number of cormorants seen at a site. *=approximately.

		No. of Days with a MAX Cormorant Count at a Site of											MAX
YR	Time Period	0-10	11-49	50-99	100-149	150-199	200-299	300-399	400-499	500-599	600-699	700 or more	No. of Corm-orants
97	April 8-30	1	9	6	1	.	.	.	.	.	.	.	95-105
97	May 1-15	6	8	.	.	.	.	.	.	.	.	.	36
97	May 16-31	3	4	2	1	1	1	.	.	.	.	.	200*
97	June 1-15	.	10	2	.	.	.	.	.	.	.	.	60-70
98	April 21-30	.	2	.	1	1	1	.	.	.	.	.	180-220
98	May 1-15	1	4	1	1	2	5	.	.	.	.	.	200-250
98	May 16-31	4	9	1	.	.	.	.	.	.	.	.	80
98	June 1-15	1	9	.	.	.	1	.	.	.	.	.	175-225

F-7d. NESTUCCA. Unfortunately, each report gives numbers of "birds" (which are presumably cormorants), and the methods of counting "birds" are not specified. The problem is compounded because there are three observers each year, and it is not stated if they counted "birds" the same way. However, counts appear to be of "birds" at a portion rather than all of Nestucca Bay.

The meaning of the "Number of Birds Observed" column in these reports is unclear and not defined. Generally, this column appears to include a sum of all "birds" counted at all sites, but at other times it may be the greatest number of "birds" seen at once in a portion of Nestucca Bay. Counts in this column for 1997 are given in Table 7; counts for 1996 and 1998 are not given because several numbers are given for some days and some counts include undefined symbols in SPP (1996), and one of the 1998 observers does not put numbers of "birds" in this column. Nevertheless, 1996 and 1998 "bird" numbers appear to be in the same order of magnitude as the numbers in SPP (1997) shown in Table 7.

In 1997, the greatest number (daily sum ?) of "birds" was reported in April and early May with a maximum of 350 "birds," and, in late May and early June, there was only one count (daily sum ?) greater than 100 "birds" (Table 7). Thus, the decrease in numbers in late May and early June is similar to that at Nehalem and Tillamook Bays, although the numbers given for Nestucca Bay can not be directly compared to those at the other bays because the Nestucca counts often appear to be a sum of all "birds" seen during a day, while counts at other bays represent the maximum seen at one area or a census of the whole estuary.

In SPP (1996-1998), the decline in the number or fishing activity of "birds" in June (1996-1997) or late May (1998) was attributed to an increase in recreational boat traffic.

In 1999, double-crested cormorant numbers were low in March and were much higher during April-May with an apparent peak in abundance during April 15-30 (Stahl et al. 2000:21, 49, 51).

TABLE 7. Daily counts of "birds" (presumably cormorants) at Nestucca Bay in 1997. These data were in the "Number of Birds Observed" column in SPP (1997). Counts were made by three different observers, and it is unclear how each counted "birds" and if they did so the same way. At least some, perhaps most, counts appeared to be sums of the number seen during the day. Since "birds" were chased around the bay and may have been recounted several times each day, these numbers may overestimate the number of "birds" that were actually present. 1996 and 1998 counts in SPP (1996, 1998) are not given because they seem even more difficult to interpret. .=zero (used to increase readability). MAX=maximum number of cormorants reported.

	No. of Days with a "Bird" Count of................											
YR Time Period	0-10	11-49	50-99	100-149	150-199	200-299	300-399	400-499	500-599	600-699	700 or more	MAX No. of "Birds"
97 April 15-30	.	2	6	3	3	1	1	.	.	.	.	350
97 May 1-15	.	.	6	5	3	1	.	.	.	.	.	231
97 May 16-31	.	10	5	.	1	.	.	.	.	.	.	170
97 June 1-15	1	8	6	.	.	.	.	.	.	.	.	86

F-8. SEASONAL ABUNDANCE OF OTHER SMOLT PREDATORS

At the Nehalem, the presence of other potential smolt predators is mentioned in the 1996-1997 reports, but the method of counting these species is unclear. In SPP (1998), as many as 11 harbor seals were counted in late April at sites where "birds" were feeding, and seal abundance declined in May and particularly in June. "Terns" were the only other species counted, and they numbered 0-4 in late April, 0-20 in May, 0-2 during June 1-8, and 2-375 during June 9-15 (SPP 1998).

At Tillamook and Nestucca Bays, the presence of other predators was occasionally mentioned in SPP (1996-1998), but their abundance is not given.

For March-June 1999, Stahl et al. (2000:21-23, 50-51, 53, 67, 69) give censuses of some other potential predators at each bay. Caspian terns had brief peaks of about 50-200 birds at each site in mid-April, and seals regularly numbered 100-200 at the Nehalem but 50 or less at Tillamook and Nestucca Bays during the hazing period. There were also often 25-75 loons, grebes, or mergansers at Nehalem and Tillamook during hazing--other cormorant species and great blue herons were less numerous.

F-9. EFFECTS OF STORMY WEATHER AND WATER TURBIDITY ON CORMORANTS

At Nehalem in 1996, cormorant abundance and/or feeding success was reported to be impaired during periods of muddy water in April, and cormorant abundance decreased during severe storms (SPP 1996). In contrast, cormorants foraged when the water was turbid in 1997, although the turbidity was less and briefer than in 1996 (SPP 1997); cormorants were also abundant during stormy weather in 1997 and 1998 (SPP 1997-1998).

At Tillamook during the 24-27 April 1996 flood, no cormorants were found (SPP 1996), but there is no indication in the 1997-1998 reports about the effects, if any, of weather on cormorant activities. At the Nestucca, dirty water or flooding occurred in April 1996, but it is not clear if this affected the numbers or feeding of "birds" (SPP 1996).

F-10. SMOLT PREDATION IN THE OCEAN

Predation in the ocean beyond where hazers could go was not mentioned in the Nehalem or Tillamook SPP reports. But birds were noted in the ocean near the mouth of Nestucca Bay that were not hazed. On 11 May 1996, hundreds of cormorants were feeding outside the surf near the Nestucca at Pacific City (SPP 1996). In SPP (1998), J. Allen wrote that on April 18 there were 150 "birds" fishing in the jaws next to the surfline that could not be moved because of unsafe tide conditions, and D. Wenzinger observed that "birds" and seals were eating smolts outside of the first breaker on April 19.

G. RESULTS AND DISCUSSION: WILD SALMONID ABUNDANCE

G-1. INTRODUCTION

The goal of the OCRSI, the Oregon Plan, and the ESA listing of coastal coho is the recovery of wild salmonids (OCSRI 1997a,b; NMFS 1998, Kitzhaber 1999). This goal is directed towards increasing the number of adults returning to spawn, but hazing may be more correlated with jack returns because jacks return sooner, so factors other than hazing may not affect their returns as much as for adults (Appendix V). Consequently, the returns of jack and adult coho, winter steelhead, and fall chinook to spawning grounds are examined; there are no spawning ground counts available for summer steelhead or summer and spring chinook.

G-2. COHO SALMON JACK RETURNS TO SPAWNING GROUNDS

At the Nehalem, Tillamook, and Nestucca basins, the average number of jacks per mile is less with hazing than without it, and jack abundance is not significantly greater with hazing (Table 8, Fig. 2). The differences between Nehalem and nonhazed stream jack returns are mixed. Graphical results suggest little if any change (Fig. 3). However, mean differences are greater with hazing at five of six basins, although annual differences are 1 jack/mi or less and are only statistically significant for two of six nonhazed streams (Table 8).

TABLE 8. Statistical tests of whether the abundance of coho jacks at spawning areas is significantly greater with hazing. See Figs. 2-3 for details and yearly graphs. The larger mean is underlined. U=Mann-Whitney statistic for the hypothesis that the number of jacks at the Nehalem, Tillamook, or Nestucca basins or Nehalem-(basin) is more abundant with hazing than without it, N=number of years, P=probability, NS=not significant (one-tailed P>0.05).

	Coho Jacks/Mi at Spawning Areas						Hazing> Nonhazing	
	Hazed			Nonhazed				
Comparison	N	Mean	Range	N	Mean	Range	U	P
Nehalem Basin	10	0.8	0-3.0	6	1.1	0.2-2.3	22.5	NSa
Tillamook Basin	4	0.1	0-0.4	15	0.5	0-1.4	13	NSa,b
Nestucca Basin	3	0.4	0-0.8	16	1.0	0-3.3	14.5	NSa,b
Nehalem-Necanicum	10	0	(-1.2)-1.7	5	-1.0	(-2.2)-(-0.3)	41.5	<0.05
Nehalem-Elk/Ecola	10	0	(-3.8)-1.1	5	-0.9	(-1.8)-0.4	40	<0.05
Nehalem-4th July	10	-1.4	(-2.7)-0.2	5	-1.4	(-2.9)-(-0.2)	27.5	NS
Nehalem-Yaquina	10	-0.6	(-2.5)-1.1	6	-1.1	(-3.1)-0.4	31	NS
Nehalem-Beaver	10	-1.7	(-5.5)-(-0.1)	6	-2.4	(-4.2)-(-1.1)	43.5	NS
Nehalem-Alsea	10	-0.9	(-3.2)-1.4	6	-1.0	(-1.7)-0	36	NS

a When the hypothesis that nonhazing abundance of jacks/mi is greater than hazing is tested, the results are nonsignificant (one-tailed P>0.05) for the Nehalem, Tillamook, and Nestucca Basins.
b The number of years with or without known hazing is less than five; statistical tests would be more robust with larger sample sizes (section E-4e).

FIGURE 2. Peak number of coho jacks per mile during ODFW Spawning Fish Surveys at the Nehalem, Tillamook, and Nestucca Basins. Data are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix II-D) and information available in August 1998 (1996-1997 data) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. 1975-1979 data are not included because of missing data for Nehalem streams.

Jacks return to freshwater in the fall of the same calendar year that they entered the ocean as smolts, so hazing to protect migrating smolts in the spring of 1988 could affect the number of returning jacks during 1988 spawning surveys in November 1988 through January 1989.

At the Nehalem Basin, the total length of creeks surveyed was 5.14 mi in 1994 and 5.64 mi in other years and included the following (with the portion surveyed in parentheses): North Fork Cronin Creek (not surveyed in 1994; 0.5 mi in other years), West Humbug Creek (1.0 mi), Hamilton Creek (1.14 mi), Oak Ranch Creek (1.6 mi), and North Fork Wolf Creek (1.4 mi). Based on maps, all these creeks are tributaries of the Nehalem River and not of the North Fork of the Nehalem River.

At the Tillamook Basin, the total length of creeks surveyed was 3.6 mi in 1980, 5.2 mi in 1981-1985, 5.1 mi in 1986-1989 and 1992-1997, and 4.8 mi in 1990-1991 and included the following (with the portion surveyed in parentheses): Sam Downs Creek of the Kilchis River (1.0 mi), Cedar Creek of the Wilson River (2.9 mi in 1980-1985 and 2.8 mi thereafter), Upper Devil's Lake Fork of the Wilson River (0.7 mi), and Simmons Creek of Tillamook River (0.3 mi in 1990-1991 and 0.6 mi in other years).

At the Nestucca Basin, the total length of creeks surveyed was 1.6 mi in 1980 and 2.4 mi in other years and included the following (with the portion surveyed in parentheses): Clear Creek (0.8 mi, although in 1982 the lower 0.2 mi was dropped and 0.2 mi was added to the upper part of the survey), Bear Creek of the mainstem of the Nestucca River (not surveyed in 1980; 0.8 mi in other years), and Bear Creek of the Little Nestucca River (0.8 mi).

```
H=affected by hazing                ?=unknown if Nehalem affected by hazing
o=not affected by hazing

----------------------- Coho Jacks/Mi -----------------------

          Nehalem Basin        Tillamook Basin        Nestucca Basin
        Nonhazing Mean= 1.1   Nonhazing Mean= 0.5   Nonhazing Mean= 1.0
           Hazing Mean= 0.8      Hazing Mean= 0.1      Hazing Mean= 0.4
   4.0-|                      -|                      -|
       |                       |                       |
   3.5-|                      -|                      -|
       |                       |                       |    o
J  3.0-|         H            -|                      -|    o
a      |         H             |                       |    o
c  2.5-|         H            -|                      -|    o
k      |    o    H             |                       |    o
s  2.0-|    o    H            -|                      -|    o      o
       |  o o    H             |                       |o  oo      o
p  1.5-|  o o    H            -|                      -|o  oo      o
e      |  o o?   H             |  o o                  |o  oooo    oo
r  1.0-|o-ooo?--HH-HH------   -|--o-o--------------   -|o--oooo----oo------
       |o ooo?? HH HH          | oooo o  o             |ooooooo    oo o H
M  0.5-|o ooo???HH HH  oHHH   -| oooooo Ho    o       -|oooooooo o oo o HH
i      |ooooo???HHHHHH oHHH    |ooooooooHoooo o H      |oooooooo o oo o HH
     0-|ooooo???HHHHHHHoHHH   -|ooooooooHoooooooHHH   -|ooooooooooooooooHHH
        |''''|''''|''''|'''     |''''|''''|''''|'''     |''''|''''|''''|'''
       80   85   90   95       80   85   90   95       80   85   90   95

                            Spawning Season
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FIGURE 3. Differences in peak numbers of coho jacks per mile during ODFW Spawning Fish Surveys between the Nehalem Basin and the Necanicum River, Elk/Ecola Creek, 4th of July Creek (Siletz River), Yaquina Basin, Beaver Creek, and Alsea Basin. These data are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix II-D) and information available in August 1998 (1996-1997) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. Hatchery fish have been excluded.

Cormorant harassment only occurred at the Nehalem and is known to have started there in the spring of 1988. Jacks return to freshwater in the fall of the same calendar year that they entered the ocean as smolts, so hazing to protect migrating smolts in the spring of 1988 could affect the number of returning jacks during 1988 spawning surveys in November 1988 through January 1989.

Basins along the north and central coasts north of the Siuslaw other than the Nehalem that were included are those without cormorant harassment, and they are arranged in the following graphs from north to south. The Nehalem Basin data are graphed and information about the creeks surveyed there are in Fig. 2. Other stream surveys include (with the portion surveyed in parentheses): the Upper Necanicum River (1.5 mi), the West Fork of Elk Creek/Ecola Creek (0.5 mi), Fourth of July Creek in the Siletz River Basin (0.8 mi), and North Fork Beaver Creek (1.0 mi). At the Yaquina Basin, the total length of streams surveyed was 2.4 mi in 1994 and 2.6 mi in other years and included the following (with the portion surveyed in parentheses): Salmon Creek (0.6 mi) and Upper Yaquina River (1.8 mi in 1994 and 2.0 mi in other years). At the Alsea Basin, the total length of streams surveyed was 2.3 mi in 1980, 4.86 mi in 1981, and 5.16 mi in other years and included the following (with the portion surveyed in parentheses): Horse Creek (1.0 mi), Nettle Creek (not surveyed in 1980 and 0.8 mi in other years), Lobster Creek (1.0 mi in 1981 and 1.3 mi in other years), Cherry Creek (not surveyed in 1980 and 0.76 mi in other years), and Wilson Creek (not surveyed in 1980 and 1.3 mi in other years).

```
H=Nehalem affected by hazing        ?=unknown if Nehalem affected by hazing
o=not affected by hazing
----------------------- Coho Jacks/Mi -----------------------

        Nehalem-Necanicum       Nehalem-Elk Creek       Nehalem-4th July
         Nonhazing Mean= -1.0    Nonhazing Mean= -0.9   Nonhazing Mean= -1.4
J     3-|   Hazing Mean=   0   -|   Hazing Mean=   0   -|  Hazing Mean= -1.4
a       |                       |                       |
c     2-|                      -|                      -|
k       |         H             |                       |
s     1-|         H            -|        HH  H         -|
        |         H       HH    |        HH  H  oHHH    |
p     0-|=oooo???HHHHHHHoHHH====|=oooo???HHHHHHHoHHH====|=oooo???HHHHHHHoHHH
e       |  ooo?? H H  HHo       | o oo???  HH           | ooo ???HHHHH  oHHH
r    -1-|  o o??    H          -| o oo???  HH          -| o o ???HHHHH  o H
        |  o o ?                | o  o???  H            | o o ???HHHHH    H
M    -2-|  o   ?               -| o  o??   H           -| o o ???HHH      H
i       |      ?                |      ??   H           | o o ?  H H
     -3-|      ?               -|      ??   H          -|   o ?
        |      ?                |      ??   H           |     ?
     -4-|                      -|      ??   H          -|     ?
        |                       |      ??               |
     -5-|                      -|      ??              -|
        |                       |      ?                |
     -6-|                      -|      ?               -|
        |                       |      ?                |
     -7-|                      -|      ?               -|
        |                       |                       |
        |___________________    |___________________    |___________________
         |''''|''''|''''|'''     |''''|''''|''''|'''     |''''|''''|''''|'''
        80   85   90   95      80   85   90   95      80   85   90   95
                               Spawning Season
```

(Fig. 3 continued on next page)

(Fig. 3 continued)

```
H=Nehalem affected by hazing        ?=unknown if Nehalem affected by hazing
o=not affected by hazing

----------------------- Coho Jacks/Mi -----------------------

       Nehalem-Yaquina         Nehalem-Beaver         Nehalem-Alsea
        Nonhazing Mean= -1.1     Nonhazing Mean= -2.4    Nonhazing Mean= -1.0
J     3-|  Hazing Mean= -0.6  -|   Hazing Mean= -1.7  -|  Hazing Mean= -0.9
a       |                      |                       |
c     2-|                     -|                      -|
k       |                      |                       |         H
s     1-|         H           -|                      -|         H
        |    o    H            |                       |         H
p     0-|ooooo???HHHHHHHoHHH====|ooooo???HHHHHHHoHHH====|ooooo???HHHHHHHoHHH
e       |oo   ???H HHHHHo H     |ooooo???HHH HHHoHHH    |oooo ???H HHHHHo H
r    -1-|oo   ???H  H  Ho H    -|ooooo???HHH HHHo HH   -|oo o ???H  HHH o
        |oo   ???   H  Ho       |ooo o???    HHHo HH    |oo    ? ?H  HHH
M    -2-|o     ??   H  Ho      -|ooo   ??    HHHo  H   -|o     ? ?H   H
i       |      ??      Ho       |o o   ??      Ho  H    |      ?  H   H
     -3-|      ?        o      -|o o   ??      H   H   -|      ?  H   H
        |                       |  o   ??          H    |      ?
     -4-|                      -|  o   ??          H   -|
        |                       |      ??          H    |
     -5-|                      -|      ??          H   -|
        |                       |      ??          H    |
     -6-|                      -|      ??          H   -|
        |                       |       ?               |
     -7-|                      -|       ?              -|
        |                       |                       |
        |___________________    |___________________    |___________________
         |''''|''''|''''|'''     |''''|''''|''''|'''     |''''|''''|''''|'''
        80   85   90   95       80   85   90   95       80   85   90   95

                         Spawning Season

---------------------------------------------------------------------------
```

G-3. WILD COHO SALMON ADULT RETURNS TO SPAWNING GROUNDS

The number of coho adults per mile has generally decreased since hazing began at the Nehalem, Tillamook, and Nestucca basins (Fig. 4), and average returns are greater without hazing than with it (Table 9). These differences are not significant at the Nehalem and Tillamook, but returns are significantly greater without hazing at the Nestucca, although there are only two years of hazing-affected returns (Table 9: footnote a). The averages of 1-7 adults/mi for hazing-affected counts (Table 9) are far below the PFMC goal of 42 adults/mi (PFMC 1996:III-5).

Graphs suggest little change in differences between Nehalem and nonhazed streams in adult returns (Fig. 5). But mean differences are greater with hazing for four of six streams, although the increase in averages with hazing is small (less than 4 adults/mi)(Table 9), and the differences are not significantly greater with hazing (Table 9).

TABLE 9. Statistical tests of whether the abundance of coho adults at spawning areas is significantly greater with hazing. See Figs. 4-5 for details and yearly graphs. The larger mean is underlined. U=Mann-Whitney statistic for the hypothesis that the number of adults at the Nehalem, Tillamook, or Nestucca basins or Nehalem-(basin) is more abundant with hazing than without it, N=number of years, P=probability, NS=not significant (one-tailed P>0.05).

	Wild Coho Adults/Mi at Spawning Areas......						Hazing> Nonhazing	
	Hazed...............			Nonhazed.............				
Comparison	N	Mean	Range	N	Mean	Range	U	P
Nehalem Basin	9	6.6	2.5-18.3	7	9.7	2.0-24.8	23	NSa
Tillamook Basin	3	2.7	1.2-5.1	16	5.3	0.8-11.9	14.5	NSa,b
Nestucca Basin	2	1.0	0-2.1	17	7.8	1.3-17.9	1	NSa,b
Nehalem-Necanicum	9	1.6	(-2.9)-8.7	6	-2.0	(-20.1)-15.5	32	NS
Nehalem-Elk/Ecola	9	-0.9	(-11.5)-6.3	6	-4.4	(-12.6)-6.8	36	NS
Nehalem-4th July	9	-12.0	(-31.3)-1.0	6	-11.8	(-42.6)-7.3	27	NSa
Nehalem-Yaquina	9	-10.0	(-49.4)-4.0	7	-5.8	(-28.9)-4.1	23	NSa
Nehalem-Beaver	9	-10.8	(-48.2)-5.3	7	-13.3	(-36.1)-0.8	37	NS
Nehalem-Alsea	9	-5.4	(-24.1)-8.7	7	-8.2	(-31.0)-2.7	39	NS

a When the hypothesis that nonhazing abundance of adults/mi is greater than hazing is tested, the results are nonsignificant (one-tailed P>0.05), except for the Nestucca Basin (U=33, one-tailed P<0.05), where there were only two years of hazing data.

b The number of years with or without known hazing is less than five; statistical tests would be more robust with larger sample sizes (section E-4e).

FIGURE 4. Peak number of wild adult coho per mile during ODFW Spawning Fish Surveys at the Nehalem, Tillamook, and Nestucca Basins. Data are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix II-D) and information available in August 1998 (1996-1997) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. Hatchery fish have been excluded. See the legend of Fig. 2 for details about the streams surveyed. 1975-1979 data are not included because of missing data for Nehalem streams.

Adults return to freshwater in the calendar year after they entered the ocean as smolts, so hazing to protect migrating smolts in the spring of 1988 could affect the number of returning adults during 1989 spawning surveys in November 1989 through January 1990.

```
H=affected by hazing                 ?=unknown if Nehalem affected by hazing
o=not affected by hazing

-------------------------- Wild Coho Adults/Mi ----------------------------
      Nehalem Basin             Tillamook Basin           Nestucca Basin
      Nonhazing Mean= 9.7       Nonhazing Mean= 5.3       Nonhazing Mean= 7.8
         Hazing Mean= 6.6          Hazing Mean= 2.7          Hazing Mean= 1.0
   30-|                     -|                    -|
A     |                      |                     |
d  25-|   o                 -|                    -|
u     |   o                  |                     |
l  20-|   o                 -|                    -|
t     |   o   H H            |                     |    o
s  15-|   o ?  H H          -|                    -|    oo
      | o o ?  H H           |    o                |  ooooo
p  10-|o-o-oo?--H-H----------|--o-o----------------|o-ooooo----o-------
e     |o o oo?  H H          | oo ooo       o      |ooooooo    o   o
r   5-|ooo oo???H HHH       -|ooo oooooH o  oo    -|ooooooo  o o ooo
      |oooooo???HHHHHHHoHH   |ooooooooooH o  oooH  |oooooooooooooooo H
M   0-|oooooo???HHHHHHHoHH  -|ooooooooooHoooooooHH-|ooooooooooooooooooHH
i      |''''|''''|''''|'''     |''''|''''|''''|'''   |''''|''''|''''|'''
      80   85   90   95      80   85   90   95     80   85   90   95

                              Spawning Season
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FIGURE 5. Differences in peak numbers of wild adult coho per mile during ODFW Spawning Fish Surveys between the Nehalem Basin and the Necanicum River, Elk/Ecola Creek, 4th of July Creek (Siletz River), Yaquina Basin, Beaver Creek, and Alsea Basin. These data are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix II-D) and information available in August 1998 (1996-1997) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. Hatchery fish have been excluded.

Cormorant harassment only occurred at the Nehalem and is known to have started there in the spring of 1988. Adults return to freshwater in the calendar year after they entered the ocean as smolts, so hazing to protect migrating smolts in the spring of 1988 could affect the number of returning adults during 1989 spawning surveys in November 1989 through January 1990.

See the Legends of Figs. 2 and 3 for details about the streams surveyed.

```
H=Nehalem affected by hazing        ?=unknown if Nehalem affected by hazing
o=not affected by hazing
----------------------------- Wild Coho Adults/Mi -----------------------

         Nehalem-Necanicum       Nehalem-Elk Creek       Nehalem-4th July
       Nonhazing Mean= -2.0   Nonhazing Mean= -4.4   Nonhazing Mean= -11.8
A    30-| Hazing Mean=  1.6    -| Hazing Mean= -0.9    -| Hazing Mean= -12.0
d       |                       |                       |
u    20-|                      -|                      -|
l       |    o                  |                       |
t    10-|    o    H H          -|                      -|
s       |    o ?  H H           |    o    H  HH    H    |    o
      0-|=ooooo???HHHHHHHoHH====|=ooooo???HHHHHHHoHH====|=ooooo???HHHHHHHoHH
p       |  oo   ??      Ho      | o o o    HH  H oH     | ooo o???HH H HHoHH
e   -10-|  o     ?       o     -| o   o          oH    -| o o o???H  H HH H
r       |  o                    |                o      |   o o? ?H  H    H
    -20-|  o                   -|                      -|     o?  H  H    H
M       |                       |                       |     o?  H  H    H
i   -30-|                      -|                      -|     o?          H
        |                       |                       |     o
    -40-|                      -|                      -|     o
        |                       |                       |     o
        |___________________    |___________________    |___________________
         |''''|''''|''''|'''     |''''|''''|''''|'''     |''''|''''|''''|'''
        80   85   90   95       80   85   90   95       80   85   90   95


         Nehalem-Yaquina         Nehalem-Beaver Cr       Nehalem-Alsea
       Nonhazing Mean=  -5.8  Nonhazing Mean= -13.3  Nonhazing Mean= -8.2
A    30-| Hazing Mean= -10.0   -| Hazing Mean= -10.8   -| Hazing Mean= -5.4
d       |                       |                       |
u    20-|                      -|                      -|
l       |                       |                       |
t    10-|    o                 -|                      -|    o      H
s       |  o o    H             |         H             |  o o      H
      0-|oooooo???HHHHHHHoHH====|oooooo???HHHHHHHoHH====|oooooo???HHHHHHHoHH
p       |oo   o??? H HHHHoH     |oooo o?     HHHHoHH    |oo o o???HH HH  oHH
e   -10-|o      ?     HHHo     -|o  o o?     H HHoHH   -| o   o???   H   o H
r       |o      ?      HHo      |o    o?     H   oHH    | o   o  ?   H
    -20-|o              Ho     -|o    o?     H         -|     o  ?   H
M       |               Ho      |     o?     H          |     o  ?   H
i   -30-|               Ho     -|     o      H         -|     o
        |               H       |     o      H          |
    -40-|               H      -|            H         -|
        |               H       |            H          |
    -50-|               H      -|            H         -|
        |___________________    |___________________    |___________________
         |''''|''''|''''|'''     |''''|''''|''''|'''     |''''|''''|''''|'''
        80   85   90   95       80   85   90   95       80   85   90   95

                              Spawning Season
```

G-4. ADULT STEELHEAD RETURNS TO SPAWNING GROUNDS

Winter steelhead spawning surveys commenced in the spring of 1998 in portions of many Tillamook County streams (see http://osu.orst.edu/Dept/ODFW/other/spawn/data). Previously, the only stream with consistent surveys along the north and central coast of Oregon is the Salmonberry River in the Nehalem Basin (Chilcote 1998:40; Bob Buckman, ODFW, pers. comm.).

The abundance of winter steelhead at the Salmonberry River has not increased after hazing commenced and has not reached Chilcote's (1998:45) recommended equilibrium level to sustain the population in 4 of 7 years that were affected by hazing (Fig. 6). Indeed, the estimated average abundance is lower with hazing (Fig. 6), and adult returns during 1991-1996 that were hazing-affected are not significantly greater than for the nonhazing-affected years of 1975-1986 (Mann-Whitney U=22.5; N1=6, N2=12, one-tailed P>0.10).

FIGURE 6. Number of spawning winter steelhead per mile at the Salmonberry River, a tributary of the Nehalem River. These ODFW data are estimated from Chilcote's (1998:45) graph. Surveys were during April and May, so these are thought to be primarily wild steelhead because hatchery steelhead typically spawn in January and February (Chilcote 1998:45). The estimated natural equilibrium level for the Salmonberry River is 31 spawners per mile (Chilcote 1998:45). In 1992, fishing regulations were changed to require the release of wild steelhead (Chilcote 1998:31), so it could be expected that the number of spawning steelhead would consequently increase.

Since naturally spawned smolts typically spend two years in freshwater, smolts originating from the 1986 Spawning Year (Brood Year) would have migrated to the ocean during 1988 and returned as adults in the 1990 Spawning Year as 2-salts and in the 1991 Spawning Year as 3-salts with some repeat spawners returning in later years (Appendix II-2d).

Salmonberry River Winter Steelhead Spawners/Mile

```
H=affected by hazing                      ?=unknown if affected by hazing
O=not affected by hazing                  --=equilibrium level
P=only 2-salts affected by hazing
#=fishers required to release wild steelhead

  S  120-| O                Nonhazing 1975-1986 Mean= 42/mi
  t     -| O                   Hazing 1991-1996 Mean= 26/mi
  e  110-| O
  e     -| O
  l  100-| O
  h     -| O
  e   90-| O
  a     -| O
  d   80-| O
        -| O                                   ?
  S   70-| O  O                                ?
  p     -| O  O                                ?
  a   60-| O  O                                ?
  w     -| O  O           O                    ?
  n   50-| O  O     O     O              O     ?     ?
  e     -| O  O  O  O     O              O     ?     ?                 H
  r   40-| O  O  O  O     O              O     ?     ?     H           H
  s     -| O  O  O  O  O  O              O     ?     ?     H           H
      30-|-O--O--O--O--O--O--------------O--O--?--?--?--P--H-----------H---
  p     -| O  O  O  O  O  O  O           O  O  ?  ?  ?  P  H        H  H  H
  e   20-| O  O  O  O  O  O  O     O     O  O  ?  ?  ?  P  H        H  H  H
  r     -| O  O  O  O  O  O  O     O     O  O  ?  ?  ?  P  H  H     H  H  H
      10-| O  O  O  O  O  O  O     O  O  O  O  ?  ?  ?  P  H  H     H  H  H
  M     -| O  O  O  O  O  O  O  O  O  O  O  O  ?  ?  ?  P  H  H  H  H  H  H
  i    0-| O  O  O  O  O  O  O  O  O  O  O  O  ?  ?  ?  P  H  H  H  H  H  H
  l      |____________________________________________________#__#__#__#__#
  e        |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
          75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96
                                 Spawning Year
```

G-5. FALL CHINOOK SALMON JACK RETURNS TO SPAWNING GROUNDS

At the Nehalem, Tillamook, and Nestucca Basins, the number of fall chinook jacks/mi appears greater in graphs and averages more without hazing than with it (Table 10, Fig. 7). The greater abundance without hazing is significant at the Nehalem and Nestucca Basins, although there are only two years of hazing data for the Nestucca (Table 10).

Relative to nonhazed streams, jack returns to the Nehalem are also significantly greater without hazing (Table 10, Fig. 8).

TABLE 10. Statistical tests of whether the abundance of fall chinook jacks at spawning grounds is significantly greater without hazing. The hypothesis throughout the rest of this paper is that abundance is greater with than without hazing, but the consistently greater means for nonhazing years make it clear that this was obviously not true for fall chinook, so a more meaningful test is if nonhazing abundance is greater than hazing. See Figs. 7-8 for details and yearly graphs of these data. The larger mean is underlined. U=Mann-Whitney statistic for the hypothesis that the number of jacks at the Nehalem, Tillamook, or Nestucca basins or Nehalem-(basin) is more abundant without hazing, N=number of years, P=probability, NS=not significant (one-tailed P>0.05).

	Fall Chinook Jacks/Mi at Spawning Areas....						Nonhazing>	
	Hazed..............			Nonhazed..............			Hazing	
Comparison	**N**	**Mean**	**Range**	**N**	**Mean**	**Range**	**U**	**P**
Nehalem (Humbug)	9	2.0	0-5.0	12	<u>15.1</u>	1.0-40.0	90	<0.01
Tillamook Basin	3	1.1	0.4-2.3	15	<u>2.9</u>	0.5-5.9	36	NSa
Nestucca Basin	2	0.4	0-0.8	18	<u>4.7</u>	0-17.0	32.5	<0.05a
Nehalem-Siletz	9	0.6	(-5.0)-3.3	11	<u>11.3</u>	(-3.8)-37.5	74	<0.05
Nehalem-Yaquina	9	0.3	(-3.5)-2.8	7	<u>11.2</u>	(-0.5)-31.9	50	<0.05
Nehalem-Alsea	9	-1.8	(-5.0)-2.0	12	<u>11.3</u>	(-8.0)-39.0	90.5	<0.01

a The number of years with or without known hazing is less than five; statistical tests would be more robust with larger sample sizes (section E-4e).

FIGURE 7. Peak number of fall chinook jacks per mile during ODFW Spawning Fish Surveys at the Nehalem, Tillamook, and Nestucca Basins. These returns are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix I-B) and information available in August 1998 (1996-1997 data) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. It is unclear if some hatchery fish may have been included (see Jacobs and Cooney 1997:6-8).

The only Nehalem Basin stream surveyed since 1975 was 1.0 mi of Humbug Creek. At the Tillamook Basin, the total length of streams surveyed since 1981 was 5.6 mi and included the following (with the portion surveyed in parentheses): Little South Fork of the Kilchis River (1.0 mi), Cedar Creek of the Wilson River (2.8 mi), and Tillamook River (1.8 mi). At the Nestucca Basin, the total length of streams surveyed since 1980 was 1.2 mi and included (with the portion surveyed in parentheses): Clear Creek (0.8 mi) and Niagara Creek (0.4 mi). Other streams in the Tillamook and Nestucca Basins were excluded if surveys commenced in 1986, had missing data, or changed survey length.

```
H=affected by hazing                ?=unknown if Nehalem affected by hazing
o=not affected by hazing

----------------- Fall Chinook Jacks/Mi-------------------------
     Nehalem                      Tillamook                  Nestucca
     Nonhazing Mean= 15.1         Nonhazing Mean= 2.9        Nonhazing Mean= 4.7
        Hazing Mean=  2.0            Hazing Mean= 1.1           Hazing Mean= 0.4

    39-o    31-oo-40
   28-o|       ||
      ||       ||
     |||       ||                |                           |          o
  16-|||       ||               -|                          -|          o
     |||       ||                |                           |          o
  14-|||       ||               -|                          -|          o
     |oo     o oo                |                           |          o
  12-|ooo    o oo               -|                          -|          o
J    |ooo    o oo                |                           |          o
a 10-|ooo    o oo               -|                          -|       o  oo      o
c    |ooo    o oo                |                           |       o  oo      o
k  8-|ooo    o oo?              -|                          -|       o  oo      o
s    |ooo    o oo?               |                           |       oo oo      o
   6-|oooo   o oo??             -|       o  o               -|       ooooo  o  o
p    |oooo   o oo??      H       |       o ooo               |       ooooo  o  o
e  4-|oooo   oooo???   H H      -|       o ooo     o        -|    o  ooooo  o  o
r    |oooo o oooo???   H HH      |       o ooo   ooo         |    o  ooooo ooooo
   2-|oooooo oooo???H  H HHo H  -|      ooooooooHooo        -|    o  ooooo ooooooo
M    |ooooooooooo???HH H HHoHH   |      ooooooooHoooooooH    |    ooooooooooooooooo H
i  0-|ooooooooooo???HHHHHHHoHH  -|      ooooooooHoooooooHH  -|    ooooooooooooooooooHH
      |''''|''''|''''|''''|'''    |''''|''''|''''|''''|'''    |''''|''''|''''|''''|'''
     75   80   85   90   95      75   80   85   90   95      75   80   85   90   95

                                 Spawning Season
```

FIGURE 8. Differences in peak numbers of fall chinook jacks per mile during ODFW Spawning Fish Surveys between the Nehalem Basin (Humbug Creek) and Sunshine Creek (Siletz River), Yaquina Basin, and Buck Creek (Alsea River). These returns are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix II-D) and information available in August 1998 (1996-1997 data) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. It is unclear if some hatchery fish may have been included (see Jacobs and Cooney 1997:6-8).

Basins along the north and central coasts north of the Siuslaw other than the Nehalem that were included are those without cormorant harassment. These basins are arranged in the following graphs from north to south. The Nehalem Basin (Humbug Creek, 1.0 mi) data are graphed in Fig. 7. The total length of streams surveyed was 1.2 mi at Sunshine Creek in the Siletz Basin and 1.0 mi at Buck Creek in the Alsea Basin. At the Yaquina Basin, the total was 2.6 mi (except in 1994 when the total was 2.35 mi) and surveys were in the Upper Yaquina River (2.0 mi, except in 1994 when 1.75 mi was surveyed) and Salmon Creek (0.6 mi). Other streams in these basins were excluded if surveys commenced in 1986 or had missing data.

```
H=Nehalem affected by hazing      ?=unknown if Nehalem affected by hazing
o=not affected by hazing

----------------------- Fall Chinook Jacks/Mi ------------------------------
   Nehalem-Siletz          Nehalem-Yaquina          Nehalem-Alsea
   Nonhazing Mean= 11.3    Nonhazing Mean= 11.2     Nonhazing Mean= 11.3
      Hazing Mean=  0.5       Hazing Mean=  0.3        Hazing Mean= -1.8

                o-38                                            o-39
    29-o    29-o|                       29-oo-32            27-o|    29-oo-25
       |       ||                          ||                  ||       ||
  16-| o       oo               -|         oo                -|oo       oo
     | o       oo                |         oo                 |oo       oo
  14-| o       oo               -|         oo                -|oo       oo
     | o       oo                |       o oo                 |oo       oo
  12-| o     o oo               -|       o oo                -|oo       oo
     | o     o oo                |       o oo                 |oo       oo
J 10-| oo    o oo               -|       o oo                -|ooo      oo
a    | oo    o oo                |       o oo                 |ooo      oo
c  8-| oo    o oo               -|       o oo                -|ooo      oo
k    | oo    o oo                |       o oo                 |ooo      oo
s  6-| ooo   o oo ?             -|       o oo                -|oooo     oo
     | ooo   o oo ?              |       o oo                 |oooo     oo ?
p  4-| ooo   o oo??             -|       o oo ?              -|oooo   oooo ?
e    | ooo   o oo???   H HH      |     o o oo ??   H          |oooo   oooo ?
r  2-| ooo   oooo???   H HHo    -|     o oooo ??H  H         -|oooo   oooo ?          H
     | ooo o oooo???   H HHoH    |     o oooo???HH H H   H    |oooo o oooo ?      H   H
M  0-| oooooooooo???HHHHHHHoHH  -|     oooooo???HHHHHHHoHH   -|ooooooooooo???HHHHHHHoHH
i    |    o o       H H      H   |      o             H H     |    o o    ? ?HHHHH H H
  -2-|    o           H         -|                    H      -|    o o      ?HHHH    H
     |    o           H          |                    H       |    o        ?HH H
  -4-|    o           H         -|                    H      -|    o        ? H H
     |                H          |                            |    o        ? H H
  -6-|                          -|                           -|    o        ?
     |                           |                            |    o        ?
  -8-|                          -|                           -|    o
     |________________________   |________________________    |________________________
      |''''|''''|''''|''''|'''    |''''|''''|''''|''''|'''     |''''|''''|''''|''''|'''
     75   80   85   90   95      75   80   85   90   95       75   80   85   90   95

                              Spawning Season
```

G-6. FALL CHINOOK SALMON ADULT RETURNS TO SPAWNING GROUNDS

At the Nehalem, the abundance of wild fall chinook adults shows a significant decline with hazing (Fig. 9, Table 11). Comparisons of adult returns to the Tillamook and Nestucca Basins are not appropriate because there have not yet been enough consecutive years of hazing, so that all age classes would be affected. Relative to nonhazed streams, adult returns affected by hazing at the Nehalem are also significantly less (Table 11, Fig. 10).

The decline with hazing may be related to increased chinook fishery catches (section J-3).

TABLE 11. Statistical tests of whether the abundance of fall chinook adults at spawning areas is significantly greater with no hazing. The hypothesis throughout the rest of this paper is that hazing abundance is greater than for nonhazing, but the consistently greater means for nonhazing make it clear that this is obviously not true for fall chinook, so a more meaningful test is if nonhazing abundance is greater than hazing. See Figs. 9-10 for details and yearly graphs of these data. The larger mean is underlined. U=Mann-Whitney statistic for hypothesis that the number of adults at the Nehalem, Tillamook, or Nestucca basins or Nehalem-(basin) is more abundant with no hazing than with it, N=number of years, P=probability, NS=not significant (one-tailed P>0.05).

	Fall Chinook Adults/Mi at Spawning Areas...						Nonhazing>	
	Hazed..............			Nonhazed..............			Hazing	
Comparison	N	Mean	Range	N	Mean	Range	U	P
Nehalem (Humbug)	4	69.0	50.0-86.0	12	142.8	61.0-280.0	42	<0.05a
Nehalem-Siletz	4	8.0	(-15.7)-35.8	11	107.3	36.7-240.8	44	<0.01a
Nehalem-Yaquina	4	-4.7	(-55.7)-32.7	7	111.9	28.4-231.9	27	<0.05a
Nehalem-Alsea	4	23.5	(-2.0)-37.0	12	108.5	16.0-225.0	44	<0.01a

a The number of years with all 3-6 yr olds affected by hazing is less than five; statistical tests would be more robust with larger sample sizes (section E-4e).

FIGURE 9. Peak number of fall chinook adults per mile during ODFW Spawning Fish Surveys at the Nehalem Basin. Data are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix I-B) and information available in August 1998 (1996-1997 data) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. It is unclear if some hatchery fish may have been included (see Jacobs and Cooney 1997:6-8). The only Nehalem Basin stream surveyed since 1975 was 1.0 mi of Humbug Creek.

```
H=all affected by hazing              ?=unknown if affected by hazing
o=not affected by hazing
P=part of, but not all, 3-6 yr old adults affected by hazing

                                                  Nehalem Fall Chinook Adults/Mi
       300-|                                       Nonhazing 1975-86 Mean= 142.8
 A       -|                   o                       Hazing 1993-96 Mean=  69.0
 d     250-|                   o o
 u       -|                   o o   ?
 l     200-|                   o o   ?
 t       -|       o o         o o   ?
 s     150-|     o o o   o     o o   ? ? ?               P
         -|   o o o o   o     o o   ? ? ?               P
 p     100-|   o o o o o o     o o o ? ? ?     P         P P
 e       -| o o o o o o o o   o o o ? ? ?     P   H   H P P
 r      50-|-o-o-o-o-o-o-o-o-o-o-o-o-?-?-?-P-P-P-H-H-H-H-P-P-- 50
         -| o o o o o o o o o o o o ? ? ? P P P H H H H P P
 M       0-| o o o o o o o o o o o o ? ? ? P P P H H H H P P
 i           | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' '
             75        80        85        90        95

                               Spawning Season
```

FIGURE 10. Differences in peak numbers of fall chinook adults per mile during ODFW Spawning Fish Surveys between the Nehalem Basin (Humbug Creek) and Sunshine Creek (Siletz River), Yaquina Basin, and Buck Creek (Alsea River). These data are calculated from data through 1995 in Jacobs and Cooney (1997:Appendix II-D) and information available in August 1998 (1996-1997 data) and February 1999 (1997-1998 data) at http://osu.orst.edu/Dept/ODFW/other/spawn/data by summing the peak counts for each stream and dividing by the total miles surveyed in a basin. It is unclear if some hatchery fish may have been included (see Jacobs and Cooney 1997:6-8).

Basins along the north and central coasts north of the Siuslaw other than the Nehalem that were included are those without cormorant harassment. These basins are arranged in the following graphs from north to south. The Nehalem Basin (Humbug Creek, 1.0 mi) data are graphed in Fig. 9. The total length of streams surveyed was 1.2 mi at Sunshine Creek in the Siletz Basin and 1.0 mi at Buck Creek in the Alsea Basin. At the Yaquina Basin, the total was 2.6 mi (except in 1994 when the total was 2.35 mi) and surveys were in the Upper Yaquina River (2.0 mi, except in 1994 when 1.75 mi was surveyed) and Salmon Creek (0.6 mi). Other streams in these basins were excluded if surveys commenced in 1986 or had missing data.

```
H=Nehalem affected by hazing       ?=unknown if Nehalem affected by hazing
o=not affected by hazing
P=part of, but not all, 3-6 yr old adults affected by hazing

------------------------ Fall Chinook Adults/Mi ----------------------------
    Nehalem-Siletz          Nehalem-Yaquina          Nehalem-Alsea
    Nonhazing Mean= 107.3   Nonhazing Mean= 111.9    Nonhazing Mean= 108.5
       Hazing Mean=   8.0      Hazing Mean=  -4.7       Hazing Mean=  23.5

A 250-|         o                  -|                            -|
d     |         o                   |         oo                  |         o
u 200-|         o  ?               -|         oo                 -|         o
l     |         oo ?                |         oo ?                |         oo ?
t 150-|   o     oo ?               -|         oo ? ?             -|  oo     oo ?
s     | ooo     oo ?                |      o  oo ???       P      | oooo o  oo ?         P
  100-| oooo o  oo ? ?       P     -|      o  oo ???       P     -| oooo o  oo ?         P
p     | oooo o  ooo???       P      |     oo  oo ???  P    PP     |ooooo o  oo ? ?       P
e  50-| oooooo  ooo???       P     -|     ooo oo ???P P    PP    -|ooooooo  ooo? ?       P
r     | ooooooooooo???  PH H PP     |     ooooooo???PPPH   PP     |oooooooooooo? ?  PHH HPP
    0-| ooooooooooo???PPPHHHHPP    -|     ooooooo???PPPHHHHPP    -|oooooooooooo???PPPHHHHPP
M     |                     H       |                    H        |             ? P
i -50-|                            -|                    H       -|             ?
      |                             |                             |             ?
 -100-|                            -|                            -|             ?

      |________________________     |________________________     |________________________
       |''''|''''|''''|''''|'''      |''''|''''|''''|''''|'''      |''''|''''|''''|''''|'''
      75   80   85   90   95        75   80   85   90   95        75   80   85   90   95

                                Spawning Season
---------------------------------------------------------------------------
```

G-7. SUMMARY FOR WILD SALMONIDS

Cormorant hazing is not correlated with increased returns of wild salmonids; consequently, it does not appear useful in achieving the goal of recovering wild salmonids in the Oregon Plan (Kitzhaber 1999) or of restoring federally Threatened coastal coho (NMFS 1998).

****

H. RESULTS AND DISCUSSION: COHO CWT RETURNS

The only Coded Wire Tag (CWT) returns that can be correlated with hazing are for coho reared at the North Fork of the Nehalem Hatchery (section E-3b). There, the percentage of CWT returns has not consistently increased since hazing began (Fig. 11). The average return is slightly (0.5%) greater with than without hazing, but this increase is not significant (Table 12).

The greatest return at the Nehalem is for the 1985 Brood Year, when it is unknown if hazing occurred or not (Fig. 11). But a peak in return rates also occurred that year at the Sandy, Klatskanie, South Umpqua, Coos, and Rogue Rivers (Lewis 1997:5), where there was no hazing, so the 1985 Nehalem peak may also not be related to hazing, if it occurred.

The hazing-affected 1988 Brood Year had a high rate of return at the Nehalem, but adults for this Brood Year returned in 1991, and the 1991 Run-Year was extraordinary and not necessarily a result of hazing (section K-2b). Further, some of the hatcheries in the Columbia River where there was no hazing also had peak returns for that Brood Year (Lewis 1997:5), so the success of that brood at the Nehalem may have been unrelated to hazing.

Compared to nonhazed basins, Nehalem returns were often relatively greater with hazing, but it is unclear if this is a result of hazing or other factors. Graphs indicate that hazing returns are consistently higher than those in some nonhazing years (1977-1980) but not others (1981-1982)(Fig. 11). Average differences are greater with hazing, but much of this is attributable to the anomalous 1988 Brood Year (Fig. 11). Annual differences are statistically significant for the Salmon River and Siletz basins but not the Alsea Basin (Table 12); however, if the 1977-1979 Brood Years are excluded, even differences between the Nehalem and the Salmon or Siletz Basins are not significant (Table 12: footnote a).

TABLE 12. Statistical tests of whether the weighted-average percent survival of CWT marked coho is significantly greater with hazing. See Fig. 11 for details and yearly graphs of these data. The years given are Brood Years; it is unknown if hazing occurred during the 1983-1985 Brood Years. The larger mean is underlined. N=number of years, U=Mann-Whitney statistic for the hypothesis that Nehalem or Nehalem-(basin) CWT survival rates are greater with hazing at the Nehalem than without it. P=probability, NS=not significant (one-tailed P>0.05).

	Weighted Average Percent Survival of CWT Marked Coho							
	Hazed (1986-1992 & 1994)..			Nonhazed (1977-1982 & 1993)....			Hazing> Nonhazing	
Comparison	**N**	**Mean**	**Range**	**N**	**Mean**	**Range**	**U**	**P**
Nehalem Basin	8	<u>1.5</u>	0.4-4.1	7	1.0	0.4-2.1	31.5	NS
Nehalem-Salmon R.	8	<u>1.0</u>	0.1-3.0	7	-0.4	(-2.0)-1.1	44	<0.05a
Nehalem-Siletz R.	8	<u>1.1</u>	0-3.3	7	-0.5	(-1.5)-1.0	46	<0.05a
Nehalem-Alsea R.	8	<u>0.4</u>	(-1.3)-2.7	7	-1.4	(-5.5)-1.1	39	NS

a If the nonhazing years of 1977-1979 are excluded, the Nehalem-Salmon differences (U=20, N1=8, N2=4, one-tailed P>0.10) and the Nehalem-Siletz differences (U=22, N1=8, N2=4, one-tailed P>0.10) are not significant.

FIGURE 11. Weighted-average percent return rates of coho at the North Fork Nehalem hatchery and differences in these return rates between the Nehalem hatchery and the Salmon, Siletz, and Alsea hatcheries. A weighted-average is necessary because there were more than one CWT group in some years, and return rates could differ markedly amongst these groups (Appendix IV); a weighted-average was calculated on the basis of the number of fish in each group (Lewis 1997:2). Return rates were determined from CWT returns from ocean fisheries, hatchery recoveries, and spawning ground surveys; data from freshwater fisheries are not available, and spawning ground surveys incompletely survey hatchery strays (Lewis 1997:2, 13-14). Mark Lewis (ODFW, pers. comm.) provided these data that are also graphed in Lewis (1997:5); Siletz CWT releases for the 1994 Brood Year were into the Yaquina, not the Siletz. Coho smolts enter the ocean two years after a given Brood Year, so hazing in the spring of 1988 might effect the return rates of the 1986 Brood Year.

```
H=affected by Nehalem hazing        ?=unknown if affected by Nehalem hazing
o=not affected by Nehalem hazing
*=unusually high return for 1988 Brood Year at hazing-affected Nehalem

        |                  Nehalem Coho CWT Returns
 R    6-|        ?         Nonhazing Mean= 1.0
 e      |        ?            Hazing Mean= 1.5
 t    5-|        ?
 u      |        ?
 r    4-|        ?  *
 n      |        ?  *
 s    3-|        ?  *
        |        ?  *
(%)   2-|    o ? ? H*
        |    oo? ?HH* H
      1-|o--ooo???HH*HH----  1%
        |oooooo???HH*HHHHoH
      0-|oooooo???HH*HHHHoH
         '''|''''|''''|''''
           80   85   90

        Nehalem-Salmon R.      Nehalem-Siletz R.      Nehalem-Alsea R.
        Nonhazing Mean= -0.4   Nonhazing Mean= -0.5   Nonhazing Mean= -1.4
           Hazing Mean=  1.0      Hazing Mean=  1.1      Hazing Mean=  0.4
      6-|                      -|                      -|
        |        ?              |        ?              |
      5-|        ?             -|        ?             -|
        |        ?              |        ?              |
      4-|        ?             -|        ?             -|        ?
        |        ?              |        ?  *           |        ?
 D    3-|        ?  *          -|        ?  *          -|        ?
 i      |        ?  *           |        ?  *           |        ?  *
 f    2-|        ?  *          -|        ?  *          -|        ?  *
 f      |        ? H*           |        ?HH*           |        ?  *
 e    1-|----oo--?HH*-H------- -|-----o--?HH*-H------- -|----oo--?-H*-H----
 r      |    oo???HH*HHH o      |    oo???HH*HHHHo      |    oo  ? H* HH oH
 e    0-|oooooo???HH*HHHHoH=====|oooooo???HH*HHHHoH=====|oooooo???HH*HHHHoH
 n      |oooo                   |oooo                   |oooo   ?  H  H
 c   -1-|oooo                  -|oooo                  -|oooo      H
 e      |o o                    |oooo                   |oooo      H
     -2-|  o                   -|                      -|oooo
(%)     |                       |                       | o o
     -3-|                      -|                      -| |
        |                       |                       | o-(-5.5)
        |__________________     |__________________     |__________________
         '''|''''|''''|''''      '''|''''|''''|''''      '''|''''|''''|''''
           80   85   90            80   85   90            80   85   90
                              Brood Year
```

****

I. RESULTS AND DISCUSSION: HATCHERY RETURNS

I-1. COHO SALMON HATCHERY RETURNS

I-1a. COHO RETURNS AS % OF RELEASE AT NEHALEM. If the number of smolts released is increased, then it would be expected that the number of jacks or adults returning would also increase. The number of smolts released was quite variable and averaged about 125,000 fewer smolts during the nonhazing years of 1975-1984 than during hazing years (Appendix III). Accordingly, differences in returns between hazing and nonhazing years could reflect differences in the numbers of smolts released and not just the occurrence of hazing, per se.

One way to analyze returns so that the number of smolts released is not a significant factor is to calculate the percent return by dividing the number of returns by the number of smolts released. However, fingerling coho were released into the Nehalem basin through 1990 and in 1992 (Table 3); they may have migrated out as smolts the following year, but their return rate is unknown and would be expected to be less than for fish released as smolts. Thus, it is only possible to accurately determine the percent return in 1992 and 1994-1997, when returns would only be from smolts (Table 3).

The percent return of jacks or adults does not seem very high at the Nehalem hatchery in some of the years with hazing, and the adult return rate in three of four hazing years was actually less than from smolts released in the nonhazing year of 1995 (Fig. 12).

When return rates at the Nehalem are compared to those at the Salmon River (where hazing did not occur and fingerlings were not released in these years), Nehalem return rates averaged 0.04% more for jacks and 0.12% less for adults (Fig. 13) and were not statistically different for jacks (paired-sample t=0.63, df=4, one-tailed P>0.25) or adults (paired-sample t=-0.91, df=3, one-tailed P>0.10).

Differences for the percentage return between the Nehalem and Siletz or Alsea hatcheries were not compared because fingerlings were sometimes released into the Siletz and Alsea and their smolt releases were not always at the hatchery, so their returns may have been affected by the release site.

FIGURE 12. Percentage of coho smolts returning as jacks or adults to the North Fork of the Nehalem River hatchery. Releases prior to 1992 and in 1993 are not included because fingerling releases into the Nehalem or smolt releases elsewhere in the Nehalem than at the hatchery in these years may have augmented returns to the hatchery (see Table 3). These data were calculated from data provided by Rick Klumph, John Leppink, and Tracy Cabe of the ODFW. Jacks returned in the same year as the Year of Smolt Release, and adults returned the following year.

```
      H=affected by hazing                    O=not affected by hazing

          % of Coho Smolts Returning to Nehalem Hatchery as
 P                   Jacks                                      Adults
 e    1.0-|                                   1.0-|
 r       -|                                      -|
 c    0.8-|                                   0.8-|
 e       -|                                      -|
 n    0.6-|                                   0.6-|   H           O
 t       -|------  ------------------ 0.5% -------|---H--  ---H---O--------
 a    0.4-|                         H         0.4-|   H       H   O   H   H
 g       -|  H                      H            -|   H       H   O   H   H
 e    0.2-|  H                      H         0.2-|   H       H   O   H   H
         -|  H              H       H            -|   H       H   O   H   H
0.01-0.04-|  H       H   O   H   H  H   0.01-0.04-|   H       H   O   H   H
        0-|__H__   __H___O___H___H__H           0-|___H__   __H___O___H___H
             |       |   |   |   |  |                 |       |   |   |   |
            92      94  95  96  97 98                92      94  95  96  97

                          Year of Smolt Release
```

FIGURE 13. Differences in the percentage of coho smolts returning as jacks or adults between the North Fork of the Nehalem River and Salmon River hatcheries. The number of smolts released at the Salmon River were provided by John Leppink and Tracy Cabe of the ODFW; all other data are calculated from data provided by Rick Klumph of the ODFW. Jacks returned in the same year as the Year of Smolt Release, and adults returned the following year.

Releases in 1985-1991 and 1993 are not included because fingerling releases or smolt releases elsewhere into the Nehalem may have augmented returns to the Nehalem Hatchery (see Table 3). An undetermined portion of these fish would be expected to return to the Nehalem Hatchery; however, their return rate would be expected to be much less than for smolts released at the hatchery.

```
      H=affected by hazing                    O=not affected by hazing

         Nehalem-Salmon River % of Coho Smolts Returning as

                    Jacks                              Adults
     0.5-|                               0.5-|
        -|  Hazing Mean= 0.04%              -|   Hazing Mean= -0.12%
     0.4-|                               0.4-|
        -|                                  -|
     0.3-|                          H    0.3-|
        -|                          H       -|
P    0.2-|                          H    0.2-|
e       -|                          H       -|
r    0.1-|                          H    0.1-|           H       H
c       -|  H                       H       -|           H       H
e      0-|==H==   ==H===O===H===H===H      0-|===H==   ==H===O===H===H
n       -|          H   O       H           -|   H           O       H
t   -0.1-|                              -0.1-|   H           O       H
a       -|                                  -|   H           O       H
g   -0.2-|                              -0.2-|   H           O       H
e       -|                                  -|   H           O       H
    -0.3-|                              -0.3-|   H                   H
        -|                                  -|   H
    -0.4-|                              -0.4-|   H
        -|                                  -|
         |_____   ___________________        |______   _______________
            |       |   |   |   |   |            |       |   |   |   |
           92      94  95  96  97  98           92      94  95  96  97

                           Year of Smolt Release
```

I-1b. NUMBER OF RETURNING COHO. The numbers of jacks returning to the Nehalem and Trask hatcheries were variable; the average was slightly higher during hazing at the Nehalem but during nonhazing at the Trask (Fig. 14). Returns with hazing are not significantly greater (Table 13).

The number of returning adults was also variable and averaged twice as great with hazing at the Nehalem but only slightly greater at the Trask hatchery (Fig. 14). Hazing-affected returns were not significantly greater for the Trask hatchery but were so for the Nehalem hatchery (Table 13). However, there was an extraordinarily high adult return for smolts released in 1990 at the Nehalem that would have returned as adults in 1991 (Fig. 14); this anomaly may not be related to hazing (section K-2b). Without the 1991 anomaly, hazing results for adults at the Nehalem were not significantly greater (Table 13: footnote b). For both hatcheries, returns during some years with hazing were less than in some years without it (Fig. 14).

If hazing is as beneficial as has been claimed for coho hatchery returns (Erickson 1995a, Monroe 1995b, 1996a; Nokes 1995), one would expect differences with hazing to be greater than they are. But even if hazing improved hatchery returns of adults, this is not a goal of salmon management because increased returns are not very useful. As it is, there are often more coho returning than are needed to coastal hatcheries (Orcutt 1992) and at the North Fork of the Nehalem hatchery, generally about 400-600 female coho were spawned each year, regardless of the number returning (John Leppink and Tracy Cabe, ODFW, pers. comm.). The number of females that were not spawned (i.e., surplus) at the Nehalem does not appear to be related to hazing; for example, there were 1,743 surplus females in the nonhazing-affected return year of 1985 but only 79 surplus females in the hazing-affected return year of 1990 (John Leppink and Tracy Cabe, ODFW, pers. comm.). Surplus fish are generally unfit for human consumption and are sold for fish food (Orcutt 1992).

TABLE 13. Statistical tests of whether the number of returning coho jacks or adults to the Nehalem or Trask hatcheries is significantly greater with hazing. Hazing-affected years of smolt releases were 1988-1994 and 1996-1998 for the Nehalem hatchery and 1988 and 1996-1998 for the Trask hatchery in the Tillamook Basin. See Fig. 14 for details and yearly graphs. The larger mean is underlined. U=Mann-Whitney statistic for the hypothesis that the number of returns at the Nehalem or Trask hatcheries is more abundant with hazing than without it, N=number of years, P=probability, NS=not significant (one-tailed P>0.05).

	Number of Returning Coho to Hatchery......						Hazing> Nonhazing	
	Hazed...............			Nonhazed............				
Comparison	**N**	**Mean**	**Range**	**N**	**Mean**	**Range**	**U**	**P**
				Coho Jacks				
Nehalem Hatchery	10	<u>1,564</u>	80-4,570	11	1,433	45-7,499	62	NS
Trask Hatchery	4	405	216-591	20	<u>608</u>	48-2,803	34	NSa
				Coho Adults				
Nehalem Hatchery	9	<u>5,185</u>	1,553-14,732	11	2,587	71-7,988	74	<0.05b
Trask Hatchery	3	<u>4,138</u>	789-10,174	20	3,833	930-9,326	26	NSa

a The number of years with known hazing is less than five; statistical tests would be more robust with larger sample sizes (section E-4e).

b Without the anomalous 1991 return of adults from smolts released in 1990 (section K-2b), returns with hazing are not significantly greater (U=63, N1=8, N2=11, one-tailed P>0.05).

FIGURE 14. Counts of coho jacks or adults returning to the North Fork of the Nehalem River or Trask hatcheries for each Year of Smolt Release during 1975-1998. These data were provided by Rick Klumph (ODFW, pers. comm.), except for the 1988 number of jacks returning to the Nehalem hatchery, for which I use the 4,570 jacks given by Leslie Schaeffer (ODFW, pers. comm.) and John Leppink (ODFW, pers. comm.) rather than the 424 jacks given by Klumph. Jacks return in the same year as the Year of Smolt Release, and adults return during the following year.

```
H=affected by hazing                      ?=unknown if affected by hazing
o=not affected by hazing

-------------------- Number of Returning Coho Jacks ----------------
N  8,000-|        Nehalem Hatchery         -|   Trask Hatchery
u        | o      Nonhazing Mean= 1,433     |   Nonhazing Mean= 608
m  7,000-| o         Hazing Mean= 1,564    -|      Hazing Mean= 405
b        | o                                |
e  6,000-| o                               -|
r        | o           ?                    |
   5,000-| o           ?                   -|
o        | o           ?H H                 |
f  4,000-| o           ?H H                -|
         | o           ?H H                 |
J  3,000-| o        o  ?H H                -| o
a        | o        o  ?H H H               | o
c  2,000-| oo       o  ?HHH H              -| o
k        | oo       o? ?HHH H               | o           o
s  1,000-| oo o   o o? ?HHHHH              -| oo       o  o oo
         | oo oo oo o???HHHHH  oH H         | ooo     ooo oHoooo o   H
   1-249-| oooooooooo???HHHHHHHoHHH        -| oooooooooooooHoooooooHHH
       0-| oooooooooo???HHHHHHHoHHH        -| oooooooooooooHoooooooHHH
           |''''|''''|''''|''''|'''           |''''|''''|''''|''''|'''
          75   80   85   90   95             75   80   85   90   95


--------------------- Number of Returning Coho Adults -------------
Nehalem: Nonhazing Mean= 2,587           Trask: Nonhazing Mean= 3,833
            Hazing Mean= 5,185                     Hazing Mean= 4,138

                   14,732-H
                          |
  10,000-|                H                -|              H
         |                H                -|         o    H
   9,000-|                H                -|         o    H
         |                H                -|         o    H
N  8,000-| o           ?  H                -|         o    H
u       -| o           ?  H                -|         o    H
m  7,000-| o           ?  H                -| o       o    H     o
b       -| o           ?H H                -| o       o o  H     o
e  6,000-| o           ?H H                -| o       o o oHo    o
r       -| o           ?H H  H             -| o       o o oHoo   o
   5,000-| o  o        ?H H HH             -| o       o o oHoo  oo
o       -| o  o        ?H H HHHo           -| o       ooo oHoo  oo
f  4,000-| o  o     o  ?H H HHHo           -| o       ooo oHoo  oo
        -| o  o     oo ?H HHHHHo           -| o   o   ooo oHoo  oo
A  3,000-| o  o     o? ?H HHHHHo           -| o   o   ooo oHoooooo
d       -| o  oo    o? ?H HHHHHoHH         -| o  oo   ooo oHoooooo
u  2,000-| o  oo    o? ?H HHHHHoHH         -| o  oo   ooo oHoooooo
l       -| o  oo   oo? ?HHHHHHHoHH         -| ooooo   oooooHoooooo  H
t  1,000-| oo oo o oo???HHHHHHHoHH         -| oooooooooooooHoooooooHH
s       -| oo oo oooo???HHHHHHHoHH         -| oooooooooooooHoooooooHH
       0-| oooooooooo???HHHHHHHoHH         -| oooooooooooooHoooooooHH
           |''''|''''|''''|''''|''            |''''|''''|''''|''''|''
          75   80   85   90   95             75   80   85   90   95
```

Year of Smolt Release

I-2. STEELHEAD HATCHERY RETURNS

I-2a. INTRODUCTION. Hatchery winter steelhead are released into the Nehalem, Tillamook, and Nestucca Basins, and summer steelhead are released into the Tillamook and Nestucca Basins (Appendix II-2a). Unfortunately, there are difficulties in determining if hazing has influenced hatchery returns. For example, the number of winter steelhead smolts released has varied at the Nehalem (Appendix III), and it would be expected that more fish would return as a consequence of larger releases. To reduce this factor, it would be ideal to calculate the percentage of smolts that were released that return to the hatchery; however, this is not appropriate for Nehalem hatchery returns for two reasons. First, most adults return as 2- or 3-salts and the proportion returning as each may vary yearly (Appendix II-2d). Second, many winter steelhead smolts reared at the North Fork of the Nehalem hatchery were released elsewhere in the Nehalem or nearby Necanicum basins (Appendix III), and a significant proportion of those would be expected to stray back to the Nehalem hatchery, since 16-24% of steelhead caught in 1993 at the Trask and Nestucca Rivers were strays from releases into other streams (Lindsey et al. 1994:9).

Another challenge in analyzing winter steelhead hatchery returns to the Nehalem hatchery is that the number of steelhead returning depends upon how long they are counted. For example, many can return in February or March, but counting ceased in January or early February in some years (Table 4) when enough fish had returned for hatchery purposes, not because fish had ceased returning (Gary Yeager, ODFW Nehalem Hatchery manager, pers. comm.).

Because of these challenges, returns must be examined cautiously to determine if hazing is correlated with increased returns. Below, returns to the Nehalem and Cedar Creek (Nestucca Basin) hatcheries are examined. There were too few returns (i.e., usually less than 100 adults and 5 jacks) to the Trask and Trask Pond (Tillamook Basin) hatcheries (John Leppink, ODFW, pers. comm.) to be useful in analyses.

I-2b. WINTER STEELHEAD. The average number of jacks returning to the Nehalem hatchery is much greater with hazing (Fig. 15), and returns are significantly greater with hazing (Mann-Whitney $U=76$, $N1=9$, $N2=11$, one-tailed $P<0.05$). However, Nehalem returns are not always greater with than without hazing, and the average number of winter steelhead jacks returning to the Cedar Creek hatchery for two years of hazing is less than the average for 13 nonhazing years (Fig. 15).

Annual adult returns to Nehalem with hazing are not consistently higher (Fig. 15). On average, slightly more adults returned, but annual returns with hazing are not significantly greater (Mann-Whitney $U=41$, $N1=6$, $N2=10$, one-tailed $P>0.10$). Years in which only 2- or 3-salts were possibly affected by hazing are not included in analyses, and returns in these years are greater than in some years when all ages were affected (Fig. 15).

Because hazing commenced in the spring of 1996 at the Nestucca, the first return year with both 2- and 3-salts would be 1998-1999. Consequently, there are not yet enough years of adult returns at the Cedar Creek Hatchery to see if hazing is correlated with increased returns.

I-2c. SUMMER STEELHEAD. Summer steelhead were not released at the Nehalem (Appendix II-2a). It is inappropriate to examine summer steelhead returns to the Trask hatchery (Tillamook Basin) because too few (i.e., less than 30 adults and 0-1 jacks) return there annually (John Leppink, ODFW, pers. comm.).

Only the returns of summer steelhead of Stock 47 to the Cedar Creek hatchery are numerous enough to analyze. However, since hazing commenced at the Nestucca in the spring of 1996 and adults may return as 2- or 3-salts as do winter steelhead (Appendix II-2d), there are no data that may entirely represent adults affected by hazing. Even for jacks (1-salts), the only two years of hazing-affected returns that are available are for 1997 and 1998; 0-1 jacks returned in these years, compared to an average of 1.1 jacks (range 0-5) during the nonhazing-affected 1984-1992 and 1994-1996 (John Leppink, ODFW, pers. comm.). So hazing is not correlated with an increase in jack returns.

I-2d. STEELHEAD DISCUSSION. The assertion that steelhead hatchery returns have increased with hazing (Erickson 1989a,b,d; Monroe 1996a) is supported only for Nehalem winter steelhead jacks, not for Cedar Creek winter or summer steelhead jacks or Nehalem winter steelhead adults. Similarly, Berry (1995) testified to the Oregon Legislature that steelhead returns to the Nehalem hatchery for 1993 releases were nearly identical to those not affected by hazing that returned to the Tillamook Basin hatchery. Further, since it is adults, not jacks, that contribute materially to fisheries and hatchery brood stock, the increased jack returns to the Nehalem with hazing are not very beneficial.

FIGURE 15. Number of winter steelhead jacks or adults returning to the North Fork of the Nehalem River and Cedar Creek hatcheries. The Run-Year is when the steelhead returned to the hatchery. For smolts released during the spring of 1988, jacks (1-salts) would return during 1988-1989 Run-Year, and most adults would return during the 1989-1990 Run-Year as 2-salts, some would return during the 1990-1991 Run-Year as 3-salts, and a few would return in later years as repeat spawners (Appendix II-2d).

Nehalem data for the 1997-1998 Run-Year were provided by John Leppink and Tracy Cabe of the ODFW; data for previous years were from Rick Klumph (ODFW). The adult return in the 1975-1976 Run-Year is excluded because only 2-salts returned then to the Nehalem hatchery; the first Run-Year with both 2- and 3-salts was 1976-1977.

Cedar Creek data were provided by John Leppink; data prior to the 1983-1984 Run Year were not necessary because there were enough years without hazing. Only jacks are graphed because the first year with hazing-affected returns of both 2- and 3-salts would be 1998-1999.

```
H=affected by hazing                    ?=unknown if affected by hazing
o=not affected by hazing                #=wild steelhead released
2=only 2-salts affected by hazing       3=only 3-salts affected by hazing

-------------------- Returning Winter Steelhead Jacks --------------------
            Nehalem Hatchery                       Cedar Creek Hatchery
            Nonhazing Mean=  5                     Nonhazing Mean= 7
               Hazing Mean= 19                        Hazing Mean= 4
      80-|                                  80-|
      70-|                     H            70-|
      60-|                     H            60-|
J     50-|             H       H            50-|
a     40-|             H       H            40-| o
c     30-|             H      oH            30-| o
k     20-|          ?  H HH  HoH            20-| o
s     10-|--------oo?--H-HH--HoH- 10        10-|-o-----ooo--o-- 10
     1-4-|        oo?  H HHHHHoH           1-4-| oooo  ooo ooHH
       0-|oooooooooo???HHHHHHHoHH            0-|oooooooooooooHH
         |________________#######              |________#######
          |''''|''''|''''|''''|''               ''|''''|''''|''
         75-  80-  85-  90-  95-                 85-  90-  95-
         76   81   86   91   96                  86   91   96
                                    Run-Year
```

```
                              Winter Steelhead Adults Returning to Nehalem
        -|                      Nonhazing 1976-77 through 1985-86 Mean= 631
   2,500-|                         Hazing 1990-91 through 1995-96 Mean= 737
        -|                    o
   2,000-|                    o
        -|                  o o
A  1,500-|                  o o
d       -|                  o o                     H 3
u  1,000-|------------------o-o-o-----------------H-H-3--- 1,000
l       -|                  o o o     ? 2     H   H H 3 2
t    500-|                o o o o ? ? ? 2 H H H   H H 3 2
s       -|    o   o o   o o o o o ? ? ? 2 H H H H H H 3 2
   1-124-|    o o o o o o o o o o ? ? ? 2 H H H H H H 3 2
       0-|    o o o o o o o o o o ? ? ? 2 H H H H H H 3 2
         |__________________________________#_#_#_#_#_#_#
            | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' ' ' ' | ' '
          75-       80-       85-       90-       95-
          76        81        86        91        96
                             Run-Year
```

I-3. CHINOOK SALMON HATCHERY RETURNS

Hatchery fall and spring chinook are released into the Tillamook and Nestucca Basins, but no chinook are released into the Nehalem Basin (Appendix II-3a).

The number of fall chinook jacks returning to the Trask hatchery did not show an increase during the two years with hazing compared to nonhazing years (Fig. 16). The fall chinook hatchery program at the Cedar Creek hatchery appears to be ceasing as eggs were last taken in 1992 and jack returns have greatly declined in following years (John Leppink, ODFW, pers. comm.). Accordingly, it would be inappropriate to test Cedar Creek jack returns for the effects of hazing.

Spring chinook jack returns to the Trask and Cedar Creek hatcheries for the two years affected by hazing were less than or about equal to the years without hazing; there clearly was not an increase with hazing (Fig. 16).

For 1986-1997, the only year with any returning winter chinook jacks to the Trask hatchery was 1993 when there were two (John Leppink, ODFW, pers. comm.). So no more returned in the hazing affected years of 1989 and 1997 than in other years, but winter chinook jacks are rare in any year.

In summary, the number of returning chinook jacks did not appear to be correlated with hazing.

FIGURE 16. Number of fall and spring chinook jacks returning to the Trask hatchery (Tillamook Basin) and spring chinook jacks returning to the Cedar Creek Hatchery (Nestucca). Data were provided by John Leppink (ODFW, pers. comm.); I did not request 1998 Trask data, so they are not shown.

```
     H=affected by hazing                o=not affected by hazing

------------------ Number of Returning Chinook Jacks -----------------------

      Trask Hatchery           Trask Hatchery           Cedar Creek Hatchery
      Fall Chinook Jacks       Spring Chinook Jacks     Spring Chinook Jacks

N  100-| o                  100-|                    100-|
u   90-| o                   90-|                     90-|   o
m   80-| o                   80-|                     80-|   o
b   70-| o                   70-|                     70-|   o o
e   60-| o                   60-|                     60-|   o oo
r   50-| o o  o              50-|                     50-|   o oo
    40-|oo o  o              40-|                     40-|  oo oo
o   30-|oooo  o              30-|                     30-|  ooooo
f   20-|oooo Ho              20-|                     20-|  ooooo
    10-|oooooHo o o          10-|  oo    o oo         10-| oooooooo  o HH
J  1-4-|oooooHo o oo        1-4-|ooooo o o oo H     1-4-| ooooooooooooHH
a    0-|oooooooooooooH        0-|oooooHoooooooH       0-|oooooooooooooHH
c       '|''''|''''|''           '|''''|''''|''           '|''''|''''|'''
k       85   90   95             85   90   95             85   90   95
s
                               Year of Return
```

****

J. RESULTS AND DISCUSSION: FISHERIES CATCHES

J-1. COHO SALMON ESTUARINE AND FRESHWATER SPORTS CATCHES

J-1a. INTRODUCTION. The coho fishery is important, although recovery of wild coastal coho takes precedence (OCSRI 1997a,b; NMFS 1998, Kitzhaber 1999). The challenge in using estuarine and stream sports catches to determine if hazing has been successful is that at least four other factors also affect catches. First, estuarine and freshwater catches are expected to be greater with hazing because ocean exploitation rates were less during hazing years than without it (Appendix V-8), so relatively more coho should escape to freshwater, where they could be caught.

Second, the number of coho caught can depend upon the number of smolts released, which has averaged greater since hazing began at the Nehalem (Appendix III) and has been variable at the Salmon and Alsea Basins (ODFW 1997a:61, 1997b:45). Standardizing catches by the number of hatchery smolts released at the Nehalem is not possible because fingerlings were released into the Nehalem Basin (e.g., Table 3), and their survival is probably much lower than for smolts, although they could still contribute to catches. Additionally, much of the available catch data prior to 1994 includes wild coho, so using the number of hatchery smolts released to standardize catches would not be appropriate.

A third factor that can influence sport catches is straying, whereby coho caught in one basin may have been released elsewhere (Appendix V-9). This factor is important along the Oregon central coast because Oregon Aqua-Foods (OAF)(a now defunct private aquaculture firm at Yaquina Estuary) released an annual average of 10.9 million coho smolts (range 3.9-20.6 million) during the nonhazing years of 1978-1984 that would have been caught during the 1979-1985 fisheries and an average of 2.9 million smolts (range 0-8.0 million) during the years of known hazing at the Nehalem in 1988-1992 that would have been available to fisheries in 1989-1993 (ODFW 1991:37; Bob Buckman, ODFW, pers. comm.); OAF ceased releases in 1993. A high percentage of OAF smolts did not return to the Yaquina but strayed elsewhere, particularly to streams between the Yachats and Salmon River Basins (Jacobs 1988:17-18, ODFW 1997a:62, 1997b:43, 1997c:57). In 1985, 78% of the adult coho captured at the Salmon River hatchery and 54% of the coho at Salmon River spawning areas were released by OAF (Jacobs 1988:17-18). Consequently, if catches are relatively less at the Alsea, Siletz, and Salmon River Basins during years with hazing at the Nehalem, the reason may be the lack of OAF strays to these basins in recent years rather than increased returns to the Nehalem from hazing.

Another factor that affects stream sports catches is fishing effort. For example, coho fishing effort at the Salmon River has ranged from 7,470 to 78,663 Angler Hours annually during 1976-1996 (ODFW 1997b:46) and could have also varied considerably at other coastal streams. Thus, a larger catch in one year than another may reflect greater fishing effort that year, not necessarily a greater number of available fish.

To sum up, the estuarine and stream catch reflects the effects of many factors (also see Appendix V), so it may not be possible to distinguish how much the catch depends upon any one factor, such as hazing. Nonetheless, fisheries are an important aspect of salmon management, so it is important to examine catch data cautiously to determine if hazing may have improved fisheries.

J-1b. INCREASED COHO POST-HAZING CATCHES. Catches are significantly greater at the Nehalem since hazing began (Table 14, Fig. 17). The huge catch in 1991 at Nehalem (Fig. 17) is probably not a result of hazing because 1991 was an anomalous year for adult returns (section K-2b), and an unusually large catch was also reported then at the nonhazing-affected Tillamook Basin and composite of other coastal streams (Fig. 17). At Tillamook Bay, this extraordinary catch in 1991 was attributed to large numbers of non-Tillamook Bay coho being caught just inside the mouth of the Bay during late summer (R. Klumph in Ellis 1998:3-8). Other evidence that the 1991 Nehalem catch may not reflect the benefits of hazing is that this catch is comparatively less than at the nonhazed Umpqua (Fig. 18).

The differences in catches between the Nehalem and the nonhazed Salmon, Siletz, and Alsea Basins are significantly greater since hazing began at the Nehalem (Table 14, Fig. 18). These nonhazed basins did not share in the extraordinarily good year of 1991 (ODFW 1998b), but even without that year, Nehalem catches were relatively greater with hazing (Fig. 18). However, it is unclear if these differences result from hazing at the Nehalem or from the decline in OAF releases during the years of hazing, so that fewer OAF coho strayed to the Salmon, Siletz, and Alsea Basins where they contributed to fisheries (section J-1a).

J-1c. UNCHANGED OR DECREASED COHO POST-HAZING CATCHES. Not all evidence suggests that catches have increased at the Nehalem with hazing. For example, the difference in catches between the Nehalem and the Tillamook Basin or the composite of all Oregon coastal streams other than the Nehalem and Tillamook averaged greater before known hazing than after hazing at the Nehalem, although these differences are not significant (Table 14). Further, differences in catches between the Nehalem Basin and the nonhazed Umpqua Basin are significantly greater without than with hazing
(Table 14: footnote b).

Finally, the 1989 catch at Tillamook Basin that would have been affected by the 1988 cormorant hazing at Tillamook is much less than for the nonhazing-affected years of 1986 and 1991 (Fig. 17).

J-1d. COHO FISHERIES DISCUSSION. Evidence that hazing resulted in increased coho catches is muddled because not all tests indicate a significant increase with hazing and because several factors other than hazing have also changed that could have contributed to relatively greater catches during the years with hazing (Appendix V).

TABLE 14. Statistical tests of whether sport catches of coho at the Nehalem Basin or differences between the Nehalem and other basins are significantly greater with hazing. See Fig. 17 for annual catches at Nehalem Basin, Tillamook Basin, and other coastal streams and bays and Fig. 18 for differences in catches between the Nehalem and Salmon River, Siletz, Alsea, and Umpqua Basins; see the legends of these figures for streams included within each of these basins. Starting in 1994, coho sport fisheries were limited to a few streams (Appendix V-8c), so comparisons are not possible for these years.

The larger mean is underlined. Other=sum of coastal stream catches minus catches at the Nehalem and Tillamook Basins; the Columbia River and its tributaries are not included with coastal stream data. N=number of years, U=Mann-Whitney statistic for the hypothesis that Nehalem or Nehalem-(basin[s]) catches are relatively greater with hazing at the Nehalem than without it, P=probability, NS=not significant (one-tailed P>0.05).

	Number of Coho Caught in Sports Fishery..........						Hazing>	
	Hazed (1989-1993)........			Nonhazed (1975-1985)...			Nonhazing	
Comparison	N	Mean	Range	N	Mean	Range	U	P
Nehalem Basin	5	3071	1280-8318	11	804	154-2534	51	<0.01
Nehalem-Tilla.	4a	-1810	(-9521)-1999	11	-376	(-1545)-404	26	NSb,c
Nehalem-Other	5	-15637	(-40945)-(-4418)	11	-8430	(-12760)-(-646)	20	NSb
Nehalem-Salmon	5	2822	1130-7955	11	465	(-97)-1971	52	<0.01
Nehalem-Siletz	5	2724	795-7861	11	-124	(-1101)-504	55	<0.01
Nehalem-Alsea	5	1149	(-1410)-6426	11	-1578	(-4833)-5	44	<0.05
Nehalem-Umpqua	5	-4937	(-14841)-107	11	-515	(-3197)-1293	10	NSb

a 1989 is not included for Nehalem-Tillamook because there was hazing at Tillamook in 1988 that may have affected the 1989 sports catch there.

b When the hypothesis that nonhazing catches are greater than those with hazing is tested, the results are nonsignificant for Nehalem-Tillamook and Nehalem-Other but are significant for Nehalem-Umpqua catches (U=45, one-tailed P<0.05).

c The number of years with known hazing is less than five; statistical tests would be more robust with larger sample sizes (section E-4e).

FIGURE 17. Sport catches of hatchery and wild coho at Oregon coastal streams and bays other than the Columbia River during 1975-1993. 1994-1996 data are not included because there was not a sports fishery at most streams in these years, although there was a fishery in part of the Nehalem Basin at the North Fork of the Nehalem River (Appendix V-8c). Data are from ODFW (1987, 1998b) punchcard/tag returns, which are explicitly for adults, although a few jacks may be mistakenly recorded (Eric Schindler, ODFW, pers. comm.). Adults return after two summers in the ocean, so smolts entering the ocean during hazing in the spring of 1988 at the Nehalem and Tillamook would be caught as adults during the 1989 Run-Year.

Other Coastal Streams & Bays=all coastal streams and bays except for Nehalem and Tillamook Basins. The Nehalem Basin includes Nehalem Bay, Nehalem River above and below Elsie, North Fork of Nehalem River, Cook Creek, Rock Creek, and Salmonberry River. The Tillamook Basin includes Tillamook Bay and the following rivers: Kilchis, Miami, Tillamook, Trask, North and South Forks of the Trask, and Wilson.

```
H=affected by hazing                ?=unknown if affected by hazing
o=not affected by hazing
*=anomalously high catches in 1991; only Nehalem catch affected by hazing

---------------------- Coho Sport Catches ---------------------------

           Other Coastal                  Nehalem                        Tillamook
           Streams & Bays                 Basin                          Basin
                                      Nonhazing Mean=   804
                                         Hazing Mean= 3,071
  50,000-|                *                                                   17,839-*
N       -|                *                                                          |
u 45,000-|                *      9,000-|                      9,000-|                *
m       -|                *           -|                *        -|                *
b 40,000-|                *      8,000-|                *     8,000-|                *
e       -|                *           -|                *        -|                *
r 35,000-|                *      7,000-|                *     7,000-|                *
        -|                *           -|                *        -|                *
o 30,000-|                *      6,000-|                *     6,000-|           o    *
f       -|                *           -|                *        -|           o    *
  25,000-|                *      5,000-|                *     5,000-|           o    *
C       -|           o    *           -|                *        -|           o    *
o 20,000-|           o    *      4,000-|                *     4,000-|           o    *
h       -|           o    *o          -|                *        -|           o    *
o 15,000-| o       o o    *o     3,000-|           ?    *     3,000-|           o    *
        -|oo     o ooo  o *o          -| o         ?    * H        -|         o o    *
  10,000-|ooo   oo ooo oo *oo    2,000-| o         ? ? H* H   2,000-| oo    o o o oH *
        -|ooo   oooooooooo*oo        -|-o---------?-?HH*HH        -| oo    o ooo oH *o
   5,000-|ooo  ooooooooooo*oo    1,000-|ooo      oo? ?HH*HH   1,000-|ooo    o ooo oHo*o
        -|oooo ooooooooooo*oo        -|ooo oo o oo???HH*HH        -|oooooooo oooooHo*oo
 1-1,249-|oooooooooooooooo*oo    1-249-|ooooooooooo???HH*HH   1-249-|ooooooooooooooHo*oo
       0-|oooooooooooooooo*oo        0-|ooooooooooo???HH*HH       0-|ooooooooooooooHo*oo
          |''''|''''|''''|*''           |''''|''''|''''|*''          |''''|''''|''''|*''
         75   80   85   90             75   80   85   90            75   80   85   90

                                              Run-Year
```

FIGURE 18. Differences in sports catches of coho between the hazing-affected Nehalem Basin and the nonhazing-affected Salmon River, Siletz, Alsea, and Umpqua Basins. The streams included in Nehalem Basin are in the legend of Fig. 17, which graphs Nehalem catches. The Siletz Basin includes Siletz Bay, Siletz River, North and South Forks of the Siletz River, Drift Creek, Rock Creek, Little Rock Creek, and Schooner Creek. The Alsea Basin includes Alsea Bay, Alsea River, North and South Forks of the Alsea River, Drift Creek, Fall Creek, Five Rivers, and Lobster Creek. The Umpqua Basin includes Umpqua River & (Winchester) Bay, North and South Umpqua River, Smith River, and North Fork of the Smith River. These data are from punchcard/tag data in ODFW (1987, 1998b).

H=Nehalem affected by hazing
?=unknown if Nehalem affected by hazing
o=not affected by hazing
***=1991 was an anomalously high catch year for the hazing-affected Nehalem but not for all nonhazing-affected basins (also see Fig. 17)**

```
---------------------- Coho Sport Catches ------------------

             Nehalem-Salmon River       Nehalem-Siletz
             Nonhazing Mean=  465       Nonhazing Mean= -124
                Hazing Mean=2,822         Hazing Mean= 2,724

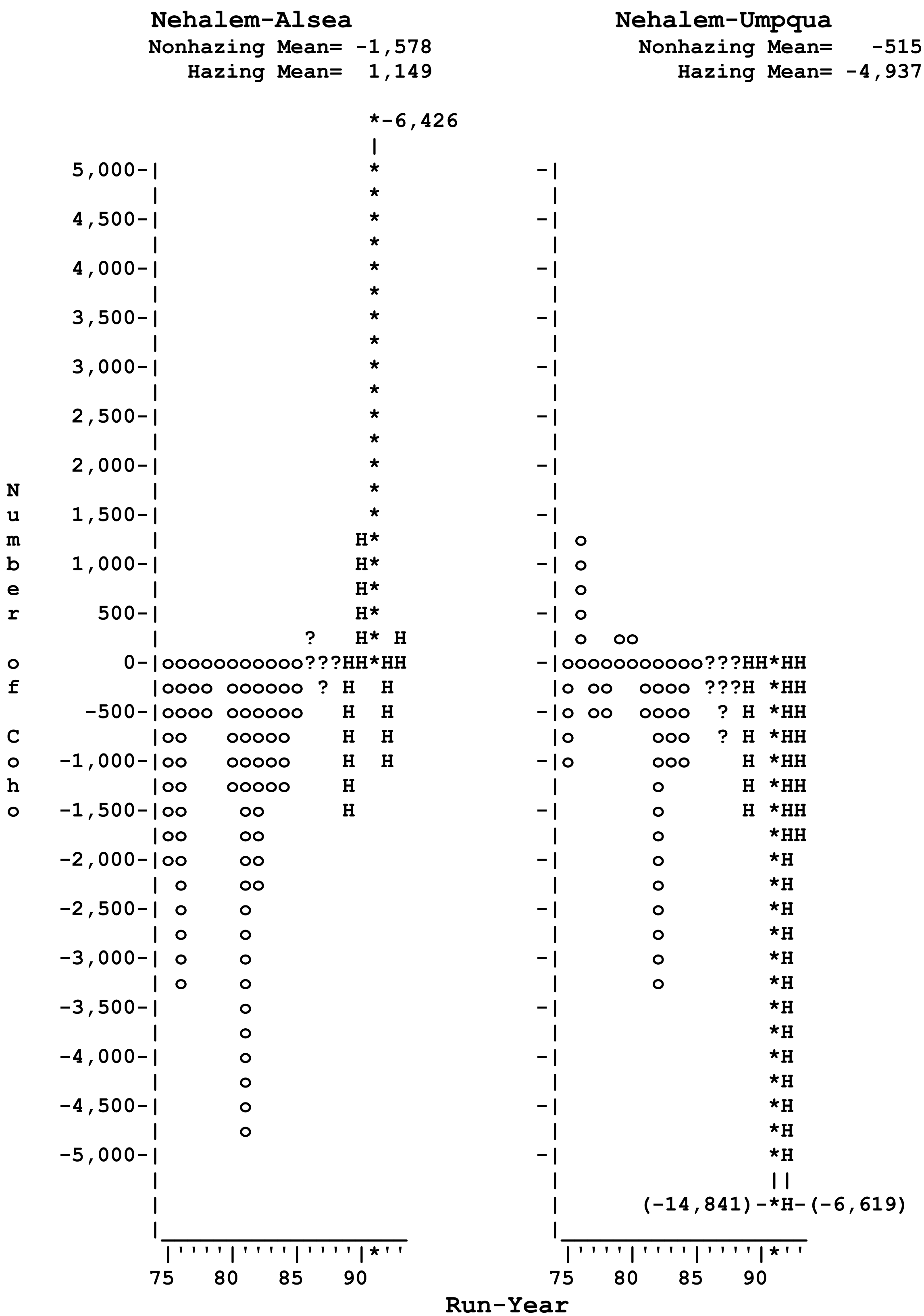
                             *-7,955                    *-7,861
                             |                          |
 N    3,000-|                *              -|          *
 u          |                *               |          *
 m    2,500-|                *              -|          *
 b          |           ?    *               |          *
 e    2,000-| o         ?    * H            -|     ?    * H
 r          | o         ? ? H* H             |     ? ? H* H
      1,500-| o         ? ? H* H            -|     ? ? H* H
 o          | o         ? ?HH*HH             |     ? ? H* H
 f    1,000-| o         ? ?HH*HH            -|     ? ?HH* H
            | o        o? ?HH*HH             |     ? ?HH*HH
 C      500-|ooo  o    o? ?HH*HH            -|    o? ?HH*HH
 o          |ooo oo o oo???HH*HH             | o  oo    o???HH*HH
 h        0-|ooooooooooo???HH*HH            -|ooooooooooo???HH*HH
 o          |                                |o o   o oo
       -500-|                               -|  o
            |                                |  o
     -1,000-|                               -|  o
            |                                |
            |___________________             |___________________
             |''''|''''|''''|*''              |''''|''''|''''|*''
             75   80   85   90                75   80   85   90

                                Run-Year
```

(Fig. 18 continued on next page)

(Fig. 18 continued)

H=Nehalem affected by hazing **?=unknown if Nehalem affected by hazing**
o=not affected by hazing
***=1991 was an anomalously high catch year for the hazing-affected Nehalem but not for all nonhazing-affected basins (also see Fig. 17)**



J-2. STEELHEAD ESTUARINE AND FRESHWATER SPORTS CATCHES

J-2a. INTRODUCTION. There is no ocean fishery for steelhead (Pauley et al. 1986, ODFW 1998b), and many factors, including the number of smolts released (see Appendix III), can affect the number of fish caught (Appendix V). For example, starting in 1992, only hatchery-reared steelhead could be caught and kept (Chilcote 1998:31). Additionally, more steelhead would be expected to be caught with increased fishing effort, and effort can be quite variable, since yearly steelhead fishing effort at the Alsea during 1975-1987 ranged from 40,000 to 153,000 hours (ODFW 1997a:79).

Standardizing catches as a percentage of the number of steelhead smolts released is not appropriate because of straying of Nehalem-reared fish released into the Necanicum (see Appendix III) back into the Nehalem, because steelhead catches could include both 2- and 3-salts and the proportion returning in each age-class can vary yearly (Appendix II-2d), and because catches prior to 1992 included wild fish.

Usually less than 50 summer steelhead were caught at the Nehalem (ODFW 1998b), which are too few to correlate with hazing. Summer steelhead catch data are not available at the Tillamook and Nestucca Basins to see if they have changed with hazing during the springs of 1996-1998. Consequently, catch data are only analyzed for winter steelhead.

J-2b. WINTER STEELHEAD CATCHES. Graphical results indicate that winter steelhead catches have not increased with hazing at the Nehalem (Fig. 19), the average Nehalem catch with hazing is less than half of the nonhazing catch, and nonhazing-affected catches are significantly greater (Table 15: footnote a). Since hazing occurred only in 1988 and 1996-1998 at the Tillamook, there are no years of catch data yet available that include all age-classes of adult steelhead that could have been affected by hazing (Fig. 19).

Annual catch differences between the Nehalem and Siletz or Alsea Basins are generally larger (Fig. 20), average more, and are significantly greater with hazing (Table 15). On the other hand, annual catch differences between the Nehalem and Necanicum and Salmon River Basins are usually less (Fig. 20), average less (Table 15), and are significantly less with hazing for the Necanicum (Table 15: footnote a).

TABLE 15. Statistical tests of whether sport catches of winter steelhead at the Nehalem Basin or differences between the Nehalem and other basins are significantly greater with hazing. See Fig. 19 for annual catches at the Nehalem Basin and Fig. 20 for annual differences in catches between the Nehalem and the Necanicum, Salmon, Siletz, and Alsea Basins; see the legends of these figures for streams included within each of these basins.

Although the catch of 2-salts in 1989-1990 at Nehalem was affected by hazing, it is not included because the proportion of the 1989-1990 catch that was 2-salts is unknown, and the proportion of the catch that year that returned as 3- or 4- salts or repeat spawners was not affected by hazing.

The larger mean is underlined. Necan.=Necanicum River. N=number of years, U=Mann-Whitney statistic for the hypothesis that Nehalem or Nehalem-(basin) catches are relatively greater for hazing than nonhazing, P=probability, NS=not significant (one-tailed P>0.05).

	Number of Winter Steelhead Caught...............							
	Hazed (1990-91 through 1995-96).....			Nonhazed (1975-76 through 1985-86).......			Hazing> Nonhazing	
Comparison	N	Mean	Range	N	Mean	Range	U	P
Nehalem Basin	6	2107	1064-3997	11	<u>4479</u>	2090-10162	10	NSa
Nehalem-Necan.	6	1109	426-2312	11	<u>2652</u>	885-7227	15	NSa
Nehalem-Salmon	6	1653	809-3560	11	<u>2570</u>	314-6844	25	NSa
Nehalem-Siletz	6	<u>549</u>	(-126)-2292	11	-1266	(-3621)-2665	55	<0.01
Nehalem-Alsea	6	<u>662</u>	(-75)-2212	11	-2595	(-5232)-514	62	<0.01

a When the hypothesis that nonhazing catches are greater than hazing is tested, the results are not significant for Nehalem-Salmon, significant for catches at the Nehalem (U=56, one-tailed P<0.01), and significant for Nehalem-Necanicum (U=51, one-tailed P<0.05).

FIGURE 19. Sport catches of hatchery and wild winter steelhead at Oregon coastal streams and bays other than the Columbia River. Data are from ODFW (1987, 1998b) punchcard/tag returns, which are explicitly for adults, although a few jacks may be mistakenly recorded on them (Eric Schindler, ODFW, pers. comm.). For smolts released during the spring of 1988, most adults would return during the spring of 1990 (1989-1990 Run-Year) as 2-salts, some would return during the spring of 1991 (1990-1991 Run-Year) as 3-salts, and a few would return in later years as repeat spawners. Kenaston (1989:16) gives the percentage of winter steelhead that were caught that were of hatchery origin.

Starting in 1992, only fin-clipped (hatchery) steelhead could be kept (Chilcote 1998:31-33), so this regulation could have reduced catches.

Other Coastal Stream & Bays=all coastal streams except for Nehalem and Tillamook Basins. The
Nehalem Basin includes Nehalem Bay, Nehalem River above and below Elsie, North Fork of Nehalem River, Cook Creek, Rock Creek, and Salmonberry River; during 1980-81 through 1984-85, 59-84% of winter steelhead caught here were of hatchery origin (Kenaston 1989:16). The Tillamook Basin includes Tillamook Bay and the following rivers: Kilchis, Miami, Tillamook, Trask, North and South Forks of the Trask, Wilson, and Devils Lake and Little North Forks of the Wilson.

```
H=affected by hazing                       ?=unknown if affected by hazing
o=not affected by hazing                   #=wild steelhead released
2=only 2-salts affected by hazing          3=only 3-salts affected by hazing
@=only 4-salts and repeat spawners affected by hazing


--------------- Winter Steelhead Sport Catches (Thousands) ----------

       Other Coastal            Nehalem                Tillamook
       Streams & Bays           Basin                  Basin
                            Nonhazing Mean= 4,479
                               Hazing Mean= 2,107

 100-|                         16-|                         16-|
    -|         o                  -|                           -|    o
  90-|  o      o               14-|                         14-|    o
    -|  o o    o                  -|                           -|  o o
  80-|  o o    o               12-|                         12-|  o o
T   -|  o o    o                  -|                           -|  ooo
h 70-|  o o    o               10-|         o               10-|  ooo
o   -|o o oo   o                  -|         o                 -| oooo    o
u 60-|o oooo   o                8-|        oo                8-|oooooo   o  o
s   -|o ooooo ooooo               -|        oo                 -|ooooooo oo oo
a 40-|ooooooo ooooo o           6-|    o   oo ?              6-|ooooooo oo oo
n   -|ooooooo ooooooo             -|    o   oo ?               -|oooooooooooooo2
d 30-|ooooooo ooooooooo         4-|  o oo  oo ?? 2  H        4-|oooooooooooooo2 @
s   -|oooooooooooooooooo o        -|oooooo  ooo???2  H         -|oooooooooooooo23@@
  20-|ooooooooooooooooooooo     2-|ooooooooooo???2HHH        2-|oooooooooooooo23@@@
    -|ooooooooooooooooooooo       -|ooooooooooo???2HHHHHH      -|oooooooooooooo23@@@@@
   0-|ooooooooooooooooooooo     0-|ooooooooooo???2HHHHHH     0-|oooooooooooooo23@@@@@
     |_________________####       |_________________####       |_________________####
      |''''|''''|''''|''''|        |''''|''''|''''|''''|        |''''|''''|''''|''''|
     75-  80-  85-  90-  95-      75-  80-  85-  90-  95-      75-  80-  85-  90-  95-
     76   81   86   91   96       76   81   86   91   96       76   81   86   91   96

                              Run-Year
```

FIGURE 20. Differences in sports catches of winter steelhead between the Nehalem Basin and the Necanicum River, Salmon River, Siletz Basin, and Alsea Basins. The streams included in Nehalem Basin are listed in Fig. 19, which graphs Nehalem catches. The Siletz Basin includes Siletz Bay, Siletz River, Drift Creek, Rock Creek, Little Rock Creek, Schooner Creek, and the North and South Forks of the Siletz River. The Alsea Basin includes Alsea River and Bay, Drift Creek, Fall Creek, Five Rivers, Lobster Creek, and North and South Forks of the Alsea River. Data are from ODFW (1987, 1998b) punchcards/tags.

```
H=Nehalem affected by hazing        ?=unknown if Nehalem affected by hazing
o=not affected by hazing            #=wild steelhead released
2=only 2-salts affected by hazing

----------------------- Winter Steelhead Sport Catches --------------------
             Nehalem-Necanicum R.            Nehalem-Salmon R.
             Nonhazing Mean= 2,652           Nonhazing Mean= 2,570
N    8,000-|     Hazing Mean= 1,109        -|     Hazing Mean= 1,653
u          |        o                       |
m    7,000-|       oo                      -|       o
b          |       oo                       |       oo
e    6,000-|       oo                      -|       oo
r          |       oo                       |       oo
     5,000-|       oo                      -|       oo
o          |       oo                       |       oo ?
f    4,000-|       oo                      -|       oo ?
           |       oo ?                     |   o   oo ?     H
S    3,000-|   o   oo ?                    -|   o   oo ?  2  H
t          |o  o   oo ?  2  H               |   oo  oo ?  2  H
e    2,000-|oo  oo  ooo?  2  H             -|   oo  ooo???2  H
e          |oo  oo oooo? ?2H H              |oo ooo oooo???2HHH
l    1,000-|ooooooooooo???2HHH H           -|oooooo oooo???2HHHHHH
h          |ooooooooooo???2HHHHHH           |ooooooooooo???2HHHHHH
e        0-|ooooooooooo???2HHHHHH          -|ooooooooooo???2HHHHHH
a          |_________________####           |_________________####
d           |''''|''''|''''|''''|            |''''|''''|''''|''''|
           75-  80-  85-  90-  95-          75-  80-  85-  90-  95-
           76   81   86   91   96           76   81   86   91   96


             Nehalem-Siletz Basin            Nehalem-Alsea Basin
             Nonhazing Mean= -1,266          Nonhazing Mean= -2,595
N    3,000-|     Hazing Mean=    549       -|     Hazing Mean=    662
u          |       o        H               |
m    2,000-|       o  ?     H              -|               H
b          |       oo ?  2  H               |               H
e    1,000-|       oo ? ?2  H              -|            2H H
r          |       oo ? ?2 HH               |       o  ?  2H H  H
         0-|ooooooooooo???2HHHHHH          -|ooooooooooo???2HHHHHH
o          |oooooooo  o ?                   |oooooooo oo ?
f   -1,000-| oooooo     ?                  -|o ooooo  oo ?
           | oooooo     ?                   |o ooooo   o ?
S   -2,000-|  ooooo                        -|o o ooo   o
t          |  ooooo                         |o o ooo   o
e   -3,000-|  ooo o                        -|o o ooo   o
e          |  oo                            |o o o o
l   -4,000-|                               -|o o o o
h          |                                |o o o o
e   -5,000-|                               -|  o o
a          |                                |  o
d          |_________________####           |_________________####
            |''''|''''|''''|''''|            |''''|''''|''''|''''|
           75-  80-  85-  90-  95-          75-  80-  85-  90-  95-
           76   81   86-  91   96           76   81   86   91-  96

                           Run-Year
```

J-3. CHINOOK SALMON ESTUARINE AND FRESHWATER SPORTS CATCHES

J-3a. NEHALEM CHINOOK CATCHES. The classification of the type of chinook at Nehalem as fall, fall/summer, summer, and/or spring (Appendix II-3a) confuses data analyses because chinook catches at the Nehalem are divided into fall and spring chinook catches with no spring chinook catches prior to 1989 (ODFW 1998b). Because Nicholas and Hankin's (1989) report may have affected classification of Nehalem chinook catch data, I suspect that "spring chinook" catches prior to 1989 were lumped with fall chinook catches.

Adult chinook can return as 3-6 yr olds (Appendix II-3c), 2-5 yrs after migrating to the ocean, so the 1993 Run-Year would be the first when all adults may have been affected by hazing. Since complete data are only available through 1996 (ODFW 1998b), there are only three years for fall chinook and four years for spring chinook that could be totally ascribed as affected by hazing (Fig. 21).

Fall chinook catches at the Nehalem have clearly increased during the time of hazing (Fig. 21), and catches in hazing years (1993-1995) are significantly greater than in nonhazing years (1975-1986) (Mann-Whitney $U=36$, $N1=3$, $N2=12$, one-tailed $P<0.01$). However, it is unclear if hazing is the cause for this increase or if changes in other factors such as fishing effort are involved. Indeed, the Nehalem run is classed by Nicholas and Hankin (1989:204) as wild, and the increase in catches since 1990 (Fig. 21) is also correlated with a decrease in the number of wild fall chinook at spawning grounds (section G-6). Consequently, the increased catches may be more a result of increased fishery exploitation in recent years, rather than hazing. A concern about overfishing was raised in 1997, when some local residents tried to reduce the daily bag limit from two to one fall chinook in Tillamook County (Monroe 1997).

Spring chinook catches have also increased in recent years, but there are no catch data for nonhazing-affected years (Fig. 21).

J-3b. NEHALEM TILLAMOOK AND NESTUCCA CATCHES. Because adult chinook return at various ages up to six years old (Appendix II-3c), hazing only consistently began at the Tillamook and Nestucca in the spring of 1996, and complete fishery data are only available through the 1995-1996 Run Year (ODFW 1998b), there are not enough data to examine chinook fishery catches at the Tillamook and Nestucca Basins to see if they may have been affected by hazing.

FIGURE 21. Sport catches of fall and spring chinook salmon at Nehalem. Nehalem includes Nehalem Bay, Nehalem River above and below Elsie, and North Fork of Nehalem River; Cook Creek, Rock Creek, and Salmonberry River are also tributaries of the Nehalem but are excluded because of missing data in some years. Data are from ODFW (1987, 1998b) punchcard/tag returns, which are explicitly for adults, although a few jacks may be mistakenly recorded on them (Eric Schindler, ODFW, pers. comm.). Adult chinook return as 3-6 yr olds (Appendix II-3c), 2-5 years after migrating to sea, so juvenile chinook entering the ocean during hazing in the spring of 1988 at the Nehalem would be caught as adults during the 1990-1991 through 1993-1994 Run-Years, and 1993-1994 would be the first Run-Year in which all adult chinook may have been affected by hazing. It is unclear if hazing occurred in 1985-1987.

Spring chinook at the Nehalem were first included in catch data in 1989 (ODFW 1987, 1998b). Since the fall, fall/summer, summer, and/or spring classification of stock(s) at the Nehalem varies among references, it is possible that "spring" chinook catches were pooled with "fall" chinook catches at the Nehalem prior to 1989 (section J-3a).

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H=all affected by hazing              ?=unknown if affected by hazing
o=not affected by hazing              P=part of catch affected by hazing

--------------------------- Nehalem Catches ------------------------------
           "Fall" Chinook
           Nonhazing Mean=  672.4
              Hazing Mean= 3493.7                   "Spring" Chinook
   4,000-|                  H
        -|                  H
   3,500-|                 H H
C       -|                  H H
h  3,000-|                  HHH
i       -|                 PHHH
n  2,500-|                 PHHH               -|                      H
o       -|             ?   PHHH          1,000-|                      H
o  2,000-|            ??  PPHHH               -|                      H
k       -|            ??  PPHHH            800-|                     HH
   1,500-|          o???PPPHHH                -|                    HHH
        -|         o o???PPPHHH            600-|                    HHH
   1,000-|         o o???PPPHHH               -|                  P HHH
        -|   o o   ooo???PPPHHH            400-|                 PPHHHH
     500-|  oooooooooo???PPPHHH               -|                 PPHHHH
        -|  oooooooooo???PPPHHH            200-|                PPPHHHH
   1-124-|oooooooooooo???PPPHHH               -|               ?PPPHHHH
      0-|oooooooooooo???PPPHHH               0-|<=No Data====>?PPPHHHH
          |''''|''''|''''|''''|                  |''''|''''|''''|''''|'
         75   80   85   90   95                 75   80   85   90   95

                                  Run-Year
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K. CONCLUDING REMARKS

K-1. GOALS OF SALMON MANAGEMENT: WILD FISH RECOVERY AND FISHERIES

The goals of salmon management are the recovery of wild salmonids and, secondarily, maintaining or improving fisheries (OCSRI 1997a,b; NMFS 1998, Kitzhaber 1999).

Improving smolt survival by hazing seems to make common sense, which is why it has been so appealing. The logic used by proponents is that cormorants eat smolts, and hazing stops cormorants from eating smolts; therefore, hazing improves smolt survival. There is no dispute that cormorants can eat smolts, although the amount and kind (wild or hatchery) can be debated (e.g., Bayer 1989:25-29, Roby et al. 1998). But the most important issue is whether hazing helps attain the goals of salmon management, and this does not appear to be the case.

K-2. CORRELATION DOES NOT MEAN CAUSATION: LINKING HAZING WITH RETURNS

K-2a. INTRODUCTION. Correlation does not mean causation--this is an axiom in statistics. But it is also important in evaluating hazing because there are several variables that can affect salmonid returns other than hazing (Appendix V). Thus, any increases or decreases in salmonid returns that are correlated with the occurrence of hazing may not have been caused by hazing.

K-2b. 1991 COHO ANOMALY. An example of where correlating returns with hazing may be misleading occurred in 1991 for returning coho. At Nehalem, the return of adults in 1991 was much higher than normal based on CWT survival rates (section H), returns to the hatchery (section I-1b), and fishery catches (section J-1b). Further, spawning ground counts of adults were also slightly higher than usual in 1991 (Fig. 4). Whatever affected the high return rate of adults in 1991 was not reflected in greater returns of jacks in 1991 to the spawning grounds (Fig. 2) or hatchery (Fig. 14).

One could assume that this extraordinary return may have been caused by hazing during 1990; however, increased CWT recoveries (section H) and sports catches (section J-1b) in 1991 also occurred at some nonhazed basins. In addition, if hazing was the cause of the greater adult returns to Nehalem in 1991, one would expect that the number of jacks returning in 1990 would also be much higher than normal. But the number of jacks returning in 1990 to spawning grounds was less than usual (Fig. 2), and the number returning to hatcheries in 1990 was not as anomalously high as the 1991 adult return (Fig. 14), so the increased return of adults in 1991 appears to be a consequence of some factor that occurred after the hazing in the spring of 1990 and the return of jacks in the fall of 1990.

K-3. IMMEDIATE VERSUS DELAYED TESTS OF HAZING

Hazing may affect the survival of juvenile salmonids during their outmigration to the ocean, so an immediate measure of their survival to the ocean would be informative (also see section E-2). However, delayed measures (i.e., returns of jacks and adults) are essential in evaluating hazing for three reasons. First, proponents have claimed that hazing has improved salmon and steelhead returns (Erickson 1989a,b,d; 1992, 1993, 1995a,b; Monroe 1995b, 1996a [see section E-3c]; Nokes 1995). For instance, Erickson (1993) wrote:

> "Many people are asking why the Nehalem River has rebounded to record numbers of coho and steelhead. Those of us who have worked on a smolt protection plan for the last six years feel very strongly that our efforts have helped considerably in the increased fish runs."

Second, the goal of recovery plans and fisheries is improving returns of adults, and increasing the number of smolts reaching the ocean may not help. For example, increasing the number of coho smolts released in Oregon has not resulted in greater adult returns (Pearcy 1992:48). Third, using returns is appropriate in assessing hazing because smolts saved from cormorants in estuaries may die anyway from disease, parasites, oceanic predators, and/or unfavorable ocean conditions (Appendix V).

K-4. HAZING NOT CORRELATED WITH IMPROVED WILD SALMONID RETURNS

The numbers of wild adult coho (section G-3), winter steelhead (section G-4), and fall chinook (section G-6) returning to spawning grounds have averaged less with than without hazing at hazed basins, so wild adult abundance has not increased significantly with hazing (Table 16). Similarly, the abundance of jack coho (section G-2) and chinook (section G-5) also was usually less with hazing at hazed basins, although the relative difference between Nehalem and nonhazed basins for coho jacks was sometimes significantly greater with hazing (Table 16).

Thus, hazing does not appear to be useful in attaining the goal of recovery of wild salmonids in the Oregon Plan, in removing coastal wild coho from a federal ESA listing, or in helping coastal steelhead from becoming listed under the federal ESA.

TABLE 16. Summary of statistical tests comparing results of hazing with nonhazing. A significant difference does not establish that hazing is the cause of a difference, only that hazing is correlated with the difference. Hazed Basins=Nehalem, Tillamook, and Nestucca Basins. Statistical tests for Hazing>Nonhazing are expressed as the number of tests with a significant difference divided by the total number of tests.

Taxon	Site(s)	Type of Count	Stat. Tests Haz> Non	Section
	Wild Fish (jacks)			
coho	Hazed Basins	spawn grounds	0/3	G-2
coho	Nehalem-Nonhazed Basins	spawn grounds	2/6	G-2
fall chinook	Hazed Basins	spawn grounds	0/3	G-5
fall chinook	Nehalem-Nonhazed Basins	spawn grounds	0/3	G-5
	Wild Fish (adults)			
coho	Hazed Basins	spawn grounds	0/3	G-3
coho	Nehalem-Nonhazed Basins	spawn grounds	0/6	G-3
winter steel	Nehalem	spawn grounds	0/1	G-4
fall chinook	Nehalem	spawn grounds	0/1	G-6
fall chinook	Nehalem-Nonhazed Basins	spawn grounds	0/3	G-6
	Hatchery Fish (jacks)			
coho	Nehalem-Nonhazed Basin	% return	0/1	I-1a
coho	Hazed Basins	returns	0/2	I-1b
winter steel	Hazed Basins	returns	1/2	I-2b
summer steel	Nestucca	returns	*	I-2c
chinook	Hazed Basins	returns	*	I-3
	Hatchery Fish (adults)			
coho	Nehalem-Nonhazed Basin	% return	0/1	I-1a
coho	Hazed Basins	returns	1/1	I-1b
winter steel	Nehalem	returns	0/1	I-2b
	Hatchery Fish (jacks + adults)			
coho	Nehalem	Coded Wire Tag	0/1	H
coho	Nehalem-Nonhazed Basins	Coded Wire Tag	2/3	H
	Fisheries (adults)			
coho	Nehalem	catches	1/1	J-1
coho	Nehalem-Nonhazed Basins	catches	3/6	J-1
winter steel	Nehalem	catches	0/1	J-2
winter steel	Nehalem-Nonhazed Basins	catches	2/4	J-2
fall chinook	Nehalem	catches	1/1	J-3

* No statistical test because of too few years of hazing-affected returns, but there was no apparent increase with hazing.

K-5. MIXED CORRELATION OF HAZING WITH HATCHERY RETURNS

Hatchery return data do not show a consistent trend of significantly increased returns for jacks, adults, or CWT marked fish with hazing (Table 16). As discussed in each of the sections cited in Table 16, even in the few cases when increased returns are correlated with hazing, other factors may have been responsible. Further, even if hazing increased the number of fish returning to hatcheries, this is not a goal of salmon management because coastal hatcheries have a surplus of fish to use for broodstock and surplus fish are usually unfit for human consumption (Orcutt 1992; section I-1b).

K-6. MIXED CORRELATION OF HAZING WITH IMPROVED FISHERIES

A secondary goal of salmon management is to maintain or improve fisheries, which have been curtailed in recent years because of concerns about wild salmonids. Increased coho and fall chinook catches (but not winter steelhead) are correlated with hazing at the Nehalem as are increased relative differences in catches between the Nehalem and half of the nonhazed basins for coho and winter steelhead (Table 16). However, the increased catches of coho may be more a result of factors other than hazing (section J-1, Appendix V). Additionally, greater fall chinook catches may have arisen from increased fishing effort, not hazing, and to have resulted in significantly decreased wild fall chinook escapement to spawning grounds (section G-6), which, potentially, could lead to a re-examination of listing coastal fall chinook under the federal ESA. Thus, evidence that hazing has improved fisheries is mixed.

K-7. REASONS WHY HAZING HAS NOT HAD A SIGNIFICANT IMPACT

Evidently the cormorant predation issue is not as simple as it may first seem or returns of wild and hatchery fish would have improved much more significantly with hazing than shown in Table 16. Similarly, Draulans (1987:221-223) noted that other fish-eating bird control programs have not demonstrated an increase in fish abundance.

There are three reasons why returns may not have greatly improved with hazing. First, smolts saved with hazing may have died anyway from factors such as disease, parasites, and/or predators in the ocean (Appendix V). Second, an increase in returns as a result of hazing may have been masked by factors such as unfavorable ocean conditions and changing fishery regulations and effort (Appendix V).

Finally, hazing may not have improved returns because hazing did not significantly reduce cormorant predation. During 1996-1998, counts of cormorants indicate that they were present after hazing commenced (section F-7), some smolts may have already migrated before hazing began each year (section C-4), hazing did not occur throughout the day at each estuary (sections C-5 and F-6), and one hazer might not have been able to adequately cover each estuary. In addition, scarecrows were used somewhat to keep cormorants away when hazers were absent (section C-2), but scarecrows are usually ineffective after a short period of time (Draulans 1987, Stickley et al. 1995). In 1999, after SPP hazing began on April 1 (Stahl et al. 2000:7), it was noted that hazed cormorants were interrupted in their feeding but did not leave an estuary (Stahl et al. 2000:34), and substantial numbers of potential predators were still counted (Stahl et al. 2000:50-51, 53, 67, 69). Further, 55% of 20 radiotagged hatchery coho smolts released at Nehalem during 1999 hazing were thought to have been caught by predators before they reached the ocean (Stahl et al. 2000:7, 28, 44), so it appears that appreciable predation occurred in spite of hazing. However, radiotagging may increase smolt vulnerability to mortality such as predation (e.g., Adams et al. 1998, Hockersmith et al. 1999), although Stahl et al. (2000:29) do not think this is true in their study. In any case, if hazing reduced predation, it may not have done so significantly.

K-8. CONCLUSION: HAZING IS NOT A PANACEA

At best, cormorant hazing is correlated with mixed results for fisheries and hatchery returns, but hazing is not correlated with increased returns of wild salmonids, which are the focus of the Oregon Plan and federal ESA listings. Consequently, it is unclear if the benefits of hazing equal the $100,000 spent on it during 1996-1999 by the Oregon Legislature and its biological and social costs (e.g., the harassment of wildlife other than cormorants, see section F-3; Bayer 1989:40-46).

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APPENDIX I. Common and scientific names of animals.

brant, black	*Branta bernicla nigricans*
cormorant spp.	*Phalacrocorax* spp.
cormorant, Brandt's	*Phalacrocorax penicillatus*
cormorant, double-crested	*Phalacrocorax auritus*
cormorant, pelagic	*Phalacrocorax pelagicus*
crow spp.	*Corvus* spp.
dogfish, spiny	*Squalus acanthias*
eagle, bald	*Haliaeetus leucocephalus*
gull spp.	*Larus* spp.
heron, green	*Butorides virescens*
heron, great blue	*Ardea herodias*
lion, sea	*Zalophus californianus* or *Eumatopias jubatus*
loon spp.	*Gavia* spp.
mackerel, Pacific	*Scomber japonicus*
merganser, hooded	*Lophodytes cucullatus*
mink	*Mustela vison*
murre, common	*Uria aalge*
osprey	*Pandion haliaetus*
otter, northern river	*Lutra canadensis*
pelican, brown	*Pelecanus occidentalis*
"perch, pink-tailed"	? (probably one of surfperches in Family Embiotocidae)
"pogey"	? (Cottidae ?)
raccoon, common	*Procyon lotor*
rockfish spp.	*Sebastes* spp.
rockfish, black	*Sebastes melanops*
salmon, Atlantic	*Salmo salar*
salmon, chinook	*Oncorhynchus tshawytscha*
salmon, coho	*Oncorhynchus kisutch*
sandlance, Pacific	*Ammodytes hexapterus*
sculpin	? (probably in Family Cottidae)
seal, harbor	*Phoca vitulina*
shearwater spp.	*Puffinus* spp.
"shiner"	? (probably one of surfperches in Family Embiotocidae)
steelhead	*Oncorhynchus mykiss*
tern spp.	*Sterna* spp.
tern, Caspian	*Sterna caspia*
trout, cutthroat	*Oncorhynchus clarki*

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APPENDIX II. Coho, steelhead, and chinook life history information.

II-1. COHO SALMON LIFE HISTORY RELEVANT TO HAZING

In Oregon, most wild juvenile coho appear to remain in freshwater one year before migrating (K. W. Myers 1980:121-122), a few may be present less than a year (Reimers 1971 as cited in K. W. Myers 1980:121), and others reside two years (Chapman 1961:35, Moring and Lantz 1975:23).

Peak emigration of wild coho smolts through Oregon estuaries is in May, but some also migrate through estuaries in April and June (Bottom and Forsberg 1978:55, K. W. Myers 1980:38, 120; J. A. Johnson et al. 1986:6, 8; O. W. Johnson et al. 1991:6). Most hatchery smolts were released in late March or April at the Nehalem (Table 3). Coho smolts only appear to remain a few days to a few weeks in estuaries (Emmett et al. 1991:138), and, at Yaquina Estuary, 50% of hatchery smolts appeared to have left within 2-9 days, and 90% or more left within a month of release (K. W. Myers 1980:56-68, 122, 133-139; K. W. Myers and Horton 1982). Thus, hazing may have the greatest effect on hatchery fish if it is done within a month of a release.

Precocious males (jacks) or females (jills or jennies) return to freshwater in the fall of the same calendar year, and adults return to spawn in freshwater during the fall of the next calendar year (Laufle et al. 1986, Kostow 1995:65, Weitkamp et al. 1995:25).

II-2. STEELHEAD LIFE HISTORY RELEVANT TO HAZING

II-2a. STEELHEAD TYPES. Steelhead returning to freshwater from the ocean in May-October are classed as summer steelhead, and those returning in November-April as winter steelhead (Pauley et al. 1986:4-5, Kostow 1995:99). Except for the timing of their return, it is unclear how life histories of summer and winter steelhead differ.

Kostow (1995:111-112) writes that wild steelhead along the north and mid-coast of Oregon are winter steelhead except for a severely depressed summer steelhead run at the Siletz River. Hatchery winter steelhead have been released into the Nehalem, Tillamook, and Nestucca Basins (Kostow 1995:112, A2-A4; Chilcote 1998:33-35, Ellis 1998:3-12). However, many hatchery winter steelhead release programs were terminated or reduced in 1995 in portions of the Nehalem, Tillamook, and Nestucca Basins, although releases of 63-83 thousand winter steelhead smolts continue into the North Fork of the Nehalem (Chilcote 1998:33-35; Appendix III). Hatchery summer steelhead are released into the hazed Tillamook and Nestucca Basins but not the Nehalem Basin (Kostow 1995:112, A2; Chilcote 1998:34-35, Ellis 1998: p. 3-12, John Leppink, ODFW, pers. comm.). Generally fewer than 50 summer steelhead are caught annually in the Nehalem Basin (ODFW 1998b); these may be strays from hatchery programs in other basins.

II-2b. FRESHWATER RESIDENCE. Hatchery-reared juvenile steelhead are often considered to remain in freshwater only one year (Pauley et al. 1986:6, Busby et al. 1996:15), but, at the Alsea in the 1950's, 32% were in freshwater two years (Chapman 1958:125). Wild juveniles usually spend two and sometimes three years in freshwater with a range of 1-4 years (Chapman 1958:125, Wagner et al. 1963, Lindsey et al. 1991:19, 1992:21, 1993:28, 1994:32, 1995:29; Busby et al. 1996:25).

II-2c. TIMING OF SMOLT EMIGRATION. Most wild winter steelhead passed through the North Fork of Nehalem River in April through mid-May of 1998-1999 (ODFW 1999), which is characteristic of other Oregon coast streams, although appreciable numbers can also be migrating in March and June (Chapman 1958:132, Wagner et al. 1963:205, ODFW 1999). At the Nehalem, hatchery smolts were generally released in April (Table 3). Accordingly, wild and hatchery steelhead smolts could have been present during cormorant hazing. Steelhead smolts spend little time in estuaries while migrating to the ocean (Emmett et al. 1991:148).

II-2d. AGE AT RETURN. Jacks return after one summer in the ocean and are consequently categorized as 1-salts; about 1-10% of returning winter steelhead were jacks (Chapman 1958:125, Weber and Knispel 1977:41-43, Lindsay et al. 1991:18-19, 1992:20-21, 1993:27-28, 1994:31-32, 1995:28-29). On average, about 75-79% of returning hatchery and 66-80% of wild winter steelhead spent two summers in the ocean (2-salts), 12% of hatchery and 8-26% of wild steelhead were in the ocean three summers (3-salts), 0-3% of steelhead were in the ocean four summers (4-salts), and 6-15% were repeat spawners, although the percentage returning in each age class often varied annually and hatchery steelhead tended to return earlier than wild steelhead (Chapman 1958:125, Weber and Knispel 1977:41-43, Lindsay et al. 1991-1995; Busby et al. 1996:29). Because many return as 3-salts, hazing must occur for at least three consecutive years before the vast majority of those that return could be assumed to have been affected by hazing.

II-3. CHINOOK LIFE HISTORY RELEVANT TO HAZING

II-3a. CHINOOK TYPES. The life history of chinook salmon is complex (Nicholas and Hankin 1989, Emmett et al. 1991:160-168, Kostow 1995:18), and the classification of run type sometimes differs among references, probably because the timing of runs sometimes does not fit into simple categories. Chinook return to the Nehalem from July through October, fall chinook return to the Tillamook Basin from September through February, fall chinook return to the Nestucca Basin from August through January, and spring chinook return to the Tillamook and Nestucca Basins from April through July (Nicholas and Hankin 1989:23, Kostow 1995:23, 25). Runs at the Nehalem have been classed as fall (Nicholas and Hankin 1989:23, 27; Jacobs and Cooney 1997), fall and summer (Nicholas and Hankin 1989:91, Kostow 1995:19, 23, 25), fall and spring (ODFW 1998b), or summer (J. M. Myers et al. 1998:43). In the Tillamook Basin, runs have been categorized as fall and spring (Nicholas and Hankin 1989:23, 134; Kostow 1995:19, 23, 27; Lewis 1997:12, J. M. Myers et al. 1998:44, ODFW 1998b), with a winter run at the Trask River (Lewis 1997:12, John Leppink, ODFW, hatchery return data). At the Nestucca Basin, runs have been described as fall and spring (Nicholas and Hankin 1989:23, 27; Kostow 1995:19, J. M. Myers et al. 1998:44, ODFW 1998b) or as fall, spring, and summer (Nicholas and Hankin 1989:94).

The Nehalem hatchery currently does not release chinook into the Nehalem system (R. Klumph, ODFW, pers. comm.), and hatchery releases of chinook in the past have been very limited (Nicholas and Hankin 1989:204, 253; Kostow 1995:26, A2-A4). However, hatchery releases of fall and spring chinook have been extensive in the Tillamook and Nestucca Basins (Nicholas and Hankin 1989: 257, 283, 289; Kostow 1995: A2-A5).

In this paper, I list the run type as the one given in a reference.

II-3b. ESTUARINE OCCURRENCE OF JUVENILES. Juvenile chinook in Oregon predominately enter the ocean before they are a year old (Nicholas and Hankin 1989:16, Kostow 1995:18, J. M. Myers et al. 1998:48). Juveniles are known to be present in the lower Nehalem estuary from late spring through at least mid-September (Nicholas and Hankin 1989:91). In Tillamook Bay, they were reported as present from January through at least November (Nicholas and Hankin 1989:134) or June through November with a peak in July (Forsberg et al. 1977:17, 34; Bottom and Forsberg 1978:44). In Nestucca Bay, juveniles occur from late spring through at least October (Nicholas and Hankin 1989:94), and they were also observed during hazing in early June 1996 (SPP 1996). Elsewhere along the Oregon coast, juvenile chinook can be present in estuaries during April through summer or fall with one or more peaks in May-August (Reimers et al. 1978:40-42, 1979:38-42; Mullen 1979:29-33, K. W. Myers 1980:38, 124-128; K. W. Myers and Horton 1982:385-388, Reimers and Downey 1982:11-13, J. A. Johnson et al. 1986:6, 8; Nicholas and Hankin 1989:11, 14-15, 18; Fisher and Pearcy 1990). There is some annual variation in the timing of peak abundance of juveniles in Oregon coast estuaries (Mullen 1979:29-33, Reimers and Downey 1982:11-13), and peaks occurred earlier in the upper than in the lower portion of an estuary (Reimers et al. 1978:18-21, 1979:38-42; Mullen 1979:29-33, K. W. Myers 1980:38, 124-128; Fisher and Pearcy 1990).

The length of residence of juvenile chinook in estuaries is variable (Nicholas and Hankin 1989:11, Emmett et al. 1991:162, Kostow 1995:18). Hatchery juvenile chinook were estimated to remain a few weeks to several months after a release in Yaquina Estuary (K. W. Myers 1980:69-70,139-144), about 10 days for spring chinook and a month for fall chinook at Coos Bay (Fisher and Pearcy 1990), but more than half appeared to have left in a week after a release at the Salmon River (Mullen 1979:29). In contrast to Coos Bay, juvenile spring chinook at Yaquina Bay seemed to reside longer than some juvenile fall chinook (K. W. Myers 1980:70, 141).

Based on their seasonal occurrence, some or many juvenile hatchery or wild chinook may have been present during April-June hazing at Nehalem, Tillamook, and Nestucca Bays.

II-3c. AGE AT RETURN. Chinook males are 2-6 years and females 3-7 years old when they return; however, most males usually return at four years and most females at five years (Nicholas and Hankin 1989:27, 93, 97, 100, 119, 123, 138, 141, 156, 162). Jacks (which may be mature, Kostow 1995:18) return the calendar year following the migration of juvenile salmon into the ocean at two years of age (Nicholas and Hankin 1989:197). Part of the considerable yearly variation in age at return (Reimers and Downey 1982:1, 8-9; Nicholas and Hankin 1989) may reflect the bias of different methods of collection. Because of the variation between years and between sexes, hazing must occur for six consecutive years before it can be fairly certain that all returning adults may have been affected by hazing.

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APPENDIX III. Number of coho and winter steelhead smolts released at Nehalem.

TABLE 17. Number of coho and winter steelhead smolts (in thousands) reared and released at the North Fork of the Nehalem hatchery. 1975-1998 coho data were provided by Rick Klumph (ODFW, pers. comm.). In 1985-1987, 15,000-25,000 coho smolts were also released elsewhere in the Nehalem River or its tributaries, and some may have also been done so prior to 1985 (John Leppink and Tracy Cabe, ODFW, pers. comm.). Steelhead data for 1984-1998 were provided by John Leppink and Tracy Cabe of the ODFW. See Table 3 for release dates into the Nehalem Basin. Occurrence of hazing at the Nehalem is from Table 2. -=data not requested. *=not enough data to calculate.

Smolt Release Year	Known Hazing	Thousands of Coho Smolts Released at North Fork Nehalem	Thousands of Winter Steelhead Smolts Released at........... North Fork Nehalem	Rest of Nehalem Basin	Necanicum River
1975	No	230	-	-	-
1976	No	1288	-	-	-
1977	No	189	-	-	-
1978	No	954	-	-	-
1979	No	871	-	-	-
1980	No	53	-	-	-
1981	No	602	-	-	-
1982	No	540	-	-	-
1983	No	85	-	-	-
1984	No	722	67	128	43
1985	?	439	54	113	36
1986	?	568	51	107	0
1987	?	568	52	116	44
1988	Yes	741	67	90	40
1989	Yes	805	64	90	40
1990	Yes	831	72	85	40
1991	Yes	736	76	63	40
1992	Yes	832	79	65	40
1993	Yes	760	77	48	31
1994	Yes	840	94	51	30
1995	No	790	80	7	40
1996	Yes	637	83	7	32
1997	Yes	629	78	15	35
1998	Yes	193	63	15	40
Nonhazing Mean		575	*	*	*
	Range	53-1288	*	*	*
Hazing Mean		700	75	53	37
Range		193-840	63-94	7-90	30-40

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APPENDIX IV. Lack of rigorous controls in testing the effects of hazing.

It is not possible to directly test whether hazing is successful because there are no control groups. When a change in hatchery practices is tested to determine if it affects survival, there is a treated group and an untreated (control) group; these groups are reared as similarly as possible and released at about the same time and location, so that the only difference between them is the treatment. Such tests are not possible with cormorant hazing because the treatment (hazing) either occurs at an estuary or it does not.

One way to design treated and untreated groups is to assume that a smolt group released into a basin before hazing commences is a control group and a smolt group released during hazing is a treated group. This assumption is not valid for two reasons. First, smolts released prior to hazing may linger in an estuary until hazing occurs (Appendix II), so that they, as well as a treated group, are affected by hazing. Second, the seasonal timing of a release can greatly affect survival (e.g., see data in Appendices of Lewis 1994, 1997), and there has been a search for the optimal time to release smolts (e.g., Bilton et al. 1982, Parker and Stohr 1983, Martin and Wertheimer 1987, Gowan 1988, Irvine and Ward 1989, Mathews and Ishida 1989). For example, the seasonal variation in the survival of coho smolts released at the North Fork of the Nehalem hatchery prior to known hazing is shown in Table 18. Prior to hazing, there was an appreciable difference of 0.5% or more between early and late releases in 4 of 6 yr, and the difference was 1.0% or more in two of six yrs (Table 18). These differences were not just a result of larger smolts surviving better because in some years they did not (Table 18). Thus, differences in survival between smolt groups released before or during hazing may reflect seasonal factors unrelated to hazing.

The converse way of creating treated and untreated groups at a basin is to assume that smolts released early in a year during hazing are a treatment group and smolts released after hazing has ceased are a control group. This is also not valid--smolts released during hazing may linger until after hazing has ceased and any differences in survival between the two groups may reflect seasonal variation in survival that is not associated with hazing.

Control and treatment groups can be formed by assigning years without hazing as control years and years with hazing at the same basin as treatment years. Then, the assumption is that the only variable affecting survival between control and treatment years is the occurrence of hazing. However, this assumption is not robust because there is substantial annual variation in catches, returns, or survival of salmon and steelhead in a basin (e.g., ODFW 1987, 1998b; Jacobs and Cooney 1997, Lewis 1997, Chilcote 1998), whether hazing has occurred or not. This variation may be a consequence of factors such as variable ocean conditions or fisheries regulations (see Appendix V).

Another way of creating control and treated groups is to designate basins without hazing as control groups and basins with hazing as treatment groups. Here, the assumption is that the only difference between basins is the occurrence of hazing. This assumption is not robust because there can be substantial differences among basins in trends of returns (Jacobs and Cooney 1997, Chilcote 1998:25-26, 43, 45), survival (Lewis 1997:5-6), and catches (ODFW 1987, 1998b), whether hazing occurs or not.

TABLE 18. Within-year variation in survival rates of coho smolts released at the North Fork of the Nehalem hatchery prior to known hazing. These data are from CWT data in Lewis (1994:19-21, 33-34) and do not include coho smolts reared at this hatchery and released into Fishhawk Creek. Two stocks are reared at this hatchery: 32=Nehalem stock reared at the hatchery for years, 99=stock from Fish Hawk Lake on Nehalem River (John Leppink, ODFW, pers. comm.). Only smolts from the same stock that were released at different times during a year are included, so that a possible difference in survival as a result of stock origin is not a factor. Weight is in grams/fish; Surv. Rate=survival rate as a percentage of smolts released that are recovered.

Brood Year	Stock	Release Date	Av. Weight (g)	Surv. Rate (%)	Brood Year	Stock	Release Date	Av. Weight (g)	Surv. Rate (%)
1977	32	3/15/79	23	1.2	1980	99	3/15/82	31	0.6
"	32	5/1/79	24	0.5	"	99	5/1/82	32	1.8
1978	32	3/15/80	30	1.0	1981	99	3/15/83	47	1.6
"	32	5/1/80	32	0.2	"	99	5/1/83	41	2.9
1979	99	3/15/81	30	0.6	1982	99	3/15/84	41	1.1
"	99	5/1/81	32	0.7	"	99	5/1/84	42	1.3

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APPENDIX V. Factors other than hazing that can affect salmonid returns.

V-1. INTRODUCTION

Proponents have claimed that hazing has improved salmonid returns (Erickson 1989a,b,d; 1992, 1993, 1995a,b; Monroe 1995b, 1996a; Nokes 1995) and the Oregon Legislature has subsequently acted to permit and fund hazing (section C-1). However, other factors influence salmonid returns besides hazing. Acknowledging these factors is important for two reasons. First, separating out their effects from those of hazing is generally not possible. Second, these other factors may result in the mortality of those smolts that are saved by hazing, so that the end result of hazing may not be as beneficial as it might first seem. Some of these factors are examined below.

V-2. OCEAN CONDITIONS

Ocean conditions in recent years have been unfavorable for juvenile salmon growth or survival, and some researchers regard ocean conditions as the most important factor in reduced salmon abundance (Nickelson 1986, Pearcy 1992, 1997; Botkin et al. 1995:122-128, National Research Council 1996:39-45, Beamish et al. 1997, Emmett and Schiewe 1997, Kaczynski 1998).

V-3. NUMBER OF SMOLTS PRODUCED

One would expect more fish to return if more smolts emigrate to estuaries or the ocean, although this has not been true for hatchery-reared coho salmon (e.g., Pearcy 1992:48). The number of hatchery coho and steelhead smolts has varied at the Nehalem (Appendix III), and the number of wild salmonids produced probably also varies considerably. For example, there has been a decline in the number of spawning adult coho, steelhead, and chinook (sections G-3, G-4, and G-6), so one would expect that the total number of resulting smolts would also decline because fewer eggs would have been produced.

Because of the variation in smolt production, it would be best if the number of smolts was known, so that returns could be measured in terms of percent smolt survival. However, such data are not available for wild salmonids.

V-4. FRESHWATER FLOWS

Some studies have found a positive correlation between fisheries and stream flows during freshwater rearing of wild salmonids, but other studies have not (Knight 1980:60-63, Hall and Knight 1981:5-9, Scarnecchia 1981). It is clearer that flooding during rearing can have a negative impact on survival (Weber and Knispel 1977:33, National Research Council 1996:186-188); for example, the 1996 flood along the Oregon Coast washed eggs away (B. Buckman in Gallob 1999).

Both hatchery and wild fish may be affected by flows or turbidity at the time of outmigration. Weber and Knight (1977:33-34, 84) found that hatchery steelhead returns at the Nehalem were better when there were high flows at the time of release, perhaps because high flows reduced susceptibility to *Ceratomyxa shasta* infection (see below). Also at the Nehalem, Stahl et al. (2000:31) noted that hatchery coho smolt migration rates were greater with increased flows at the time of release. Similarly, Hvidsten and Hansen (1988) observed increased returns with high flows during release of Atlantic salmon smolts, and Gregory and Levings (1998) found that high turbidity (which can be associated with high flows) during smolt migration also reduced predation of juvenile salmon by piscivorous fish.

V-5. IMPAIRED HATCHERY SMOLTS

Hatchery fish can be impaired after release for several reasons, and thus they may be more vulnerable to mortality (Mesa et al. 1994). First, they have been stressed, disoriented, and forced into an unfamiliar environment; these stressors can be compounded by the additional stress of trying to adapt to seawater (Wedemeyer 1980, Schreck 1990:31-32). Second, hatchery smolts are easily detectable to predators because some behave inappropriately in their new environment. Since they feed on pellets spread on the water surface, many hatchery smolts come to the surface to feed shortly after release and in so doing are easily seen by potential predators; they also often jump out of the water or roll, exposing their highly conspicuous silver sides, which makes it very easy for predators to find them (Bayer 1986). Third, hatchery smolts are vulnerable to predation because they are not wary of predators (e.g., Bayer 1989:61-63; Suboski and Templeton 1989, Olla et al. 1998).

V-6. DISEASE, PARASITES, AND CHEMICAL CONTAMINANTS

Post-release mortality of juvenile salmonids can result directly from diseases or parasites (e.g., Noga 1996). In the Nehalem Basin, both *Ceratomyxa shasta* and *Nanophyetus salmincola* occur and can cause mortality in salmonids (Weber and Knispel 1977, Wade 1986:12-13). In Washington, it has been suggested that *Nanophyetus* infection plus other stressors resulted in the death of coho smolts (Schroder and Fresh 1992: 207-208, 262-263). Further, chemical contaminants can make juvenile salmonids more susceptible to disease (Arkoosh et al. 1998). Together, or separately, these factors may also increase mortality by impairing smolts, so that they are more vulnerable to predation (Mesa et al. 1994).

V-7. OCEAN AND NEARSHORE PREDATION OF SALMONIDS

V-7a. PREDATORS OF JUVENILE SALMONIDS. Although cormorants are the predator of most interest in Tillamook County, Caspian terns are of more concern in the Columbia River (Roby et al. 1998), and common murres have been suggested to have had a major impact at Yaquina and Coos Bays (Varoujean in Ward 1983, Matthews 1983, Bayer 1986, Emmett 1997:152). In the ocean near the mouth of the Nestucca, hazers reported that "birds" and seals were feeding on smolts (section F-10), and, in the Pacific Northwest, several species of birds can prey on juvenile salmonids in the ocean (Bayer 1989:36-38, Fresh 1997).

Fish can also be significant predators. Limited studies in Oregon nearshore areas indicate that various subadult or adult salmonids (Angstrom and Reimers 1964, Fresh et al. 1981:17, 27, 35; Stuart and Buckman 1985, Brodeur et al. 1987:9) and black rockfish (Brodeur et al. 1987:9) prey on juvenile salmonids. Elsewhere in the Pacific Northwest, significant predation of juvenile salmonids has been reported by spiny dogfish, Pacific mackerel, Pacific whiting, and lamprey (Beamish et al. 1992, Beamish and Neville 1995, National Research Council 1996:40, Pearcy 1997:341).

Predation in the ocean is important to acknowledge in assessing hazing because juvenile salmonids saved by hazing in estuaries may be taken by nearshore predators (Bayer 1989:36).

V-7b. PREDATORS OF JACK OR ADULT SALMONIDS. Marine mammals are predators of adult salmonids, although the significance of this predation is controversial (Kaczynski and Palmisano 1993, Botkin et al. 1995:132-141, Emmett 1997, Fresh 1997). Bald eagles and osprey can also prey on adult salmonids in estuaries (Emmett 1997), but there are so few of them along the Oregon Coast that they probably have little impact. This predation would reduce numbers of returning salmonids, and thus complicate analyzes of hazing on adult returns.

V-8. FISHERIES RESTRICTIONS AND EFFORT

V-8a. INTRODUCTION. Fishing regulations alter the length of season and number and type of fish (wild or hatchery) caught; they have become more restrictive as wild coho and steelhead populations have become of increasing concern. The goal of these regulations is to increase the number of wild fish returning to spawning areas, but they could also increase the number of wild or hatchery fish returning to hatcheries and the number caught in freshwater fisheries.

V-8b. OCEAN FISHERIES. In an attempt to improve the escapement of wild coho to freshwater, regulations reducing ocean commercial and sports catches of both coho and chinook (e.g., PFMC 1999:I-18, I-19) have decreased the ocean exploitation rate of coho (Fig. 22). In 1994, ocean coho fisheries were limited to incidental catches during the ocean chinook fishery (Kostow 1995:84, 97). For the nonhazing years of 1975-1985, the average ocean exploitation rate of coho was generally 70% or more (Fig. 22) and averaged 68% (range 27-88%), but the average for the hazing-affected years at the Nehalem of 1989-1997 was 30% (range 2-62%)(calculations from PFMC 1999:I-20).

The number of fish caught depends upon how much effort is spent trying to catch them. Ocean fishing effort has declined greatly in Oregon; for example, ocean salmon commercial troll effort has declined from about 25,000-40,000 days fished annually in 1979-1990 to 4,000-9,000 in 1992-1998, and the ocean salmon recreational effort has declined from about 225,000 angler trips yearly in 1981-1990 to 25,000-45,000 in 1994-1998 (PFMC 1999:I-8, I-10). Most of this decline can be attributed to the increasingly restrictive fishing regulations, but ocean fishing effort can also depend upon weather and, for commercial fishers, the price of salmon and the profitability of the salmon fishery.

FIGURE 22. Coho Oregon Production Index (OPI) Ocean Exploitation Rate Index. The OPI extends from Leadbetter Point, Washington to the U.S./Mexican border. Data are from PFMC (1999:I-20); 1998 data are preliminary.

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               Coho: OPI Ocean Exploitation Rate Index (%)
P  100-|
e     -|             X X
r   80-|   X X X X X X X X     X   X
c     -|---X-X-X-X-X-X-X-X-X-X-X---X------------------------------ 70%
e   60-| X X X X X X X X X X X X X X       X     X
n     -|-X-X-X-X-X-X-X-X-X-X-X-X-X-X-------X-X-X-X---------------- 50%
t   40-| X X X X X X X X X X X X X X   X   X X X X X X
a     -|-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X---------- 30%
g   20-| X X X X X X X X X X X X X X X X X X X X X X X X   X
e     -|-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X-X---X-X-X-X- 10%
   1-4-| X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
     0-| X X X X X X X X X X X X X X X X X X X X X X X X X X X X X
       |__________________________________________________________
         | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
         |         |         |         |         |         |
        70        75        80        85        90        95

                                 Year
```

V-8c. ESTUARINE AND FRESHWATER FISHERIES. These fisheries have also been restricted in recent years to increase the escapement of wild salmon and steelhead to spawning areas. In 1994-1996, estuary and freshwater sports coho fisheries were discontinued in most coastal streams; however, fisheries continued in the North Fork of the Nehalem River (but not the rest of the Nehalem Basin), North Umpqua River, Umpqua River and Bay (1995 only), Coos River and Bay, Tenmile Creek and Lakes (1994 only), and Rogue River (ODFW 1998b). Starting in 1992, recreational fishery regulations along the Oregon coast required the release of all wild steelhead (Chilcote 1998:31).

Catches also depend on fishing effort, and effort has been variable in estuarine and freshwater fisheries (sections J-1a and J-2a).

V-9. STRAYING

Another challenge in testing returns for the effects of hazing is straying, whereby salmon or steelhead reared or released in one basin return as adults to a different basin. Although some straying is a natural process, the number of hatchery-reared coho (Jacobs 1988, ODFW 1997a:62, 1997b:43, 1997c:57; Quinn 1997) or hatchery-reared winter steelhead (Lindsey et al. 1995, Chilcote 1998:31-36) that stray can be significant. For instance, strays from Oregon Aqua-Foods coho releases increased the number of coho in streams from the Salmon River to Yachats (section J-1a). If there is appreciable straying, then it cannot be robustly assumed that all salmon or steelhead returning to a basin with hazing were released there and affected by hazing.

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