FISHERY DATA SERIES NO. 90-44

HARVEST AND PARTICIPATION IN ALASKA SPORT FISHERIES DURING 1989[1]

By

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September 1990

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-5, Job No. RT-1.

Appendix A65. Kenai Peninsula Area[a] sport fish saltwater harvest and effort by fisheries for shellfish species, 1989.

	Anglers	Trips	Days Fished	DC	TC	SHR (Gallons)	HCL (Gallons)	CC	RCL
SALTWATER:									
Kachemak Bay (Homer)	4,766	6,265	8,314	9,632	0	1,142	15,169	10,874	13,813
Resurrection Bay (Seward)	442	428	442	257	0	0	14	0	0
Other Sites	802	771	1,402	443	0	71	3,026	2,141	3,568
Clams between Kasilof and Anchor Point	18,894	17,024	22,658		Total Clams Taken:		13,328	1,427	832,155
SALTWATER TOTAL	23,503[b]	24,488	32,816	10,332	0	1,213	31,537	14,442	849,536

[a] Kenai Peninsula (Area P): All Alaskan saltwater around the Kenai Peninsula from Cape Puget around to Portage Creek at Portage, including waters around Kalgin Island.

[b] Angler totals may not equal sum of sites due to some anglers fishing at more than one site.

Appendix A66. Kodiak Area[a] sport fish harvest and effort by fisheries and species, 1989.

	Anglers	Trips	Days Fished	KI[b]	KS	SS	LL	RS	PS	CS	DV AC	SH	RT	GR	SM	HA	RF	RCL	OTHER
SALTWATER:																			
Boat - Chiniak Bay Area	3,250	7,269	8,392	24	36	934	0	218	168	0	269	0	0	0	0	4,130	1,932	0	706
Boat - Afognak Island Area	2,411	4,546	6,963	0	12	1,783	0	590	1,317	28	439	0	0	0	0	2,464	1,398	0	443
Boat - Barren Islands	1,149	903	1,149	0	12	0	0	54	0	0	0	0	0	0	0	1,846	0	0	66
Boat - Other	1,245	2,821	3,304	0	6	371	0	336	318	18	189	0	0	0	0	1,376	331	0	213
Shoreline - Chiniak Bay Area	2,199	5,727	6,902	6	18	663	0	100	3,554	57	1,006	0	0	0	0	160	555	821	66
Shoreline - Afognak Island Area	574	706	966	0	0	779	0	281	88	0	0	20	0	0	0	203	107	0	0
Shoreline - Other	1,558	4,363	7,809	6	0	808	0	27	2,121	122	868	229	0	0	0	256	747	656	99
SALTWATER TOTAL	8,894[c]	26,335	35,485	36	84	5,338	0	1,606	7,566	225	2,771	249	0	0	0	10,435	5,070	1,477	1,593
FRESHWATER:																			
Buskin River	5,744	24,976	26,145	0	0	4,782	0	1,816	4,402	66	7,092	0	0	0	0	0	0	0	164
Pasagshak River	3,282	5,399	5,578	18	0	2,065	0	1,244	804	0	588	0	0	0	0	0	0	0	0
Karluk River and Lagoon	870	1,313	2,420	102	457	906	0	799	35	9	418	20	10	0	0	0	0	0	0
American River	2,199	3,955	3,506	0	0	1,500	0	0	1,397	95	448	0	0	0	0	0	0	0	0
Olds River (or Creek)	2,511	5,333	5,378	0	0	2,571	0	0	2,325	142	259	0	0	0	0	0	0	0	0
Saltery Creek	410	1,067	1,175	0	0	1,013	0	390	97	0	129	30	20	0	0	0	0	0	0
Other Streams	1,671	3,856	4,596	132	258	1,198	0	644	1,115	94	1,564	329	458	0	0	0	0	0	0
Roadside Lakes	442	919	887	0	0	0	60	0	44	0	100	60	717	40	0	0	0	0	0
Other Lakes	901	1,017	1,172	0	0	429	0	290	9	0	897	100	329	149	0	0	0	0	0
FRESHWATER TOTAL	8,763[c]	47,835	50,857	252	715	14,464	60	5,183	10,228	406	11,495	539	1,534	189	0	0	0	0	164
GRAND TOTAL	12,849[c]	74,170	86,342	288	799	19,802	60	6,789	17,794	631	14,266	788	1,534	189	0	10,435	5,070	1,477	1,757

[a] Kodiak (Area Q): All Alaskan waters, including drainages, of the Kodiak and Afognak Island groups, including the Barren and Trinity Islands.

[b] King Salmon less than 20 inches.

[c] Angler totals may not equal sum of sites due to some anglers fishing at more than one site.

Appendix A56. Prince William Sound Area[a] sport fish harvest and effort by fisheries and species, 1989.

	Anglers	Trips	Days Fished	KI[b]	KS	SS	RS	PS	CS	LT	DV AC	SH	RT	CT	GR	WF	SM	HA	RF	RCL	OTHER
SALTWATER:																					
Boat - Valdez Bay	10,336	17,417	28,985	76	298	13,868	326	14,740	1,497	0	416	0	0	0	0	0	0	4,086	6,668	0	2,313
Boat - Passage Canal (Whittier)	2,408	3,318	6,592	35	35	587	352	918	147	0	87	0	0	0	0	0	0	684	1,898	0	80
Boat - Orca Inlet	510	1,579	2,468	0	0	180	53	172	0	0	145	0	0	0	0	0	0	747	239	0	351
Boat - Other	3,562	8,922	15,437	35	345	953	1,321	1,983	596	0	185	39	0	0	0	0	64	2,807	3,524	0	16,078
Shoreline - Valdez Road System	8,278	11,229	15,740	0	35	2,857	264	15,770	964	0	300	0	0	0	0	0	0	21	41	0	415
Shoreline - Remainder of Valdez Arm	2,154	4,035	3,746	0	117	1,409	238	2,369	257	0	19	0	0	0	0	0	0	124	363	64	479
Shoreline - Orca Inlet	447	1,340	1,929	0	0	596	0	240	64	0	223	0	0	0	0	0	0	21	31	0	0
Shoreline - Other	1,326	2,155	5,222	0	117	850	53	497	37	0	77	0	0	0	0	0	0	207	155	4,179	686
SALTWATER TOTAL	24,069[c]	49,995	80,119	146	947	21,300	2,607	36,689	3,562	0	1,452	39	0	0	0	0	64	8,697	12,919	4,243	20,402
FRESHWATER:																					
Eyak River	1,228	4,163	7,347	0	0	2,100	203	137	0	0	813	0	0	300	0	0	0	0	0	0	0
Coghill River	415	415	415	0	0	9	344	86	0	0	29	0	0	0	0	0	0	0	0	0	0
Other Streams	2,029	3,927	6,012	0	0	2,213	767	971	73	155	1,752	0	96	872	194	0	0	0	0	0	64
Lakes	1,070	1,277	1,402	0	0	9	18	111	0	155	290	0	581	339	174	0	0	0	0	0	0
FRESHWATER TOTAL	3,796[c]	9,782	15,176	0	0	4,331	1,332	1,305	73	310	2,884	0	677	1,511	368	0	0	0	0	0	64
GRAND TOTAL	26,238[c]	59,777	95,295	146	947	25,631	3,939	37,994	3,635	310	4,336	39	677	1,511	368	0	64	8,697	12,919	4,243	20,466

a Prince William Sound (Area J): All Alaskan waters, including drainages, from and including Cape Suckling through Prince William Sound to Cape Puget, including all waters emptying into Port Bainbridge; and, that portion of the Copper River drainage downstream of a line between the south bank of Haley Creek and the south bank of Canyon Creek in Wood Canyon.

b King Salmon less than 16 inches.

c Angler totals may not equal sum of sites due to some anglers fishing at more than one site.

Appendix A5. Number of anglers who sport fished in Alaska by area of residence, 1977-1989.

	Number of Anglers												
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Alaska													
Southeast	20,387	21,799	20,740	24,534	26,923	30,642	31,671	34,252	35,267	36,426	37,297	36,798	37,435
Upper Copper-Susitna River	1,885	1,377	1,255	1,302	1,195	1,254	1,600	1,353	1,470	1,539	1,622	1,701	1,320
Prince William Sound	2,802	2,788	2,675	3,018	3,064	3,537	3,044	3,632	4,149	4,313	4,558	4,248	3,731
Kenai Peninsula	14,690	13,939	15,429	13,514	15,229	18,736	20,789	21,693	21,332	22,058	24,025	24,180	24,211
West Cook Inlet-Lower Susitna Drainage	85,062	85,844	86,210	89,370	94,707	109,757	116,914	125,464	129,335	133,715	135,476	134,465	124,257
Kodiak	4,597	4,950	5,317	4,915	5,491	5,983	6,354	6,995	7,509	7,767	8,342	7,005	7,110
Bristol Bay	933	1,113	1,260	1,666	1,667	1,922	2,825	2,518	3,115	3,356	2,922	3,233	3,825
Arctic-Yukon-Kuskokwim	22,261	25,866	29,624	30,163	32,822	40,127	41,072	41,474	38,958	40,455	39,961	38,656	39,722
Total	152,617	157,676	162,510	168,482	181,098	211,958	224,269	237,381	241,135	249,629	254,203	250,286	241,611
Other Than Alaska													
Other United States	38,717	41,604	44,723	49,718	61,697	73,060	77,432	88,784	98,262	100,120	105,380	118,372	136,573
Foreign	9,724	6,905	6,076	6,213	6,434	7,993	8,297	9,443	9,370	9,634	10,755	8,346	13,124
Total	48,441	48,509	50,799	55,931	68,131	81,053	85,729	98,227	107,632	109,754	116,135	126,718	149,697
Percent	24.1	23.5	23.8	24.9	27.3	27.7	27.7	29.3	30.9	30.5	31.4	33.6	38.3
TOTAL	201,058	206,185	213,309	224,413	249,229	293,011	309,998	335,608	348,767	359,383	370,338	377,004	391,308

Appendix A4. 1989 Alaska sport fish harvest survey summary of mailings and responses.

	Mailing 1	Mailing 2	Mailing 3	Total
Date of Mailing	10/27/89	12/15/89	1/31/90	
Number Mailed	28,422	20,305	16,257	64,984
Number Nondeliverable	3,219	715	509	4,443
Percent Nondeliverable	11.3	3.5	3.1	6.8
Number Delivered	25,203	19,590	15,748	60,541
Percent Delivered	88.7	96.5	96.9	93.1
Responses				
Number	8,446	3,797	2,274	14,517
Percent of Mailed	29.7	18.7	14.0	
Percent of Delivered	33.5	19.4	14.4	
Percent of 1st Delivery	33.5	15.1	9.0	57.6
Cumulative Responses				
Number	8,446	12,243	14,517	
Percent of 1st Delivery	33.5	48.6	57.6	

where ϵ_i is the normal variate with mean 0 and variance σ^2. Parameters α a
β were estimated according to procedures in Draper and Smith (1981). The se
$\{n_4, n_5, ..., n_I\}$ was estimated from regression (2) where I is the minimu
number of mailings that satisfied the condition $\sum_{i=1}^{I} n_i = n$. Regression (3) wa
used to estimate the set $\{Y_4, Y_5, ... Y_I\}$ for each harvest and effort statisti
Confidence intervals were bootstrapped using the percentile method (Efr
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RESULTS

The Alaska sport fish harvest survey indicated that 391,308 anglers to 1,731,202 household trips and fished 2,264,079 days to harvest 3,213,867 fi in 1989. Of the 391,308 anglers who fished in 1989, 241,611 (62%) were Alas residents while 149,697 (38%) were nonresidents.

Of the 2,264,079 angler-days fished in 1989, 1,583,381 (70%) were expended the Southcentral region of Alaska, 440,906 (19%) were expended in t Southeast region, and 239,792 (11%) were expended in the Arctic-Yuko Kuskokwim region. The Cook Inlet area had 1,209,483 days (53%) of the State total sport fishing. The Kenai Peninsula had 799,409 angler days or 35% the State total. The Kenai River alone had 376,902 angler-days, 17% of t State total. An estimated 741,806 days, 33% of all sport fishing, was saltwater; 1,522,273 days, 67% of all sport fishing, was in freshwater.

The 3,213,867 fish harvested in 1989 included 917,963 razor clams *Siliq patula* and 207,826 smelt and capelin Osmeridae. Of the remaining 2,088,0 harvested fish, 1,097,228 (53%) were sea-run salmon *Oncorhynchus* spp 229,016 (11%) were halibut *Hippoglossus stenolepis*, 209,961 (10%) were rainb trout *Oncorhynchus mykiss*, 136,127 (7%) were Dolly Varden *Salvelinus malma* a Arctic char *Salvelinus alpinus*, 105,469 (5%) were Arctic grayling *Thymall arcticus*, and 86,776 (4%) were rockfish *Sebastes* spp. Also harvested we 49,424 landlocked salmon (chinook salmon *Oncorhynchus tshawytscha*, coho salm *Oncorhynchus kisutch*, and Kokanee *Oncorhynchus nerka*), 24,337 whitefi *Coregonus* spp. and *Prosopium* spp., 21,659 northern pike *Esox lucius*, 20,3 cutthroat trout *Oncorhynchus clarki*, 17,070 lake trout *Salvelinus namaycus* 9,268 burbot *Lota lota*, 6,387 steelhead *Oncorhynchus mykiss*, 2,306 sheefi *Stenodus leucichthys*, and 887 brook trout *Salvelinus fontinalis*.

Except for razor clams, shell fisheries are not included in the 3,213,8 total fish harvest reported above. For the Kenai Peninsula, however, the fisheries were surveyed for dungeness crab *Cancer magister*, tanner cr *Chionoecetes bairdi*, shrimp Pandalidae, and hardshell clams. Harvest a effort for these species are reported in Appendix A65.

The 1989 total sea-run salmon harvest of 1,097,228 included 122,737 chino salmon, 338,195 coho salmon, 436,871 sockeye salmon, 164,778 pink salm *Oncorhynchus gorbuscha*, and 34,647 chum salmon *Oncorhynchus keta*. The mari salmon harvest total of 330,052 included 44,366 chinook salmon, 129,884 co salmon, 18,131 sockeye salmon, 124,537 pink salmon, and 13,134 chum salmo The freshwater total of 767,176 salmon included 78,371 chinook salmon, 208,3 coho salmon, 418,740 sockeye salmon, 40,241 pink salmon, and 21,513 ch salmon. Regionally, 214,728 sea-run salmon were harvested in Southeast Alaska, 858,733 in Southcentral, and 23,767 in the Arctic-Yukon-Kuskokwim. The sport harvest of small chinook salmon statewide totaled 16,001 and is included in the 122,737 reported above.

Harvest and effort for 1989 are tabulated by region, area, fishery, and species in Appendix A. Detailed tabulations for 1977 through 1988 may be found in Mills (1979, 1980, 1981a, 1981b, 1982, 1983, 1984, 1985, 1986, 1987, 1988, 1989).

DISCUSSION

Angler effort (anglers-days) declined statewide (Appendix A8) for only the second time since the sport fish harvest survey was initiated in 1977. This 2% decline from 1988 to 1989 still left 1989 as the second highest year on record. Regionally, effort increased 11% in Southeast and 7% in Arctic-Yukon-Kuskokwim over 1988, but decreased 6% in Southcentral Alaska. Since 1977, statewide effort has increased 189%, 5% per year.

The number of anglers participating in Alaska sport fishing increased by 4% from 1988 to 1989. The number of resident anglers decreased by 3%, but the number of nonresident anglers increased by 18%. Regionally, angler participation increased 2% in Southeast, 2% in Southcentral, and 7% in Arctic-Yukon-Kuskokwim. Since 1977, the number of anglers fishing in Alaska has increased 195%, 6% per year. Resident angler participation since 1977 has increased 158%, 4% per year; nonresident participation has increased 309%, 10% per year.

The anadromous salmon harvest statewide was an all-time record high, exceeding one million for the first time (Appendix A16). The coho salmon harvest (Appendix A21) was an all-time record, as was the odd-year pink salmon harvest (Appendix A25). Chinook, sockeye, and chum salmon harvests (Appendices A18, A23, A27) were each the second largest ever. Southeast and Southcentral salmon harvests were all-time record highs (Appendix A16). The Kenai River produced over 406,000 salmon in the sport (352,000) and personal use dipnet (54,000) fisheries, including over 326,000 sockeye salmon--all of which were record highs. Not included in these Kenai River totals was a sockeye salmon harvest of 67,000 in the Russian River, a tributary to the Kenai River.

Other notable 1989 statewide harvests include halibut, a record high, and Arctic grayling, a record low. Burbot, Dolly Varden/Arctic char, and razor clam harvests were significantly below historical averages.

Over the past thirteen years the statewide sport fish harvest survey has proved effectual in economically meeting management needs for reliable estimates of effort for and harvest of Alaska's game fishes. The survey has been well received by the angling public. Results have been consistent with creel surveys (Appendix A76), and sport fish biologists report that harvest survey estimates for areas not creel surveyed are generally in accordance with their own knowledge and observations.

Thus, in the interest of economic efficiency, the statewide harvest survey has replaced on-site creel surveys in cases where creel surveys were not required

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ABSTRACT

This report presents 1989 findings from an annual survey providing statewide estimates of Alaska sport fishing participation and harvests by fisheries, areas, regions, and species. The survey indicated that 391,308 anglers took 1,731,202 household trips and fished 2,264,079 days to harvest 3,213,867 fish in 1989. The methodology of the survey, based primarily on mailing questionnaires to a sample of licensees, continued to prove effectual.

KEY WORDS: Harvest, catch, fish, fisheries, sport, recreation, Alaska, effort, survey, angler, angler-days.

need codes/abbreviations for species listed in the harvest tables (see Mills, Fisher Series Data No2)

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The 3,213,867 fish harvested in 1989 included 917,963 razor clams *Sili patula* and 207,826 smelt and capelin Osmeridae. Of the remaining 2,088, harvested fish, 1,097,228 (53%) were sea-run salmon *Oncorhynchus* sp 229,016 (11%) were halibut *Hippoglossus stenolepis*, 209,961 (10%) were rain trout *Oncorhynchus mykiss*, 136,127 (7%) were Dolly Varden *Salvelinus malma* Arctic char *Salvelinus alpinus*, 105,469 (5%) were Arctic grayling *Thymal arcticus*, and 86,776 (4%) were rockfish *Sebastes* spp. Also harvested w 49,424 landlocked salmon (chinook salmon *Oncorhynchus tshawytscha*, coho sal *Oncorhynchus kisutch*, and Kokanee *Oncorhynchus nerka*), 24,337 whitef *Coregonus* spp. and *Prosopium* spp., 21,659 northern pike *Esox lucius*, 20, cutthroat trout *Oncorhynchus clarki*, 17,070 lake trout *Salvelinus namaycu* 9,268 burbot *Lota lota*, 6,387 steelhead *Oncorhynchus mykiss*, 2,306 sheef *Stenodus leucichthys*, and 887 brook trout *Salvelinus fontinalis*.

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DISCUSSION

Angler effort (anglers-days) declined statewide (Appendix A8) for only the second time since the sport fish harvest survey was initiated in 1977. This 2% decline from 1988 to 1989 still left 1989 as the second highest year on record. Regionally, effort increased 11% in Southeast and 7% in Arctic-Yukon-Kuskokwim over 1988, but decreased 6% in Southcentral Alaska. Since 1977, statewide effort has increased 189%, 5% per year.

The number of anglers participating in Alaska sport fishing increased by 4% from 1988 to 1989. The number of resident anglers decreased by 3%, but the number of nonresident anglers increased by 18%. Regionally, angler participation increased 2% in Southeast, 2% in Southcentral, and 7% in Arctic-Yukon-Kuskokwim. Since 1977, the number of anglers fishing in Alaska has increased 195%, 6% per year. Resident angler participation since 1977 has increased 158%, 4% per year; nonresident participation has increased 309%, 10% per year.

The anadromous salmon harvest statewide was an all-time record high, exceeding one million for the first time (Appendix A16). The coho salmon harvest (Appendix A21) was an all-time record, as was the odd-year pink salmon harvest (Appendix A25). Chinook, sockeye, and chum salmon harvests (Appendices A18, A23, A27) were each the second largest ever. Southeast and Southcentral salmon harvests were all-time record highs (Appendix A16). The Kenai River produced over 406,000 salmon in the sport (352,000) and personal use dipnet (54,000) fisheries, including over 326,000 sockeye salmon--all of which were record highs. Not included in these Kenai River totals was a sockeye salmon harvest of 67,000 in the Russian River, a tributary to the Kenai River.

Other notable 1989 statewide harvests include halibut, a record high, and Arctic grayling, a record low. Burbot, Dolly Varden/Arctic char, and razor clam harvests were significantly below historical averages.

Over the past thirteen years the statewide sport fish harvest survey has proved effectual in economically meeting management needs for reliable estimates of effort for and harvest of Alaska's game fishes. The survey has been well received by the angling public. Results have been consistent with creel surveys (Appendix A76), and sport fish biologists report that harvest survey estimates for areas not creel surveyed are generally in accordance with their own knowledge and observations.

Thus, in the interest of economic efficiency, the statewide harvest survey has replaced on-site creel surveys in cases where creel surveys were not required

Appendix A4. 1989 Alaska sport fish harvest survey summary of mailings and responses.

	Mailing 1	Mailing 2	Mailing 3	Total
Date of Mailing	10/27/89	12/15/89	1/31/90	
Number Mailed	28,422	20,305	16,257	64,984
Number Nondeliverable	3,219	715	509	4,443
Percent Nondeliverable	11.3	3.5	3.1	6.8
Number Delivered	25,203	19,590	15,748	60,541
Percent Delivered	88.7	96.5	96.9	93.1
Responses				
Number	8,446	3,797	2,274	14,517
Percent of Mailed	29.7	18.7	14.0	
Percent of Delivered	33.5	19.4	14.4	
Percent of 1st Delivery	33.5	15.1	9.0	57.6
Cumulative Responses				
Number	8,446	12,243	14,517	
Percent of 1st Delivery	33.5	48.6	57.6	

Appendix A5. Number of anglers who sport fished in Alaska by area of residence, 1977-1989.

	Number of Anglers												
	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Alaska													
Southeast	20,387	21,799	20,740	24,534	26,923	30,642	31,671	34,252	35,267	36,426	37,297	36,798	37,435
Upper Copper-Susitna River	1,885	1,377	1,255	1,302	1,195	1,254	1,800	1,353	1,470	1,539	1,822	1,701	1,320
Prince William Sound	2,802	2,788	2,675	3,018	3,064	3,537	3,044	3,632	4,149	4,313	4,558	4,248	3,731
Kenai Peninsula	14,690	13,939	15,429	13,514	15,229	18,736	20,789	21,693	21,332	22,058	24,025	24,180	24,211
West Cook Inlet-Lower Susitna Drainage	85,062	85,844	86,210	89,370	94,707	109,757	116,914	125,464	129,335	133,715	135,476	134,465	124,257
Kodiak	4,597	4,950	5,317	4,915	5,491	5,983	6,354	6,995	7,509	7,767	8,342	7,005	7,110
Bristol Bay	933	1,113	1,260	1,666	1,667	1,922	2,825	2,518	3,115	3,356	2,922	3,233	3,825
Arctic-Yukon-Kuskokwim	22,261	25,866	29,624	30,163	32,822	40,127	41,072	41,474	38,958	40,455	39,961	38,656	39,722
Total	152,617	157,676	162,510	168,482	181,098	211,958	224,269	237,381	241,135	249,629	254,203	250,286	241,611
Other Than Alaska													
Other United States	38,717	41,604	44,723	49,718	61,697	73,060	77,432	88,784	98,262	100,120	105,380	118,372	136,573
Foreign	9,724	6,905	6,076	6,213	6,434	7,993	8,297	9,443	9,370	9,634	10,755	8,346	13,124
Total	48,441	48,509	50,799	55,931	68,131	81,053	85,729	98,227	107,632	109,754	116,135	126,718	149,697
Percent	24.1	23.5	23.8	24.9	27.3	27.7	27.7	29.3	30.9	30.5	31.4	33.6	38.3
TOTAL	201,058	206,185	213,309	224,413	249,229	293,011	309,998	335,608	348,767	359,383	370,338	377,004	391,308

Appendix A56. Prince William Sound Area[a] sport fish harvest and effort by fisheries and species, 1989.

	Anglers	Trips	Days Fished	KI[b]	KS	SS	RS	PS	CS	LT	DV AC	SH	RT	CT	GR	WF	SM	HA	RF	RCL	OTHER
SALTWATER:																					
Boat - Valdez Bay	10,336	17,417	28,985	76	298	13,868	326	14,740	1,497	0	416	0	0	0	0	0	0	4,086	6,668	0	2,313
Boat - Passage Canal (Whittier)	2,408	3,318	6,592	35	35	587	352	918	147	0	87	0	0	0	0	0	0	684	1,898	0	80
Boat - Orca Inlet	510	1,579	2,468	0	0	180	53	172	0	0	145	0	0	0	0	0	0	747	239	0	351
Boat - Other	3,562	8,922	15,437	35	345	953	1,321	1,983	596	0	185	39	0	0	0	0	64	2,807	3,524	0	16,078
Shoreline - Valdez Road System	8,278	11,229	15,740	0	35	2,857	264	15,770	964	0	300	0	0	0	0	0	0	21	41	0	415
Shoreline - Remainder of Valdez Arm	2,154	4,035	3,746	0	117	1,409	238	2,369	257	0	19	0	0	0	0	0	0	124	363	64	479
Shoreline - Orca Inlet	447	1,340	1,929	0	0	596	0	240	64	0	223	0	0	0	0	0	0	21	31	0	0
Shoreline - Other	1,326	2,155	5,222	0	117	850	53	497	37	0	77	0	0	0	0	0	0	207	155	4,179	686
SALTWATER TOTAL	24,069[c]	49,995	80,119	146	947	21,300	2,607	36,689	3,562	0	1,452	39	0	0	0	0	64	8,697	12,919	4,243	20,402
FRESHWATER:																					
Eyak River	1,228	4,163	7,347	0	0	2,100	203	137	0	0	813	0	0	300	0	0	0	0	0	0	0
Coghill River	415	415	415	0	0	9	344	86	0	0	29	0	0	0	0	0	0	0	0	0	0
Other Streams	2,029	3,927	6,012	0	0	2,213	767	971	73	155	1,752	0	96	872	194	0	0	0	0	0	64
Lakes	1,070	1,277	1,402	0	0	9	18	111	0	155	290	0	581	339	174	0	0	0	0	0	0
FRESHWATER TOTAL	3,796[c]	9,782	15,176	0	0	4,331	1,332	1,305	73	310	2,884	0	677	1,511	368	0	0	0	0	0	64
GRAND TOTAL	26,238[c]	59,777	95,295	146	947	25,631	3,939	37,994	3,635	310	4,336	39	677	1,511	368	0	64	8,697	12,919	4,243	20,466

[a] Prince William Sound (Area J): All Alaskan waters, including drainages, from and including Cape Suckling through Prince William Sound to Cape Puget, including all waters emptying into Port Bainbridge; and, that portion of the Copper River drainage downstream of a line between the south bank of Haley Creek and the south bank of Canyon Creek in Wood Canyon.

[b] King Salmon less than 16 inches.

[c] Angler totals may not equal sum of sites due to some anglers fishing at more than one site.

Appendix A65. Kenai Peninsula Area[a] sport fish saltwater harvest and effort by fisheries for shellfish species, 1989.

	Anglers	Trips	Days Fished	DC	TC	SHR (Gallons)	HCL (Gallons)	OC	RCL
SALTWATER:									
Kachemak Bay (Homer)	4,766	6,265	8,314	9,632	0	1,142	15,169	10,874	13,813
Resurrection Bay (Seward)	442	428	442	257	0	0	14	0	0
Other Sites	802	771	1,402	443	0	71	3,026	2,141	3,568
Clams between Kasilof and Anchor Point	18,894	17,024	22,658		Total Clams Taken:		13,328	1,427	832,155
SALTWATER TOTAL	23,503[b]	24,488	32,816	10,332	0	1,213	31,537	14,442	849,536

[a] Kenai Peninsula (Area P): All Alaskan saltwater around the Kenai Peninsula from Cape Puget around to Portage Creek at Portage, including waters around Kalgin Island.

[b] Angler totals may not equal sum of sites due to some anglers fishing at more than one site.

Appendix A66. Kodiak Area[a] sport fish harvest and effort by fisheries and species, 1989.

	Anglers	Trips	Days Fished	KI[b]	KS	SS	LL	RS	PS	CS	DV AC	SH	RT	GR	SM	HA	RF	RCL	OTHER
SALTWATER:																			
Boat - Chiniak Bay Area	3,250	7,269	8,392	24	36	934	0	218	168	0	269	0	0	0	0	4,130	1,932	0	706
Boat - Afognak Island Area	2,411	4,546	6,963	0	12	1,783	0	590	1,317	28	439	0	0	0	0	2,464	1,398	0	443
Boat - Barren Islands	1,149	903	1,149	0	12	0	0	54	0	0	0	0	0	0	0	1,846	0	0	66
Boat - Other	1,245	2,821	3,304	0	6	371	0	336	318	18	189	0	0	0	0	1,376	331	0	213
Shoreline - Chiniak Bay Area	2,199	5,727	6,902	6	18	663	0	100	3,554	57	1,006	0	0	0	0	160	555	821	66
Shoreline - Afognak Island Area	574	706	966	0	0	779	0	281	88	0	0	20	0	0	0	203	107	0	0
Shoreline - Other	1,558	4,363	7,809	6	0	808	0	27	2,121	122	868	229	0	0	0	256	747	656	99
SALTWATER TOTAL	8,894[c]	26,335	35,485	36	84	5,338	0	1,606	7,566	225	2,771	249	0	0	0	10,435	5,070	1,477	1,593
FRESHWATER:																			
Buskin River	5,744	24,976	26,145	0	0	4,782	0	1,816	4,402	66	7,092	0	0	0	0	0	0	0	164
Pasagshak River	3,282	5,399	5,578	18	0	2,065	0	1,244	804	0	588	0	0	0	0	0	0	0	0
Karluk River and Lagoon	870	1,313	2,420	102	457	906	0	799	35	9	418	20	10	0	0	0	0	0	0
American River	2,199	3,955	3,506	0	0	1,500	0	0	1,397	95	448	0	0	0	0	0	0	0	0
Olds River (or Creek)	2,511	5,333	5,378	0	0	2,571	0	0	2,325	142	259	0	0	0	0	0	0	0	0
Saltery Creek	410	1,067	1,175	0	0	1,013	0	390	97	0	129	30	20	0	0	0	0	0	0
Other Streams	1,671	3,856	4,596	132	258	1,198	0	644	1,115	94	1,564	329	458	0	0	0	0	0	0
Roadside Lakes	442	919	887	0	0	0	60	0	44	0	100	60	717	40	0	0	0	0	0
Other Lakes	901	1,017	1,172	0	0	429	0	290	9	0	897	100	329	149	0	0	0	0	0
FRESHWATER TOTAL	8,763[c]	47,835	50,857	252	715	14,464	60	5,183	10,228	406	11,495	539	1,534	189	0	0	0	0	164
GRAND TOTAL	12,849[c]	74,170	86,342	288	799	19,802	60	6,789	17,794	631	14,266	788	1,534	189	0	10,435	5,070	1,477	1,757

[a] Kodiak (Area Q): All Alaskan waters, including drainages, of the Kodiak and Afognak Island groups, including the Barren and Trinity Islands.

[b] King Salmon less than 20 inches.

[c] Angler totals may not equal sum of sites due to some anglers fishing at more than one site.

not really relevant

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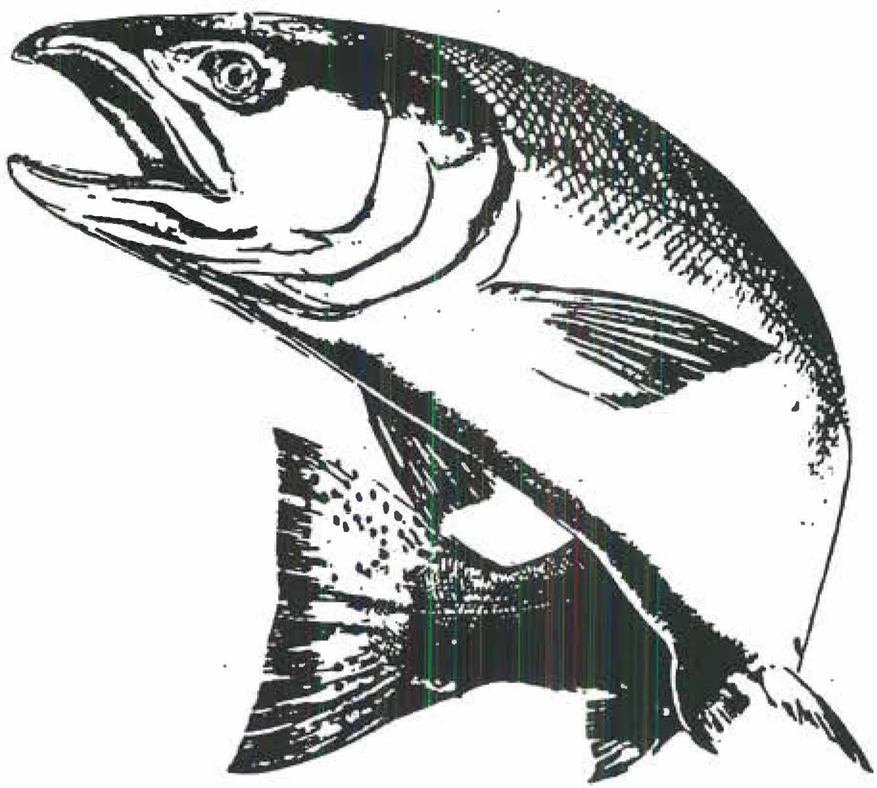
FISHERY MANAGEMENT PLAN

For The

SALMON FISHERIES

In The

EEZ Off The Coast Of ALASKA



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APRIL 1990

NORTH PACIFIC FISHERY MANAGEMENT COUNCIL

200 mile economic fish zone

2.0 DESCRIPTION OF THE FISHERY MANAGEMENT UNIT

2.1 Areas

The Fishery Management Unit consists of all of the EEZ off the coast of Alaska and the salmon and fisheries that occur there.

The area covered by this fishery management plan is the EEZ off the coast of Alaska (See Figure 1), including parts of the Gulf of Alaska, Bering Sea, Chukchi Sea, and Arctic Ocean. Two management areas are established within the fishery management unit, with the border between the two at the longitude of Cape Suckling (143°53'36" W).

As long as the International Convention for the High Seas Fisheries of the North Pacific Ocean remains in effect (or it is replaced by an equivalent convention), the Council leaves the management of the salmon fisheries west of 175° east longitude under the control of the International North Pacific Fisheries Commission (or equivalent organization). Otherwise, this plan will govern the salmon fisheries in the EEZ west of 175° east longitude as an integral part of the West Area.

The West Area is the area of the EEZ off the coast of Alaska west of the longitude of Cape Suckling (143°53'36" W.). It includes the EEZ in the Bering, Chukchi, and Beaufort Seas, as well as well as the EEZ in the North Pacific Ocean west of Cape Suckling.

The East Area is the area of the EEZ off the coast of Alaska east of the longitude of Cape Suckling.

2.2 Fisheries

Except as provided by other Federal law (see Appendix C), this plan allows commercial salmon fishing only in the East Area. It allows sport (or recreational) salmon fishing in the West and East areas. Specific regulations are promulgated by the Alaska Department of Fish and Game.

2.2.1 The Sport (or Recreational) Salmon Fishery.

The sport fishery for salmon in marine waters off Alaska takes place almost entirely within State waters (there is little reason for sport fishermen to fish for salmon seaward of State waters). The little sport fishing that does occur in the EEZ (primarily the charter boat fishery) takes place to a minor extent in both areas, but the sport harvest of salmon from the

EEZ is probably less than several hundred salmon for both areas combined.

2.2.2. The Commercial Salmon Fishery in the West Area.

In the West Area, the only commercial salmon fishery is the incidental fishery allowed under 50 CFR 210 (see Appendix C). Federal regulations implementing the North Pacific Fisheries Act (16 U.S.C. 1021, et seq.), prohibit U.S. fishermen from fishing for or taking salmon with nets in the North Pacific outside Alaskan waters except for three historical fisheries managed by the State; these are the (a) False Pass (South Peninsula), (b) Cook Inlet, and (c) Copper River net fisheries. These fisheries technically extend into the EEZ, but they are conducted and managed by the State of Alaska as nearshore fisheries. Thus, aside from those traditional fisheries, this plan prohibits commercial salmon fishing in the EEZ west of the longitude of Cape Suckling.

2.2.3 The Commercial Troll Salmon Fishery in the East Area.

Within the East Area, the troll fishery (hand-troll and power-troll) is the only commercial salmon fishery allowed. From Alaska statehood in 1959 until 1979, this fishery was conducted and managed with little recognition of the boundary separating Federal from State waters, although at one time the State banned hand trolling seaward of the surf line. Upon implementation of the Council's plan in 1979, the fishery in the Federal EEZ came under Federal regulations even though the trollers continued to fish in State and Federal waters as if the troll fishery were a unit.

Entry into the troll fishery is limited by the Alaska Commercial Fisheries Entry Commission and the North Pacific Fishery Management Council. At the present time, only two trollers have Federal limited-entry permits; the rest have Alaska limited entry permits (Tables 1 and 2). The Council's original plan contains descriptions of the Alaska and Federal limited entry systems (NPFMC, 1978). The appendix tables contain information on the number of permits issued to residents and nonresidents of Alaska and average prices for permits.

Commercial trolling in the East Area takes place in two seasons. A winter troll fishery (15 October through 14 April) takes place in internal waters of Southeast Alaska lying east of the ocean surfline and in Yakutat Bay; all outer coastal areas and the EEZ are closed during the winter fishery. The summer troll fishery now takes place from June through 20 September in three parts: (1) a June fishery in small defined areas within Alaska's internal waters, (2) a fishery adjacent to certain

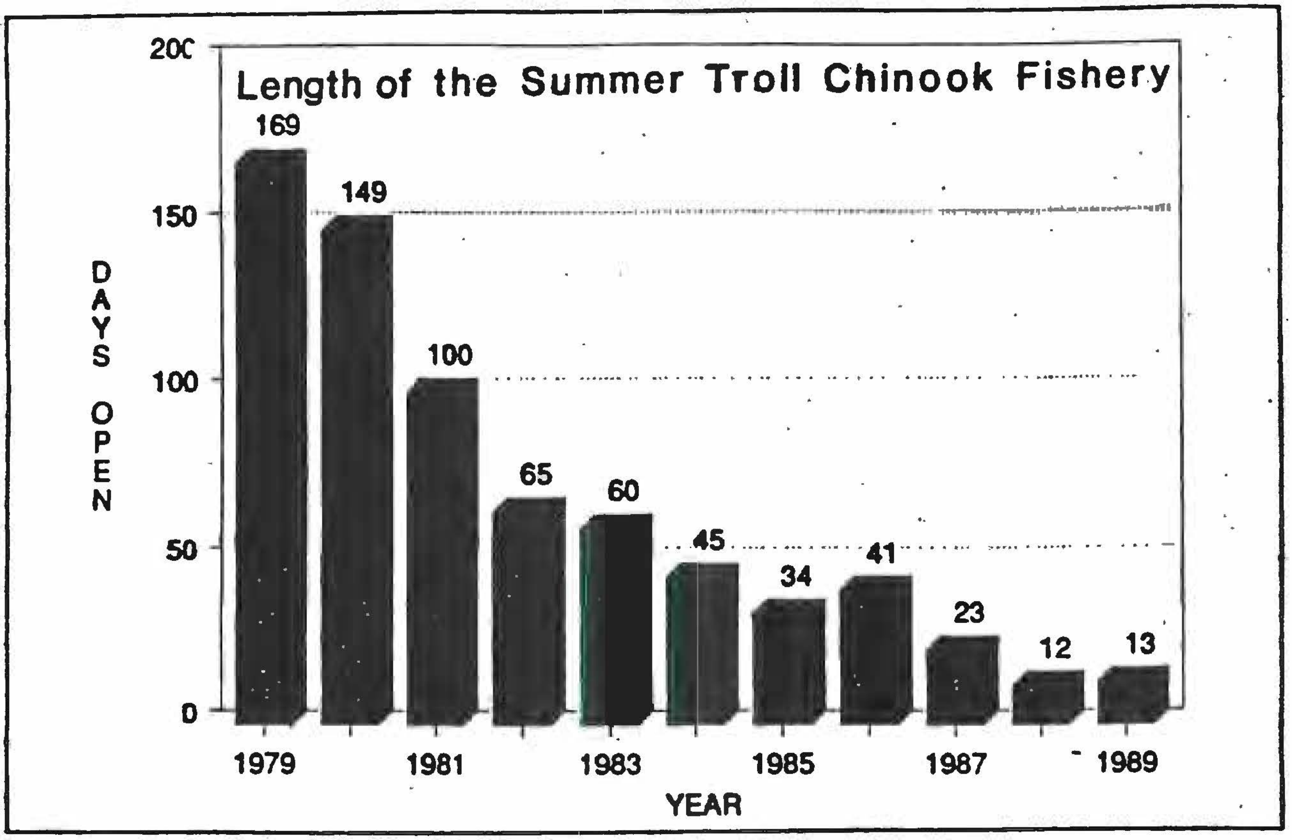


Figure 3. Length of the commercial summer troll fishery for chinook salmon in Southeast Alaska, 1978 through 1989. Source: ADF&G, Report to the Board of Fisheries, Regional Information Report 1J90-02.

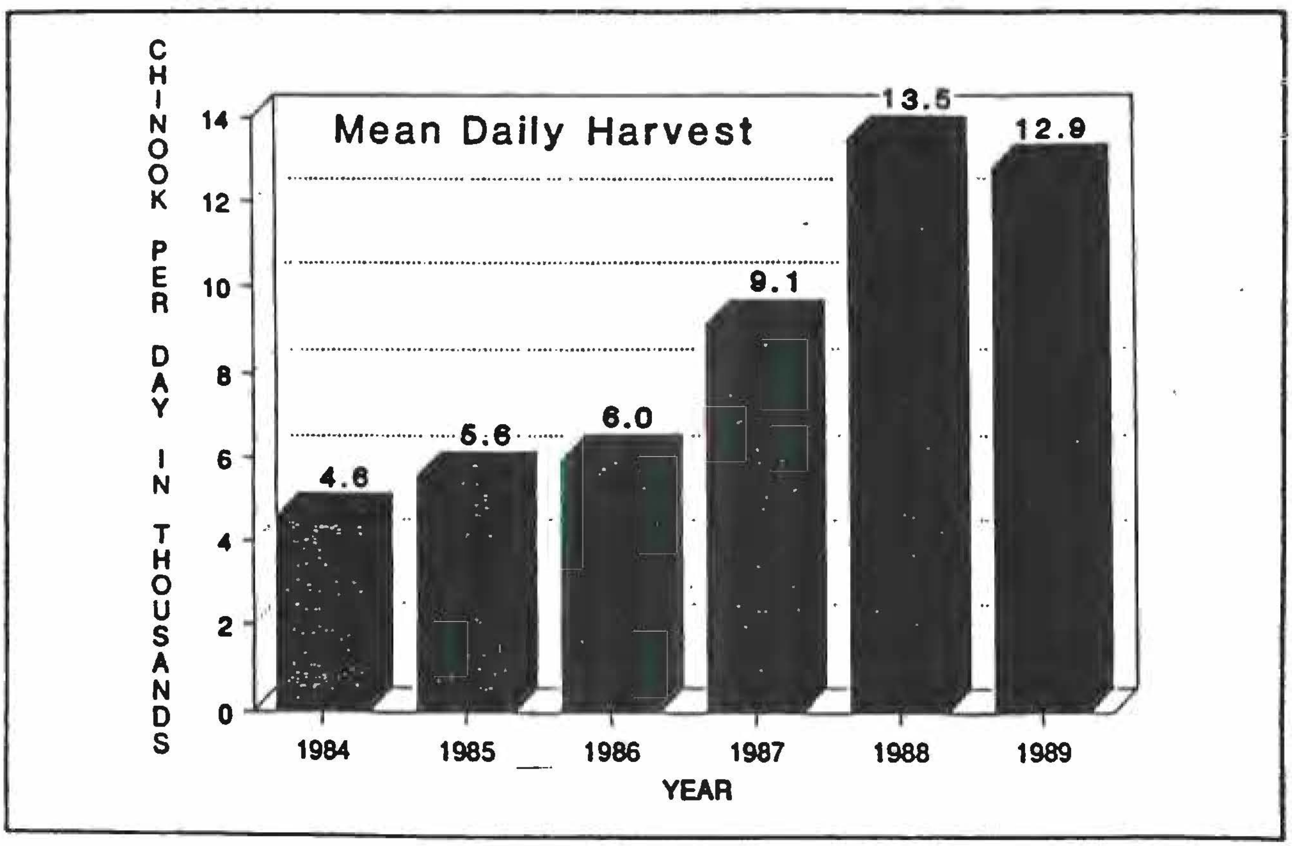


Figure 4. Mean daily harvest rate of chinook salmon by the Southeast Alaska commercial troll fishery during the summer season, 1984 through 1988. (Ibid.)

5.2 Role of the U. S. Department of Commerce, NOAA, and NMFS

The Magnuson Act assigns to the Secretary of Commerce (Secretary) the authority to approve fishery management plans and implement them with Federal regulations and to provide the regional fishery management councils with a number of services. The Secretary has delegated some of this fishery management authority and responsibilities to the National Oceanic and Atmospheric Administration (NOAA), a major agency within the Department of Commerce, and NOAA, in turn, has delegated some of its authority and responsibilities to the National Marine Fisheries Service (NMFS), an agency within NOAA. In its regular activities, the Council works with the Secretary, the Department of Commerce, and NOAA through the Alaska Region of NMFS.

The NMFS Alaska Regional Director has been delegated the authority to approve fishery management plans and amendments adopted by the Council. Following his approval, the RD will transmit the approved plan or amendment, draft implementing regulations, and other documents to NMFS Headquarters for further review and implementation, according to the Magnuson Act; NMFS, NOAA, and Commerce regulations; and the NMFS Operational Guidelines for the Fishery Management Plan Process.

In addition, this plan authorizes the Regional Director to issue Federal limited-entry commercial power-troll permits or transfer authority to fish commercially for salmon in the EEZ under certain specific conditions. See §8.3.1.3 of the Council's original plan for managing the salmon fisheries for discussions of the Council's findings as to limited entry into the commercial salmon fisheries (NPFMC 1978). The exact regulations, restrictions, procedures, and conditions of these Federal limited-entry permits are contained in 50 CFR 674.4.

Staff of the NMFS Alaska Region will assist the Council staff in performing analyses and drafting documents, will participate on the Council's salmon plan team, and will consult with the Alaska Department of Fish and Game on regulations and inseason adjustments of regulations for the salmon fisheries in the EEZ.

The NMFS Enforcement Division, Alaska Region, will help enforce the regulations that implement this plan, in cooperation with the United States Coast Guard and the Alaska Department of Public Safety.

The NOAA Office of General Counsel, Alaska Region, will provide legal advice and will prosecute violators of Federal regulations.

5.3 Role of the State of Alaska

Four agencies of Alaska are involved in managing the salmon fisheries under its jurisdiction. The Alaska Board of Fisheries sets policy and promulgates the regulations, the Alaska Department of Fish and Game manages the fisheries according to the policies and regulations of the Board and State law, the Alaska Commercial Fisheries Entry Commission controls the amount of fishing effort, and the Alaska Department of Public Safety enforces the regulations.

With regulation of the salmon fisheries in the EEZ being deferred to the State of Alaska, the State will manage those salmon fisheries to the extent participating vessels are registered under the laws of the State of Alaska (16 USC 1856(3).

5.3.1 The Alaska Board of Fisheries (Board)

The Council will rely on the Board of Fisheries to hold public hearings on proposed management measures, establish fishing seasons, and allocate harvests among groups of fishermen. The Council considers that the public review and comment process of the Alaska Board of Fisheries will satisfy most, if not all, of the Council's needs for public review, thereby making maximum use of limited State and Federal resources and preventing duplication of effort.

Each year, this Board solicits proposed changes to the regulations governing Alaska's fisheries. Usually, chief among those submitting proposals is the Alaska Department of Fish and Game. The Board distributes these proposals to the public for review and comment and then conducts open public meetings to evaluate and take action on the proposals. The fishing community has come to rely on this regularly scheduled participatory process as the basis for changing Alaska's fishing regulations.

Among those things considered by the Board are fishing periods and areas for the salmon fisheries, and the allocation of harvests among the various groups of fishermen.

The Board system provides for extensive public input, ensures necessary annual revisions, is flexible enough to accommodate changes in salmon abundance and fishing patterns, and is familiar to salmon fishermen, fish processors, and other members of the public.

5.3.2 The Alaska Department of Fish and Game (ADF&G)

The department manages the fisheries inseason and issues emergency regulations to achieve conservation objectives and to implement allocation policies established by the Alaska Board of Fisheries. The department also monitors the fisheries and collects data on the stocks and the performance of the fisheries.

The department managed salmon fisheries in Federal waters from the time of statehood in 1959 until 1979 when the Council's salmon plan was first implemented, and has made substantial investments over the years in facilities, communications, information systems, vessels, equipment, experienced personnel capable of carrying out extensive management, research, and enforcement programs. Since 1979, the State has played the major role in managing the salmon fisheries off Alaska, and the Council, for the most part, has coordinated its management with the State.

Under this plan, the Council defers the regulation of the salmon fisheries in the EEZ off the coast of Alaska to ADF&G, unless the Director of the NMFS Alaska Region, after consultation with the members of the Council, determines there is a need to issue specific Federal regulations for the salmon fisheries in the EEZ to achieve the objectives of this plan or be consistent with the Pacific Salmon Treaty or Magnuson Act. The State regulations apply to the extend that participating vessels are registered under the laws of the State of Alaska.

As a part of their normal duties, regional staff of the Department prepare annual reports on the status of the stocks and the fisheries for each of the management regions. The Department will provide the Council with copies of these reports which will then serve as major components of the Council's annual Stock Assessment and Fishery Evaluation Report.

5.3.3 <u>The Alaska Commercial Fisheries Entry Commission</u>

The Commercial Fisheries Entry Commission is an independent, quasi-judicial State agency responsible for promoting the conservation and sustained yield management of Alaska's fishery resources and the economic health and stability of commercial fishing by regulating entry into the fisheries. The Commission's activities fall into three categories: licensing, research, and adjudication. In 1974, the Commission began establishing the maximum number of power trollers that may participate in the commercial salmon fisheries in Southeast Alaska; in 1982, it began limiting hand trollers.

5.3.4 <u>The Alaska Department of Public Safety.</u>

The Fish and Wildlife Protection Division of the Alaska Department of Public Safety enforces the State regulations that waters. The overall revenues from the Alaskan salmon sport fishery, however, will probably increase slowly for some time into the future as the number of residents increase and tourist continue to come to Alaska to sport fish. The sport charter business in Alaska is still in its early years and will probably grow for some more years. Accordingly, the revenues from sport fishing will increase, and likely they will do so at the cost of decreased revenues to the commercial fisheries.

The ex-vessel value (prices paid to the fishermen) of the troll harvests (in the EEZ and State waters combined) from 1976 through 1985 are listed in Appendix D, Table 4. The total ex-vessel value of the Alaska troll salmon harvest averaged $19,838 thousand from 1976 through 1985, with a peak of $26,570 thousand in 1984.

If the fishery remains under the present limited-entry system, the Pacific Salmon Commission continues to set limits on the harvest of chinook, the Alaska Board of Fisheries continues its present policies on allocations, and the stocks of salmon produce average numbers of salmon, then it is unlikely that the future harvests by the Alaska troll fishery will vary much from the recent average in terms of number or pounds of salmon.

The ex-vessel price determines what revenues are earned from the sale of those salmon. The price of troll-caught salmon varies considerably from year to year (Appendix D, Table 5). The prices for troll-caught chinook and coho salmon landed in Alaska depend to a large extent on the amount of troll-caught chinook and coho landed elsewhere, the overall harvests of chinook and coho and other species of salmon (particularly sockeye), the supply of salmon in cold storage, and the supply of fresh Pacific and Atlantic salmon from domestic and foreign fish farms. Many fishermen and others perceive pen-farmed salmon as a major threat to the price and demand for Alaska troll-caught chinook and coho salmon.

The troll harvest of chinook salmon is expected to increase somewhat as the depressed chinook salmon runs are rebuilt under provisions of the Pacific Salmon Treaty. That increased harvest will result in increased revenues to the troll fleet. The greatest potential for some increase in harvests and revenues, however, is from the expected increased production of chinook salmon from Alaska's salmon hatcheries.

Eventually, however, the Alaska Board of Fisheries might decrease its allocations of salmon to the troll fleet as the sport fishery grows and becomes more important; if so, the harvests by and revenues to the troll fleet will decrease.

not really relevant

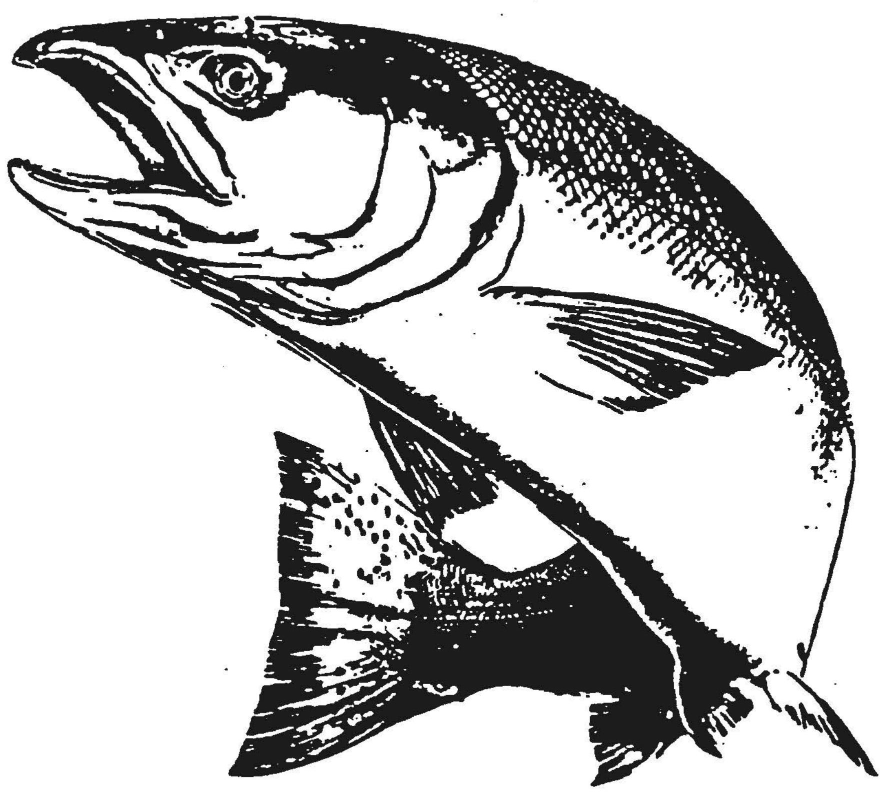
FISHERY MANAGEMENT PLAN

For The

SALMON FISHERIES

In The

EEZ Off The Coast Of ALASKA



Rosa's Shop.

APRIL 1990

NORTH PACIFIC FISHERY MANAGEMENT COUNCIL

200 mile economic fish zone

2.0 DESCRIPTION OF THE FISHERY MANAGEMENT UNIT

2.1 Areas

The Fishery Management Unit consists of all of the EEZ off the coast of Alaska and the salmon and fisheries that occur there.

The area covered by this fishery management plan is the EEZ off the coast of Alaska (See Figure 1), including parts of the Gulf of Alaska, Bering Sea, Chukchi Sea, and Arctic Ocean. Two management areas are established within the fishery management unit, with the border between the two at the longitude of Cape Suckling (143°53'36" W).

As long as the International Convention for the High Seas Fisheries of the North Pacific Ocean remains in effect (or it is replaced by an equivalent convention), the Council leaves the management of the salmon fisheries west of 175° east longitude under the control of the International North Pacific Fisheries Commission (or equivalent organization). Otherwise, this plan will govern the salmon fisheries in the EEZ west of 175° east longitude as an integral part of the West Area.

The West Area is the area of the EEZ off the coast of Alaska west of the longitude of Cape Suckling (143°53'36" W.). It includes the EEZ in the Bering, Chukchi, and Beaufort Seas, as well as well as the EEZ in the North Pacific Ocean west of Cape Suckling.

The East Area is the area of the EEZ off the coast of Alaska east of the longitude of Cape Suckling.

2.2 Fisheries

Except as provided by other Federal law (see Appendix C), this plan allows commercial salmon fishing only in the East Area. It allows sport (or recreational) salmon fishing in the West and East areas. Specific regulations are promulgated by the Alaska Department of Fish and Game.

2.2.1 The Sport (or Recreational) Salmon Fishery.

The sport fishery for salmon in marine waters off Alaska takes place almost entirely within State waters (there is little reason for sport fishermen to fish for salmon seaward of State waters). The little sport fishing that does occur in the EEZ (primarily the charter boat fishery) takes place to a minor extent in both areas, but the sport harvest of salmon from the

EEZ is probably less than several hundred salmon for both areas combined.

2.2.2. The Commercial Salmon Fishery in the West Area.

In the West Area, the only commercial salmon fishery is the incidental fishery allowed under 50 CFR 210 (see Appendix C). Federal regulations implementing the North Pacific Fisheries Act (16 U.S.C. 1021, et seq.), prohibit U.S. fishermen from fishing for or taking salmon with nets in the North Pacific outside Alaskan waters except for three historical fisheries managed by the State; these are the (a) False Pass (South Peninsula), (b) Cook Inlet, and (c) Copper River net fisheries. These fisheries technically extend into the EEZ, but they are conducted and managed by the State of Alaska as nearshore fisheries. Thus, aside from those traditional fisheries, this plan prohibits commercial salmon fishing in the EEZ west of the longitude of Cape Suckling.

2.2.3 The Commercial Troll Salmon Fishery in the East Area.

Within the East Area, the troll fishery (hand-troll and power-troll) is the only commercial salmon fishery allowed. From Alaska statehood in 1959 until 1979, this fishery was conducted and managed with little recognition of the boundary separating Federal from State waters, although at one time the State banned hand trolling seaward of the surf line. Upon implementation of the Council's plan in 1979, the fishery in the Federal EEZ came under Federal regulations even though the trollers continued to fish in State and Federal waters as if the troll fishery were a unit.

Entry into the troll fishery is limited by the Alaska Commercial Fisheries Entry Commission and the North Pacific Fishery Management Council. At the present time, only two trollers have Federal limited-entry permits; the rest have Alaska limited entry permits (Tables 1 and 2). The Council's original plan contains descriptions of the Alaska and Federal limited entry systems (NPFMC, 1978). The appendix tables contain information on the number of permits issued to residents and nonresidents of Alaska and average prices for permits.

Commercial trolling in the East Area takes place in two seasons. A winter troll fishery (15 October through 14 April) takes place in internal waters of Southeast Alaska lying east of the ocean surfline and in Yakutat Bay; all outer coastal areas and the EEZ are closed during the winter fishery. The summer troll fishery now takes place from June through 20 September in three parts: (1) a June fishery in small defined areas within Alaska's internal waters, (2) a fishery adjacent to certain

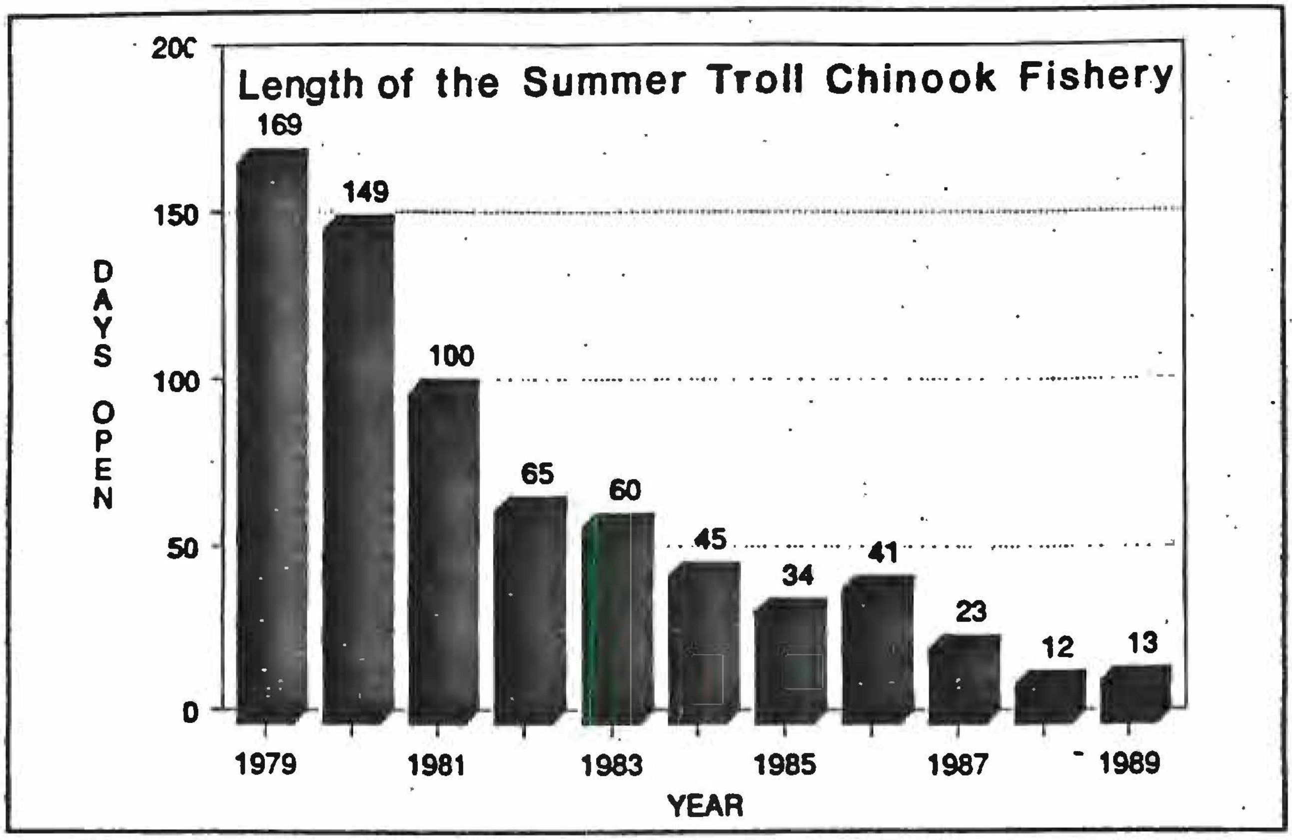


Figure 3. Length of the commercial summer troll fishery for chinook salmon in Southeast Alaska, 1978 through 1989. Source: ADF&G, Report to the Board of Fisheries, Regional Information Report 1J90-02.

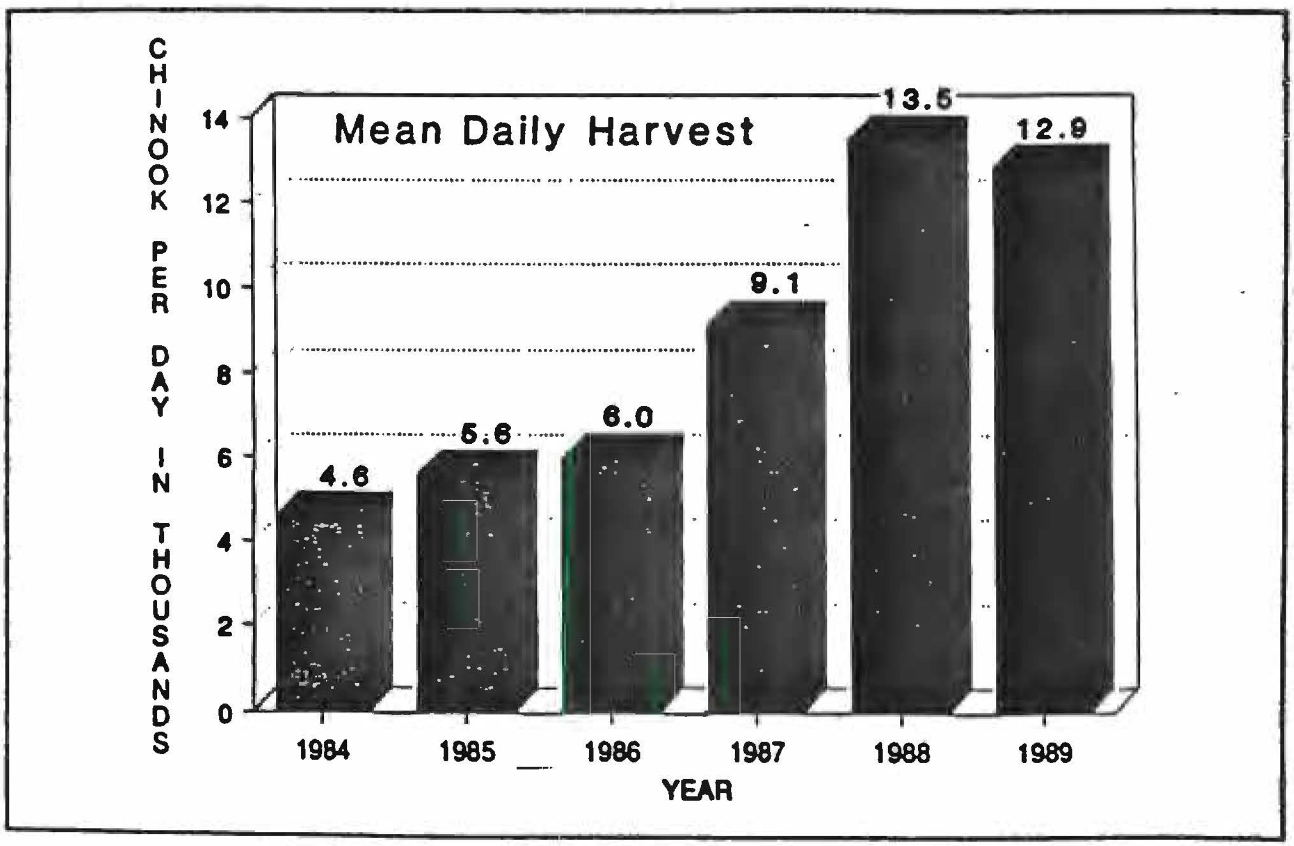


Figure 4. Mean daily harvest rate of chinook salmon by the Southeast Alaska commercial troll fishery during the summer season, 1984 through 1988. (Ibid.)

5.2 Role of the U. S. Department of Commerce, NOAA, and NMFS

The Magnuson Act assigns to the Secretary of Commerce (Secretary) the authority to approve fishery management plans and implement them with Federal regulations and to provide the regional fishery management councils with a number of services. The Secretary has delegated some of this fishery management authority and responsibilities to the National Oceanic and Atmospheric Administration (NOAA), a major agency within the Department of Commerce, and NOAA, in turn, has delegated some of its authority and responsibilities to the National Marine Fisheries Service (NMFS), an agency within NOAA. In its regular activities, the Council works with the Secretary, the Department of Commerce, and NOAA through the Alaska Region of NMFS.

The NMFS Alaska Regional Director has been delegated the authority to approve fishery management plans and amendments adopted by the Council. Following his approval, the RD will transmit the approved plan or amendment, draft implementing regulations, and other documents to NMFS Headquarters for further review and implementation, according to the Magnuson Act; NMFS, NOAA, and Commerce regulations; and the NMFS Operational Guidelines for the Fishery Management Plan Process.

In addition, this plan authorizes the Regional Director to issue Federal limited-entry commercial power-troll permits or transfer authority to fish commercially for salmon in the EEZ under certain specific conditions. See §8.3.1.3 of the Council's original plan for managing the salmon fisheries for discussions of the Council's findings as to limited entry into the commercial salmon fisheries (NPFMC 1978). The exact regulations, restrictions, procedures, and conditions of these Federal limited-entry permits are contained in 50 CFR 674.4.

Staff of the NMFS Alaska Region will assist the Council staff in performing analyses and drafting documents, will participate on the Council's salmon plan team, and will consult with the Alaska Department of Fish and Game on regulations and inseason adjustments of regulations for the salmon fisheries in the EEZ.

The NMFS Enforcement Division, Alaska Region, will help enforce the regulations that implement this plan, in cooperation with the United States Coast Guard and the Alaska Department of Public Safety.

The NOAA Office of General Counsel, Alaska Region, will provide legal advice and will prosecute violators of Federal regulations.

5.3 Role of the State of Alaska

Four agencies of Alaska are involved in managing the salmon fisheries under its jurisdiction. The Alaska Board of Fisheries sets policy and promulgates the regulations, the Alaska Department of Fish and Game manages the fisheries according to the policies and regulations of the Board and State law, the Alaska Commercial Fisheries Entry Commission controls the amount of fishing effort, and the Alaska Department of Public Safety enforces the regulations.

With regulation of the salmon fisheries in the EEZ being deferred to the State of Alaska, the State will manage those salmon fisheries to the extent participating vessels are registered under the laws of the State of Alaska (16 USC 1856(3).

5.3.1 The Alaska Board of Fisheries (Board)

The Council will rely on the Board of Fisheries to hold public hearings on proposed management measures, establish fishing seasons, and allocate harvests among groups of fishermen. The Council considers that the public review and comment process of the Alaska Board of Fisheries will satisfy most, if not all, of the Council's needs for public review, thereby making maximum use of limited State and Federal resources and preventing duplication of effort.

Each year, this Board solicits proposed changes to the regulations governing Alaska's fisheries. Usually, chief among those submitting proposals is the Alaska Department of Fish and Game. The Board distributes these proposals to the public for review and comment and then conducts open public meetings to evaluate and take action on the proposals. The fishing community has come to rely on this regularly scheduled participatory process as the basis for changing Alaska's fishing regulations.

Among those things considered by the Board are fishing periods and areas for the salmon fisheries, and the allocation of harvests among the various groups of fishermen.

The Board system provides for extensive public input, ensures necessary annual revisions, is flexible enough to accommodate changes in salmon abundance and fishing patterns, and is familiar to salmon fishermen, fish processors, and other members of the public.

5.3.2 The Alaska Department of Fish and Game (ADF&G)

The department manages the fisheries inseason and issues emergency regulations to achieve conservation objectives and to implement allocation policies established by the Alaska Board of Fisheries. The department also monitors the fisheries and collects data on the stocks and the performance of the fisheries.

The department managed salmon fisheries in Federal waters from the time of statehood in 1959 until 1979 when the Council's salmon plan was first implemented, and has made substantial investments over the years in facilities, communications, information systems, vessels, equipment, experienced personnel capable of carrying out extensive management, research, and enforcement programs. Since 1979, the State has played the major role in managing the salmon fisheries off Alaska, and the Council, for the most part, has coordinated its management with the State.

Under this plan, the Council defers the regulation of the salmon fisheries in the EEZ off the coast of Alaska to ADF&G, unless the Director of the NMFS Alaska Region, after consultation with the members of the Council, determines there is a need to issue specific Federal regulations for the salmon fisheries in the EEZ to achieve the objectives of this plan or be consistent with the Pacific Salmon Treaty or Magnuson Act. The State regulations apply to the extend that participating vessels are registered under the laws of the State of Alaska.

As a part of their normal duties, regional staff of the Department prepare annual reports on the status of the stocks and the fisheries for each of the management regions. The Department will provide the Council with copies of these reports which will then serve as major components of the Council's annual Stock Assessment and Fishery Evaluation Report.

5.3.3 The Alaska Commercial Fisheries Entry Commission

The Commercial Fisheries Entry Commission is an independent, quasi-judicial State agency responsible for promoting the conservation and sustained yield management of Alaska's fishery resources and the economic health and stability of commercial fishing by regulating entry into the fisheries. The Commission's activities fall into three categories: licensing, research, and adjudication. In 1974, the Commission began establishing the maximum number of power trollers that may participate in the commercial salmon fisheries in Southeast Alaska; in 1982, it began limiting hand trollers.

5.3.4 The Alaska Department of Public Safety.

The Fish and Wildlife Protection Division of the Alaska Department of Public Safety enforces the State regulations that waters. The overall revenues from the Alaskan salmon sport fishery, however, will probably increase slowly for some time into the future as the number of residents increase and tourist continue to come to Alaska to sport fish. The sport charter business in Alaska is still in its early years and will probably grow for some more years. Accordingly, the revenues from sport fishing will increase, and likely they will do so at the cost of decreased revenues to the commercial fisheries.

The ex-vessel value (prices paid to the fishermen) of the troll harvests (in the EEZ and State waters combined) from 1976 through 1985 are listed in Appendix D, Table 4. The total ex-vessel value of the Alaska troll salmon harvest averaged $19,838 thousand from 1976 through 1985, with a peak of $26,570 thousand in 1984.

If the fishery remains under the present limited-entry system, the Pacific Salmon Commission continues to set limits on the harvest of chinook, the Alaska Board of Fisheries continues its present policies on allocations, and the stocks of salmon produce average numbers of salmon, then it is unlikely that the future harvests by the Alaska troll fishery will vary much from the recent average in terms of number or pounds of salmon.

The ex-vessel price determines what revenues are earned from the sale of those salmon. The price of troll-caught salmon varies considerably from year to year (Appendix D, Table 5). The prices for troll-caught chinook and coho salmon landed in Alaska depend to a large extent on the amount of troll-caught chinook and coho landed elsewhere, the overall harvests of chinook and coho and other species of salmon (particularly sockeye), the supply of salmon in cold storage, and the supply of fresh Pacific and Atlantic salmon from domestic and foreign fish farms. Many fishermen and others perceive pen-farmed salmon as a major threat to the price and demand for Alaska troll-caught chinook and coho salmon.

The troll harvest of chinook salmon is expected to increase somewhat as the depressed chinook salmon runs are rebuilt under provisions of the Pacific Salmon Treaty. That increased harvest will result in increased revenues to the troll fleet. The greatest potential for some increase in harvests and revenues, however, is from the expected increased production of chinook salmon from Alaska's salmon hatcheries.

Eventually, however, the Alaska Board of Fisheries might decrease its allocations of salmon to the troll fleet as the sport fishery grows and becomes more important; if so, the harvests by and revenues to the troll fleet will decrease.

ALASKA'S SALMON FISHERIES

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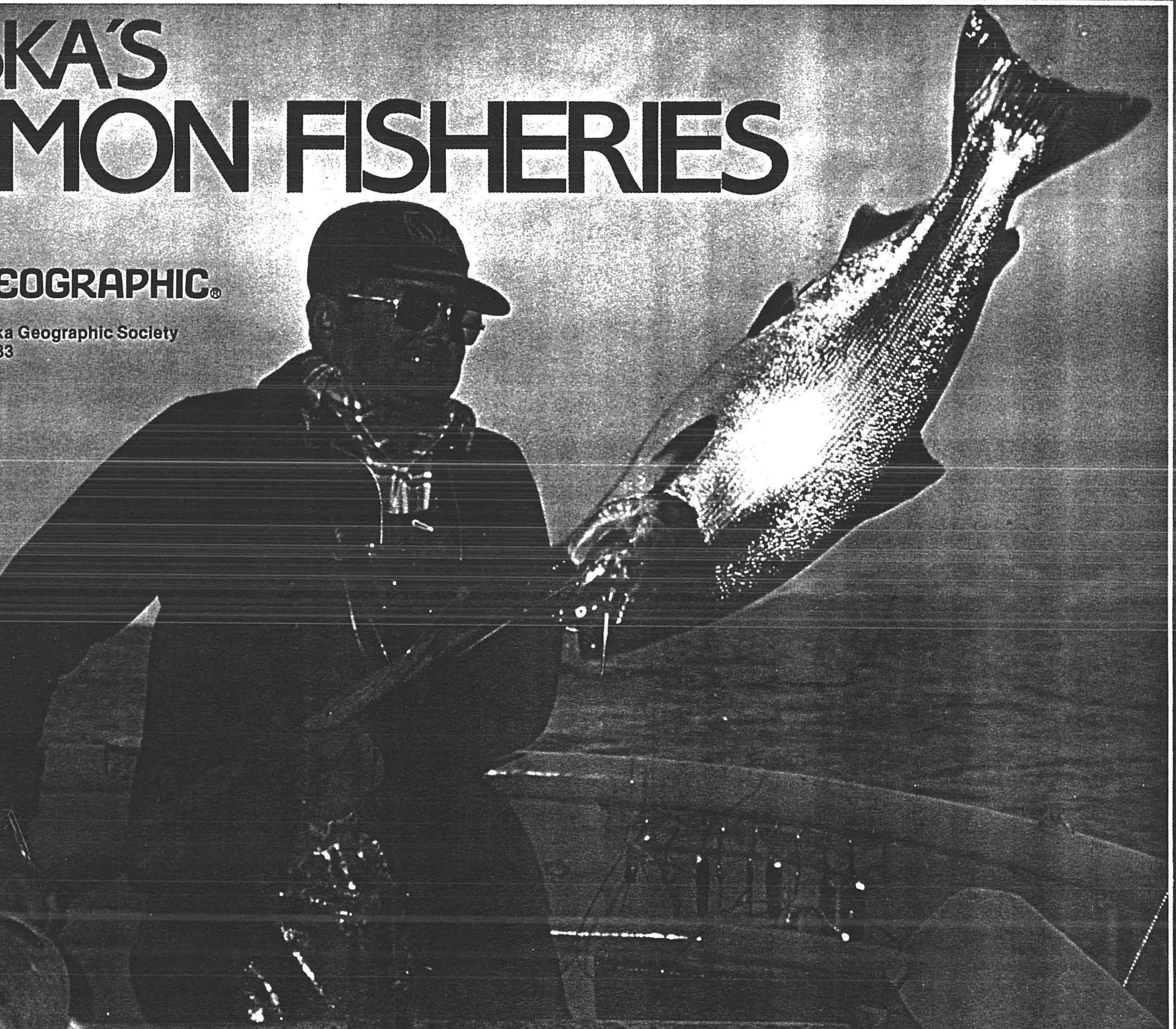
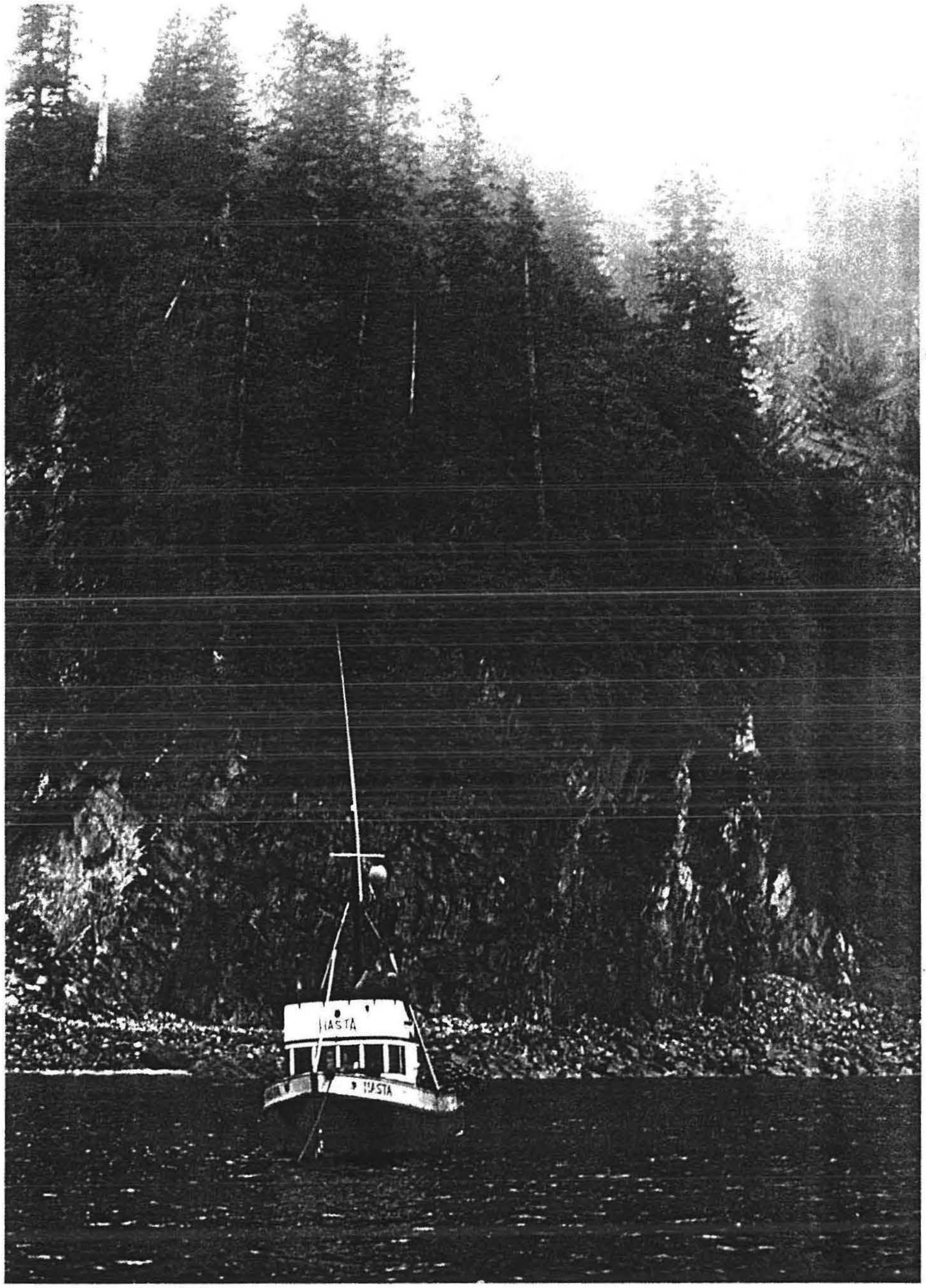


Prince William Sound

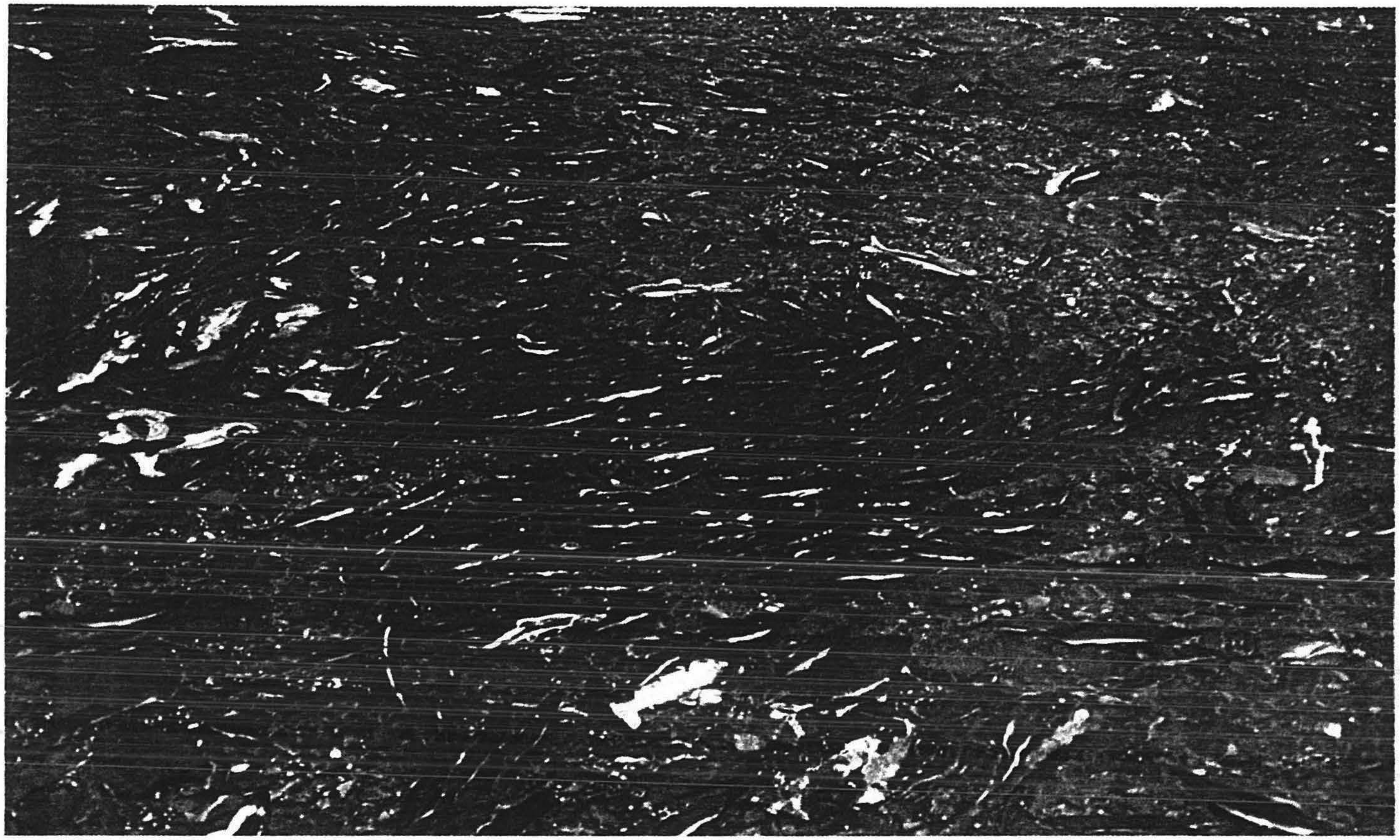
Prince William Sound is fished by purse seines, drift gill nets and set gill nets. As in all other areas of the state salmon fishermen of Prince William Sound have become increasingly more efficient in recent years. High investment in vessels, gear, and entry permits have created an incentive to use each boat and each net as effectively as possible. The fishing vessels are faster and can carry more fish and synthetic fiber nets are stronger and far more efficient than those of earlier decades.

During the 10 years 1973-82 Prince William Sound fishermen caught an annual average of 10.5 million salmon of five species, or 15.7% of the state's total salmon catch. Most of these salmon (83.5%) were pink salmon (an annual average of 8.8 million, 1973-82) for, like Southeastern Alaska, Prince William Sound is pink salmon country. In recent years (1973-82) Prince William Sound produced 23.3% of the pink salmon caught in Alaska.

Next numerous are sockeye salmon, with an annual average of 796,800 caught during the years 1973-82, 4.2% of the statewide sockeye catch. Also, during these years, an annual average of 643,190 chum salmon (8.8% of the statewide catch in recent years), 270,360 coho salmon (10.3% of the statewide catch), and 25,140 chinook



A small Prince William Sound seiner at anchor, awaiting a tide and time to go fishing. *(Jim Rearden, staff)*



Chum and pink salmon in fresh water, as they approach spawning, near Valdez. Dead, spawned-out fish lay on the bottom. The schooled fish have yet to break up into pairs. When paired and actively spawning, salmon scatter out. *(Tom Walker)*

salmon (3.7% of the statewide catch) were caught in Prince William Sound.

Prince William Sound proper is administratively divided into nine major fishery districts, six for the management of the purse seine fishery for pink and chum salmon, and three smaller districts for the management of sockeye salmon runs which are caught by set gill nets, drift gill nets, and purse seines.

In addition, the Copper River and Bering River districts are included in the Prince William Sound management area; both are restricted to drift gill-net fishing, mainly for sockeye and coho salmon.

Purse seiners, which catch most of the fish in the sound, fish all Prince William Sound districts, except Eshamy, usually beginning in early or mid-July (late July in some years), depending upon the strength of early pink salmon runs, and usually fish into the first or second week of August.

Mountain-surrounded, island-dotted, sheltered Prince William Sound is roughly 60 miles north and south, and 125 miles east and west at the northernmost point in the Gulf of Alaska. The sound is a huge bay containing many coves, bays, harbors, sheltered fjords, narrows and straits, lagoons and islands. Islands range down from 50-mile-long Montague, which lies between the violent Gulf of Alaska and the sound. The Copper River basin, which contributes most of the sockeye and chinook salmon to the Prince

William Sound catch, has long cold winters, and short hot summers. The great valley from which this turbulent giant flows has many clear streams and lakes which are ideal for spawning red and chinook salmon, where fry can grow and feed for the year or three they spend in fresh water, after which they descend the swift stream to the sea.

This is a region of great tectonic activity, with frequent severe earthquakes. One of the world's strongest recorded earthquakes occurred here on March 27, 1964, with shock waves over a 500-mile-wide area. It registered between 8.4 and 8.6 on the Richter scale with the primary epicenter in northern Prince William Sound. A vertical shift ranging from 32 feet of uplift to 6 feet of subsidence occurred in various pink and chum salmon streams of Prince William Sound, with a profound effect on salmon runs to those streams: the pink salmon catch for the sound decreased sharply immediately following the great earthquake.

The most pronounced effect of this uplift and subsidence was in the intertidal area where 35% to 77% of pink salmon spawning had occurred. Stream banks and beds became unstable and surface flows dropped or disappeared in the uplifted intertidal area. Channels were exposed to salt water and increased sedimentation in areas of subsidence. It seems that somehow nature can compensate for even great disasters: decreased numbers of spawning salmon occurred in streams where changes were observed, and increased spawning occurred on unchanged streams.

Between 1967 and 1971 the Alaska Department of Fish and Game attempted to improve Prince William Sound salmon spawning areas damaged by the great earthquake, using state and available federal money. The goal was to stabilize pink and chum salmon streams that had been uplifted or had subsided. Mechanical renovation of such streams included: 1. emplacement of drop structures, 2. channel extension, 3. bank stabilization, 4. channel excavation, and 5. construction of water deflectors on nine high value streams.

The work had to be done between the times when immature salmon left the stream and when spawning adults returned — from about early April until July. The ADF&G vessel *Shad* with a 24' x 60' barge, a tractor, a loader-backhoe, and a crew with hand tools performed the work.

In addition to mechanically improving streams, pink salmon spawners were also fenced into streams. Incubation boxes were used in an attempt to renew lost pink, chum, and sockeye salmon stocks, using eggs from streams with surviving stocks. Adult sockeye spawners were transplanted to Solf Lake from Eshamy Lake.

After several years of field work there was no evidence that the production of pink salmon was increasing, so mechanical renovation was stopped in 1972, and only limited restocking work continued.

Incubation boxes in a few locations produced good survival of pink salmon eggs, while several others failed, due primarily to inadequate water supply.

The natural evolution of streams eased the problem, and the bulldozing and other work speeded the process. Within about a decade of the big earthquake spawning areas had returned to near-normal, and the salmon fishery of Prince William Sound has essentially recovered from what, at the time, appeared to be severe damage.

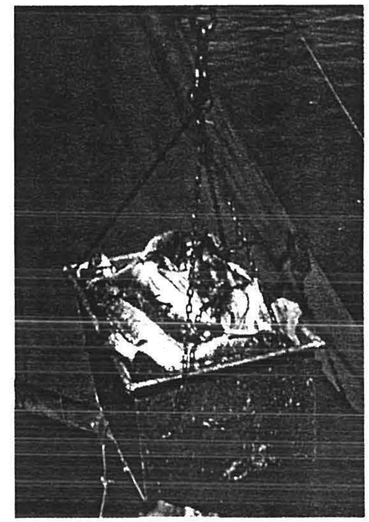
Volcanism shaped many of the peaks that surround the sound, and scientists keep a wary eye on many of these apparently dormant mountains. Glaciers provide source water for many of the mainland streams, including the great Copper River, one of Alaska's largest.

High peaks of the Chugach Mountains on the east and north, and the great Kenai Mountains on the west, form three walls around Prince William Sound. Moisture-laden air from the Gulf of Alaska dumps vast amounts of rain and snow on the steep and high mainland mountains to create a typical wet and windy maritime climate, with abundant snow and rain, varying between different parts of the sound. During fall and winter winds of the gulf commonly blow from 30-50 MPH, occasionally reaching 100 MPH.

Cordova's average annual temperature is about 38° F, with precipitation of about 92 inches: Valdez, farther from the sea, is cooler, averaging 36° F, with 59 inches of precipitation. For real precipitation, there is Whittier, at the base of the high weather-blocking

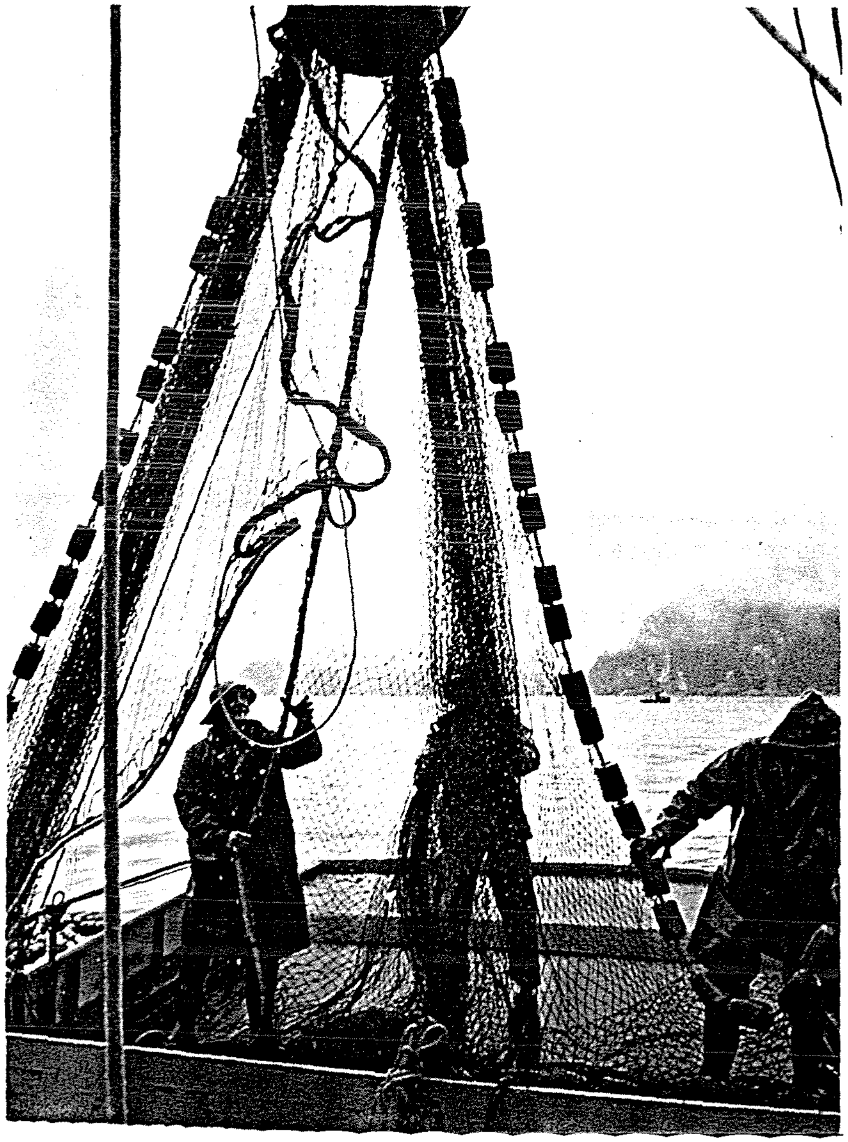
Opposite — ***Sheep Bay, Prince William Sound, with an anchored fishing boat.*** *(Jim Rearden, staff)*

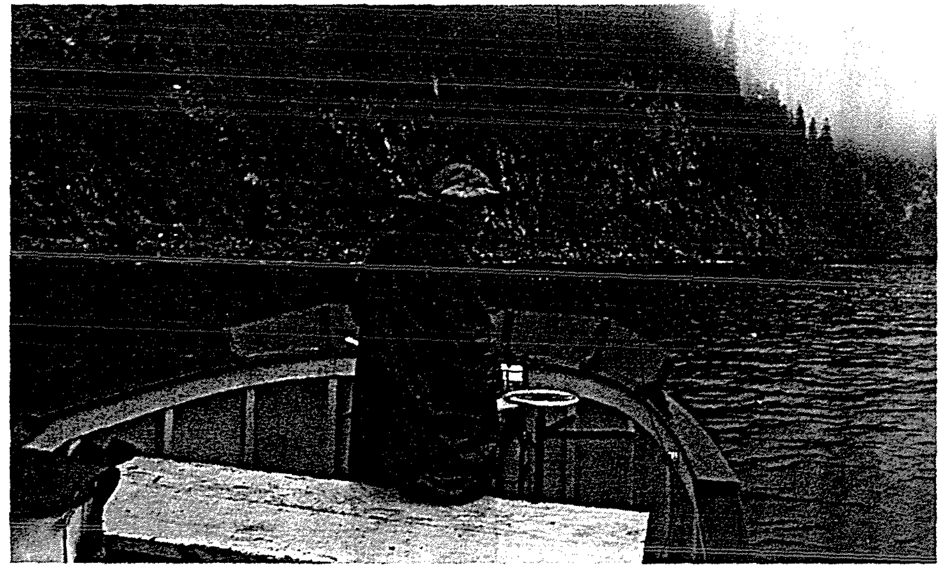
Below — ***A box of fresh-caught coho salmon is lifted from a salmon boat.*** *(Matt Donohoe)*



*Below — **Crewmen pile the purse seiner of the** Invader **during a set in Prince William Sound. Net is being pulled aboard by the hydraulically powered block at the top of this photo.** (Jim Rearden, staff)*

*Right — **Harry Hamilton, skipper of the seiner** Invader**, at Point Elrington, Prince William Sound, waiting his turn at the lead.** (Jim Rearden, staff)*





Chugach Range, with an average of 175 inches annually. These are the three major ports in Prince William Sound.

The pink salmon fishery of the sound has produced more than 1 billion pounds since 1896. Peak year for pinks in Prince William Sound was 1982 when about 20.3 million of the spotted, rich-fleshed swimmers were caught as they returned to their home spawning streams.

An abrupt increase in catch of Prince William Sound pink salmon, from an average of about 3 million, occurred in 1979 when 15.6 million were caught: each year since has seen catches above any previous year's back to 1910. The 1980 catch was 14.2 million, in 1981 it was 20.5 million, and the 1982 catch was 20.3 million. Since 1910, the pink catch of the sound has exceeded 10 million only eight times: four of those have been since 1979.

The abundant short streams and the high rainfall of Prince William Sound closely resemble those of Southeastern Alaska, and, as in Southeastern, pinks bound for widely distributed streams arrive at capes and passes and points in large schools as they reenter the sound. Fishermen meet them, and large numbers of the schooled fish are taken at these well-known concentration points or "cape fisheries."

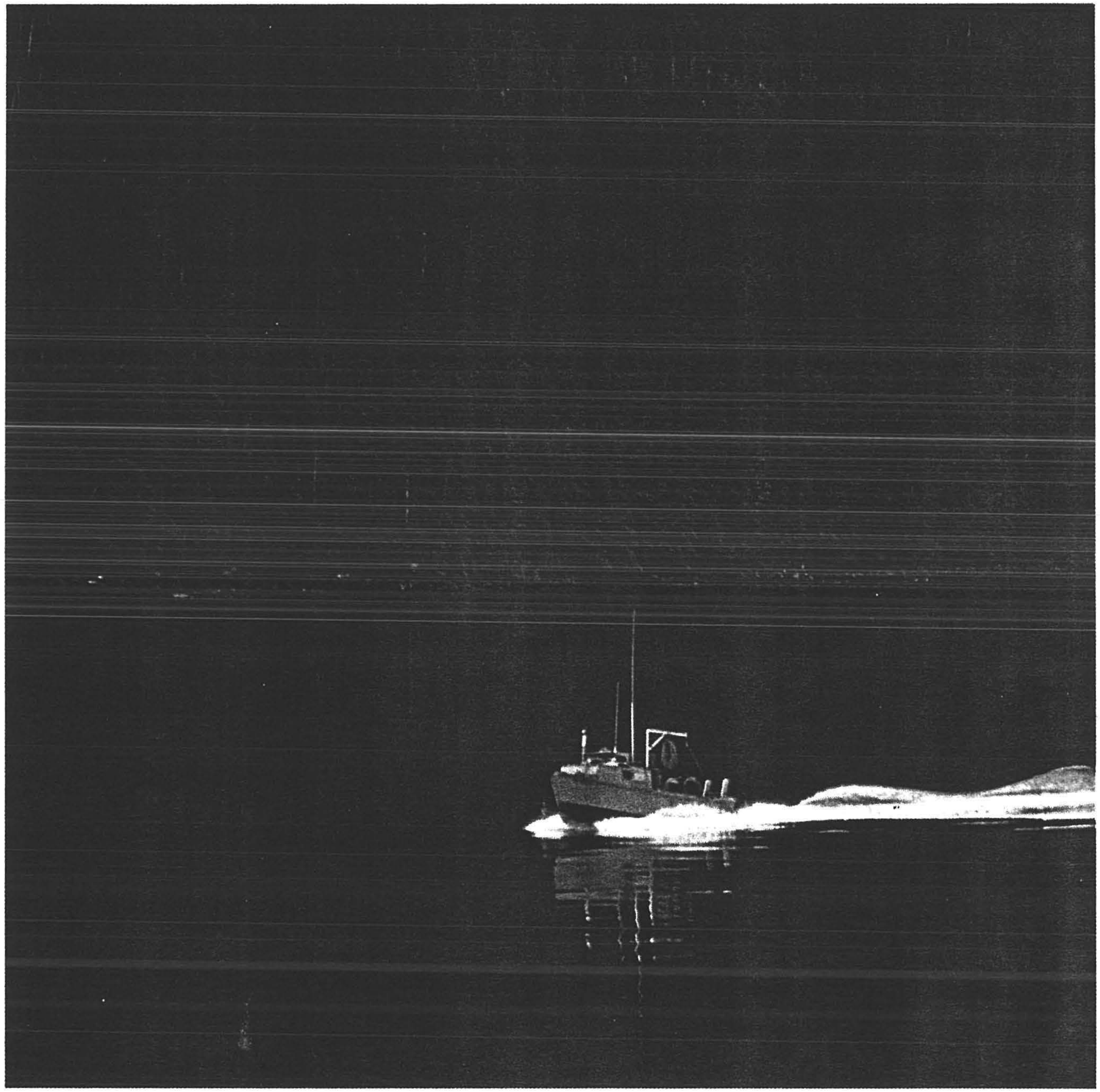
Sockeye salmon. The average catch of sockeye salmon from Prince William Sound (including the Copper and Bering rivers) averaged 796,800 annually during the 10 years 1973-82. Most of these fish were caught in the Copper River fishery.

The Copper River District opens for the fishing of sockeye salmon in mid-May, the earliest salmon fishery in Prince William Sound, and one of the earliest in the state. The Copper River fishery averages a catch of about 625,000 sockeye salmon annually. The 1982 catch of 1.2 million was the highest recorded in recent years.

The dry catch statistics don't show it, but the Copper River drift gill-net fishery is probably the most dangerous salmon fishery in Alaska. Fishing takes place off the mouth of the great, muddy, rapids-filled Copper River, which flows for 250 miles from the north side of the Wrangell Mountains through the Chugach Range into the Gulf of Alaska east of Prince William Sound.

Upon their return as approximately 7-pound ruby-fleshed, silver-sided, fat, vigorous adults, eager fishermen, with 24- to 30-foot mostly fiberglass bow-pickers (the net is layed and retrieved from the bow), with inboard-outboard power, brave the surging seas just outside the breakers where they lay out their 150 fathoms of drift gill net to catch these prime fish. During the 1950s through the 1970s Copper River flats fishermen used beamy, shallow-drift, rugged, outboard-powered "Cordova skiffs," with a tiny forward cabin and a gill net roller astern. Sudden storms and cranky slow-starting engines that allowed boats to drift into the violent surf both claimed many lives over the years in this rich fishery.

The Bering River District, adja-



A drift gill-netter speeds across Prince William Sound. *(Frank Bird)* cent to the Copper River, is a drift fishery mostly for coho and sockeye salmon: fishing starts in mid-June and may continue as late as mid-September. Coho salmon is the major species in the Bering River District, with average catches of around 60,000 annually.

The earliest salmon fishery in the sound proper is that of the Coghill-Unakwik district, which starts in late June and normally ends about mid-July for drift gill nets. Purse seine fishing in these districts coincide with drift gill-net fishing, but lasts beyond the mid-July gill net closing date in order to harvest later runs of pink and chum salmon.

A surprise run of sockeye hit the Coghill district in 1982. The 10-year average catch prior to 1982 was 108,000; but the 1982 catch was 942,000 sockeye, averaging 6.5 pounds. Further, at the Coghill weir 180,000 sockeye were counted into spawning areas: goal for that area was 50,000 to 60,000. For every parent spawner, about 40 fish returned in 1982, an almost unheard-of survival rate.

The Eshamy district, where there is a late red salmon run, usually begins in early July and extends into September. Purse seines fishing in the Southwestern district in July and August catch about 30% of the Eshamy reds before they reach the gill-net fishery.

Chum salmon, like the pink salmon, thrive in the short stream environment of Prince William Sound proper. Over the years chum catches have been less prone to great variations in run size: it is a relatively stable fishery. In the early 1970s the maximum sustained yield (MSY) for the chum fishery for the sound was estimated to be about 605,000 fish annually, based upon the catches of the years 1924-48.

The average catch of chums for the years 1973-82 was 643,190 — reasonably close to the estimated MSY.

Coho salmon are caught in Prince William Sound proper mostly incidentally to pink and chum salmon in the purse seine fishery. The Copper and Bering rivers gill-net fisheries produce far more cohos. The cohos are incidental to the sockeye during the early season, but later the catch is almost all cohos. The estimated maximum sustained yield for the Copper-Bering coho fishery is about 207,000 fish annually.

The total coho catch for Prince William Sound, including that of the Copper-Bering rivers, averaged 270,360 fish annually from 1973-82, with catches that ranged from 76,000 to 615,000 — the latter a record breaker in 1982.

King Salmon of Prince William Sound are mostly caught incidentally to the sockeye in the Copper River fishery. During the 10 years 1973-82 the annual average catch (for all Prince William Sound, including the Copper and Bering rivers) was 25,140 kings. The 1982 catch of kings, following the trend of other species for the sound, was also a record breaker, with 49,200 fish netted. The previous high catch of kings was 32,800 caught in 1976.

Pink salmon piled in the hold of a cannery tender bound for the cannery, Prince William Sound. *(Jim Rearden, staff)* ment managed the Cook Inlet (and all of Alaska's) fishery was 1959. In that year inlet fishermen caught the fewest salmon taken since the earliest days of the fishery — only 1.3 million, about one-third the average of the previous five years' annual catch.

It was now the state's job to rebuild the salmon fishery.

Cook Inlet — How It Is Today

Cook Inlet is a tapered bay that extends north and east for about 220 miles from the northern Gulf of Alaska. During the 10 years 1973-82, Cook Inlet's commercial salmon fishermen caught an annual average of 4.6 million salmon, or about 6 % of the statewide catch.

Cook Inlet's waters, in common with the other great gill-net fishing districts of Alaska, are silty. Most major streams that pour into the inlet carry silt, much of it from glaciers. The biggest include the great Susitna River, at the head of the inlet, the nearby Little Susitna and Matanuska rivers, and, about halfway down the inlet on the east side, the Kenai and Kasilof rivers.

The northern 190 miles of the inlet are perpetually murky, and the line between clear and murky water is often abrupt. Usually this line is found at about the latitude of Ninilchik, but it moves north with large tides, and south with minus low tides. Above the Forelands — which is the sharp narrowing about two-thirds the way up the inlet — the inlet appears to be liquid mud.

The inlet is rimmed on the west by volcanic peaks: cone-shaped Mount Augustine, which last errupted in 1975, is an island in the lower inlet; Mounts Iliamna and Redoubt are perpetually snow-capped steam-venting peaks of around 10,000 feet in the Aleutian Range; and Mount Spurr, which last errupted in the early 1950s, is an 11,020-foot peak in the Alaska Range. The generally low shoreline of the Kenai Peninsula lies on the eastern side of the inlet.

The climate is primarily northern maritime, although colder continental conditions prevail in the northern interior basins of the inlet. Cool cloudy summers, wet autumns, variable but typically cold winters, and relatively cool, dry springs are found.

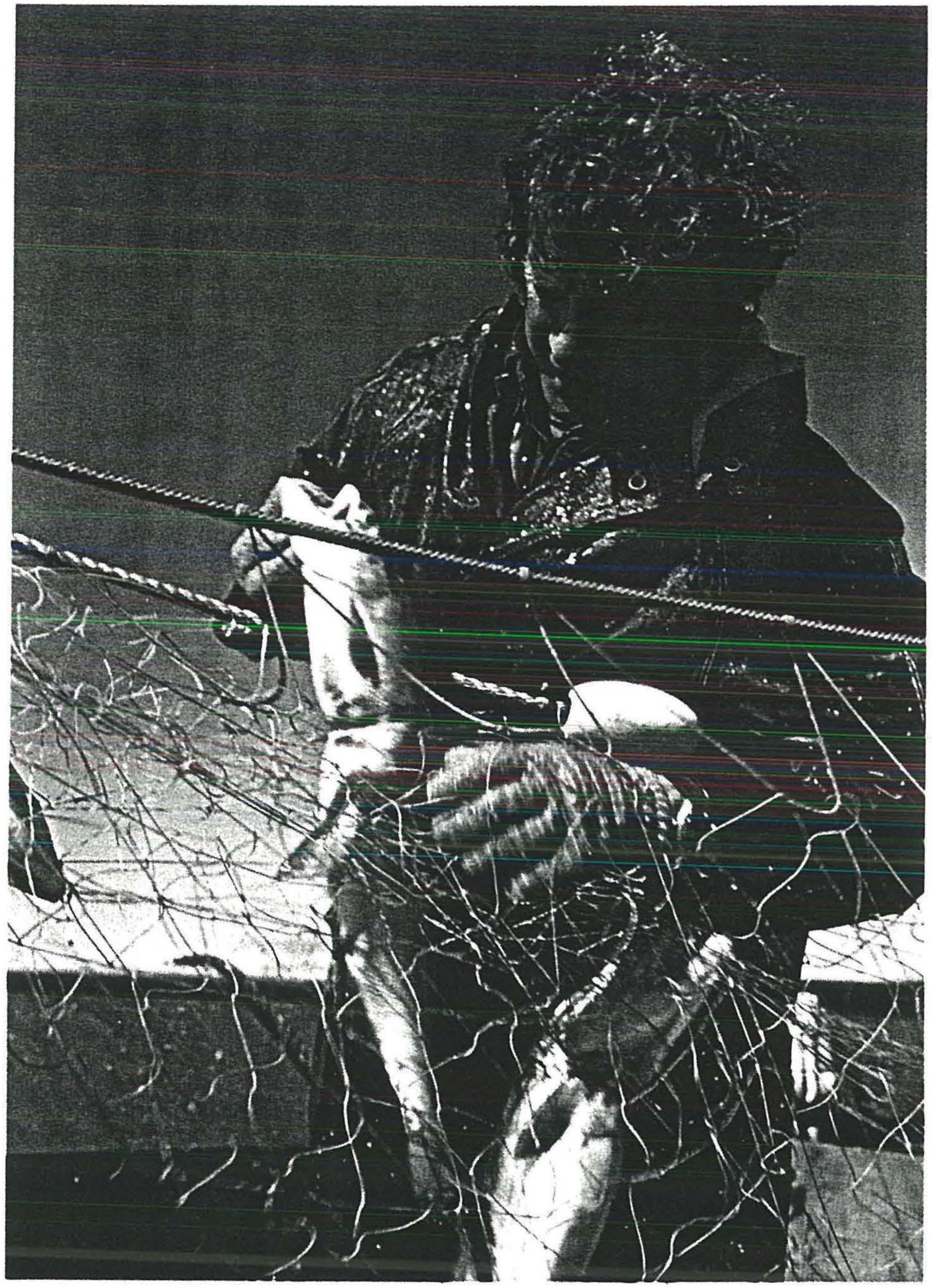
About half of Alaska's human population lives in the Cook Inlet basin. Anchorage (pop. 173,000), Alaska's largest city, lies at the head of the inlet. Kenai (4,300), and Soldotna (2,320) are found on the upper Kenai Peninsula. Homer (2,211) and Seldovia (473) lie on opposite sides of Kachemak Bay, a 30-mile-long, deep, clear-water bay which juts easterly from Cook Inlet near the tip of the Kenai Peninsula. Ninilchik (336), Tyonek (239), English Bay (53), and Port Graham (162) are villages on the shores of the inlet.

Cook Inlet has long been known for its stable salmon fishery: cycles of abundance and scarcity are not generally as severe as those of many other of Alaska's salmon fisheries. The great diversity of spawning streams and lakes that surround the inlet, with the broad range of climatic conditions, probably account for this: when severe weather causes mortality in streams and lakes of one part of the inlet, moderate conditions may be found elsewhere, with consequent higher salmon survival.

The inlet has the largest tides in Alaska, with maximum high tides reaching nearly 33 feet at the northern end. The inlet narrows to the north, compressing the incoming tide. At narrow points, as between the Forelands, and between Harriet Point and Kalgin Island, tides may flow at 8 knots or more. Tidal swirls and rips are common throughout the inlet, making small boat navigation interesting.

Fishermen pay a penalty for fishing in the gill net districts of Cook Inlet, for compared with many other fishing

A bear-killed red salmon. Alaska's coastal bears feast on spawning salmon. *(Tom Walker)*



Skipper Pete Islieb picking sockeye salmon from his drift gill net. Nylon fish gloves hold slippery fish. *(Freda Shen)*

districts, the inlet is rough and difficult to navigate. Distances are considerable — with about 70 miles of open water between the northern and southern boundaries of the drift gill net (Central) district and 30 to 40 miles between the eastern and western shores. The usually rough seas that build with strong southwest summer afternoon breezes whooping up the inlet toss the average 30- to 35-foot drift gill-netters about violently, often forcing a stop to fishing. The 20-foot set-net fishermen's skiffs are difficult to launch, and the, nets hard to pick.

Although the upper inlet is not considered important as a salmon feeding and rearing area, it is the route for the five species of salmon that leave their home streams and go to sea; they return as adults through the swift tides and murky turbulent waters to their home streams.

Sockeye salmon, with its ruby red flesh, was the lure that brought early salmon packers and fishermen to the inlet. It is still the main lure. The fish arrive in a great flood in July, pouring from the Gulf of Alaska through Shelikof Strait and the wind-and-tide-tossed waters between the Barren Islands and the tip of the Kenai Peninsula. Scientists who have tagged these fish in the lower inlet found that most arrived on the west side of the lower inlet to swim northeast, heading mostly for the great Kenai and Kasilof rivers. The Kenai River is the largest producer of sockeye salmon in the inlet, and the huge Susitna is second largest. Depending upon weather, Susitna-bound fish may follow the east or west shore of the inlet as they seek the mouth of the Susitna. Others home on numerous other streams around the inlet.

The multiplicity of streams connected to lakes that flow into all sides of Cook Inlet (sockeye generally spawn only in drainages where there are lakes) has resulted in a wide variety of races or types of sockeye salmon: some are big, deep, and heavy. Others are long and slim. A few are tiny, barely 2 or 4 pounds.

Cook Inlet's sockeye salmon catch, on average, is the second largest for that species in Alaska, coming only after that of Bristol Bay, although the inlet produced only about 8.5% of the sockeye caught in Alaska during the years 1973-82. Normally about 60% of returning Cook Inlet sockeye are five-year-olds; from 15% to 20% are four-year-olds; and less than 20% are six-year-olds.

Sockeye is the money fish in Cook Inlet, and during 1973-82 an annual average of 1.6 million sockeye were caught — about 8.5% of the statewide catch of sockeye for the period. Sockeye made up 34.5% of the total inlet catch. Major runs of sockeye swim into the Kenai, Kasilof, Susitna, and Crescent rivers — all in the Northern and Central districts. The peak of the sockeye fishery is usually between July 15 and 20.

Salmon traps caught most of the inlet's sockeye for many years. Since statehood, and the banning of salmon traps, gill nets have caught virtually all of the inlet's sockeye. By the early 1950s between 500 and 600 drift gill nets annually fished the silty waters of the inlet for reds — about the same number as today. However, fishing time allowed in those years was five 24-hour fishing periods a week: today the basic time is two 12-hour fishing periods a week.

A fresh-caught pink salmon, its scales as shiny as new dimes, lays on the deck of the seiner that caught it.
(Jim Rearden, staff)

From its start in 1893 the inlet's sockeye catch has reached or exceeded 2 million 10 times. Largest catch ever, of 3.1 million, was made in 1982.

While sockeye was the original attraction for packers and fishermen, in recent years the other four species have also become important.

Pink salmon are the most abundant salmon in Cook Inlet. For the years 1973-82 this species made up 39.6% of the total catch (numbers of fish), with an annual average catch of 1.8 million. This was about 4.4% of the statewide catch of pinks of those years.

Pink salmon in the gill net districts of the inlet (north of Anchor Point) have a distinct even-year cycle: catches range to perhaps 100,000 fish in odd years (although there was an inexplicable catch of 554,000 pinks in these districts in 1977 — the largest ever odd-year pink catch) but it ranges from 1 to 2 million in even years.

Major pink-producing streams include Kenai River and the Susitna River at the head of the inlet: the clear-water Talachulitna River, a tributary of the Susitna, is probably the most important pink producer, with as many as 1 million pink salmon spawners in some years.

Prior to about 1940 the smaller (average 3 to 4 pounds), spotted, and soft-fleshed pink salmon were incidentally caught by fishermen using large-mesh (5¼-inch or larger) gill nets seeking sockeye, chum, coho, and chinook salmon, but now pinks are of importance on their own, and pink gill nets with a 4-inch or slightly larger mesh are commonly fished after the bulk of the sockeye have passed.

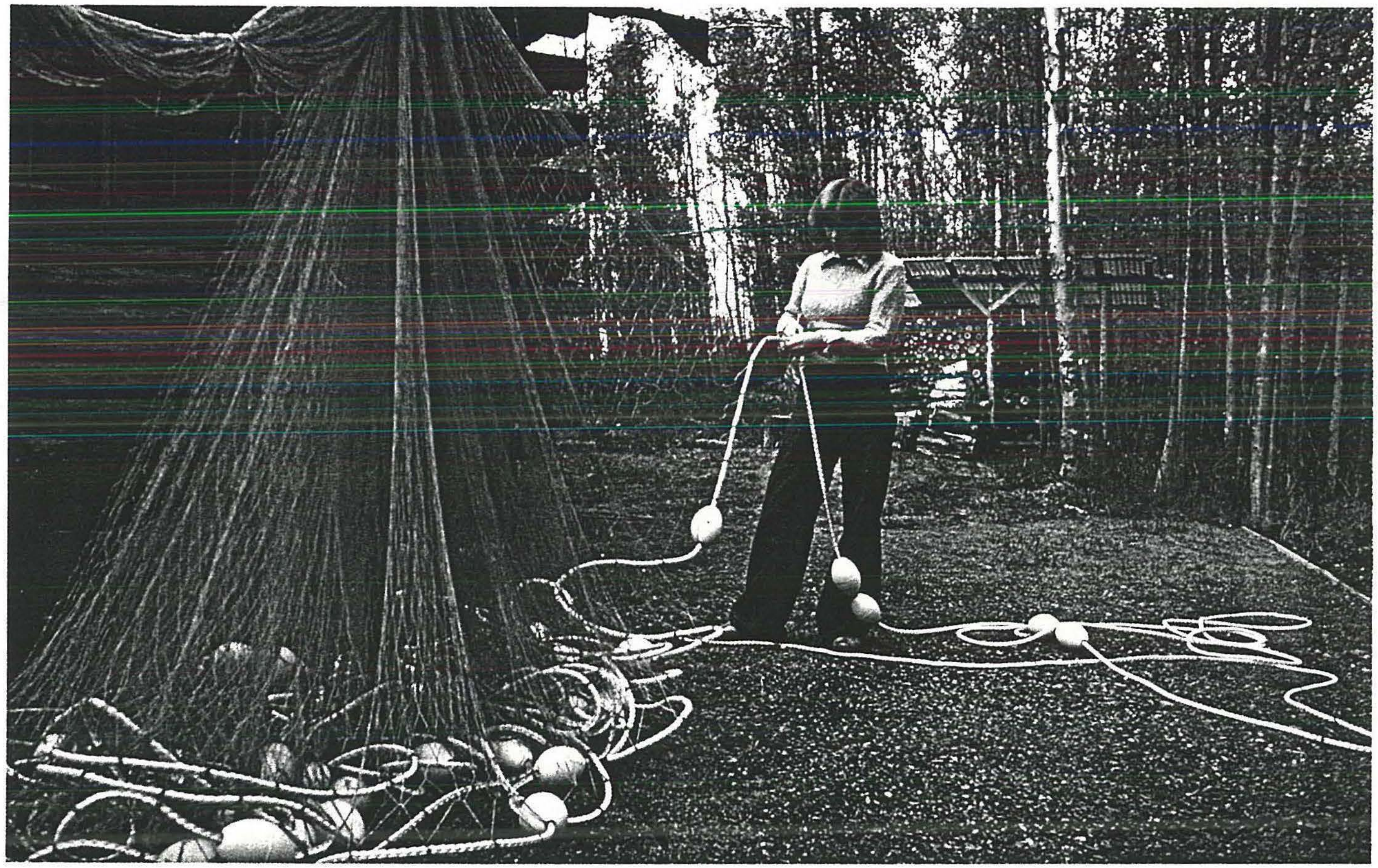
Pink salmon are the primary species caught by Cook Inlet's hand purse seine fishermen who fish south of Anchor Point. During the period 1948-61 the annual average catch here was around 480,000 pinks. Then, unexpectedly, in 1962, the catch soared to 2 million pinks. Two years later, in 1964, the catch was still high at 1 million.

From 1965 through the early 1970s the annual pink catch south of Anchor Point averaged 374,000. Catches during the early 1970s were poor. Then in the late 1970s a major change took place: the dominant even-year pink runs changed so that the odd-year pink runs became dominant. In 1979 the catch was 2.9 million, of which 375,000 were produced by a state hatchery in Tutka Lagoon — on the south side of Kachemak Bay.

The 1980 catch of 728,000 was well above the average. Then in 1981, the catch was 2.8 million pinks, of which 1 million were produced by the Tutka Lagoon hatchery. Instead of a 1% to perhaps 3% return of fry, biologists estimated that the return to the hatchery was perhaps 15% to 18% — an almost unheard-of survival rate for pink salmon. Credit was given to short-time rearing and feeding of the fry before they were released in Tutka Lagoon to make their way on to their 14-month sea-faring odyssey.

In 1982 the Tutka Lagoon hatchery return was only 231,800 pinks — far below that expected.

Chum salmon in upper Cook Inlet are a "me too" fish: they are caught



Susan Beeman hanging a set gill net (attaching lead and cork lines). She's working on the cork line. *(Tom Walker)* mostly by gill-net fishermen who are seeking the more valuable sockeye. They are about the same size as the sockeye and nets designed for sockeye are equally effective in taking chums. Chums made up about 19% of the Cook Inlet catch for the 10 years 1973-82, with an average annual catch for those years of about 871,000. Normally about 85% of these are caught by gill-net fishermen north of Anchor Point, and the balance by hand purse seiners fishing in the sheltered bay of the lower Kenai Peninsula, and in the often-stormy Kamishak Bay.

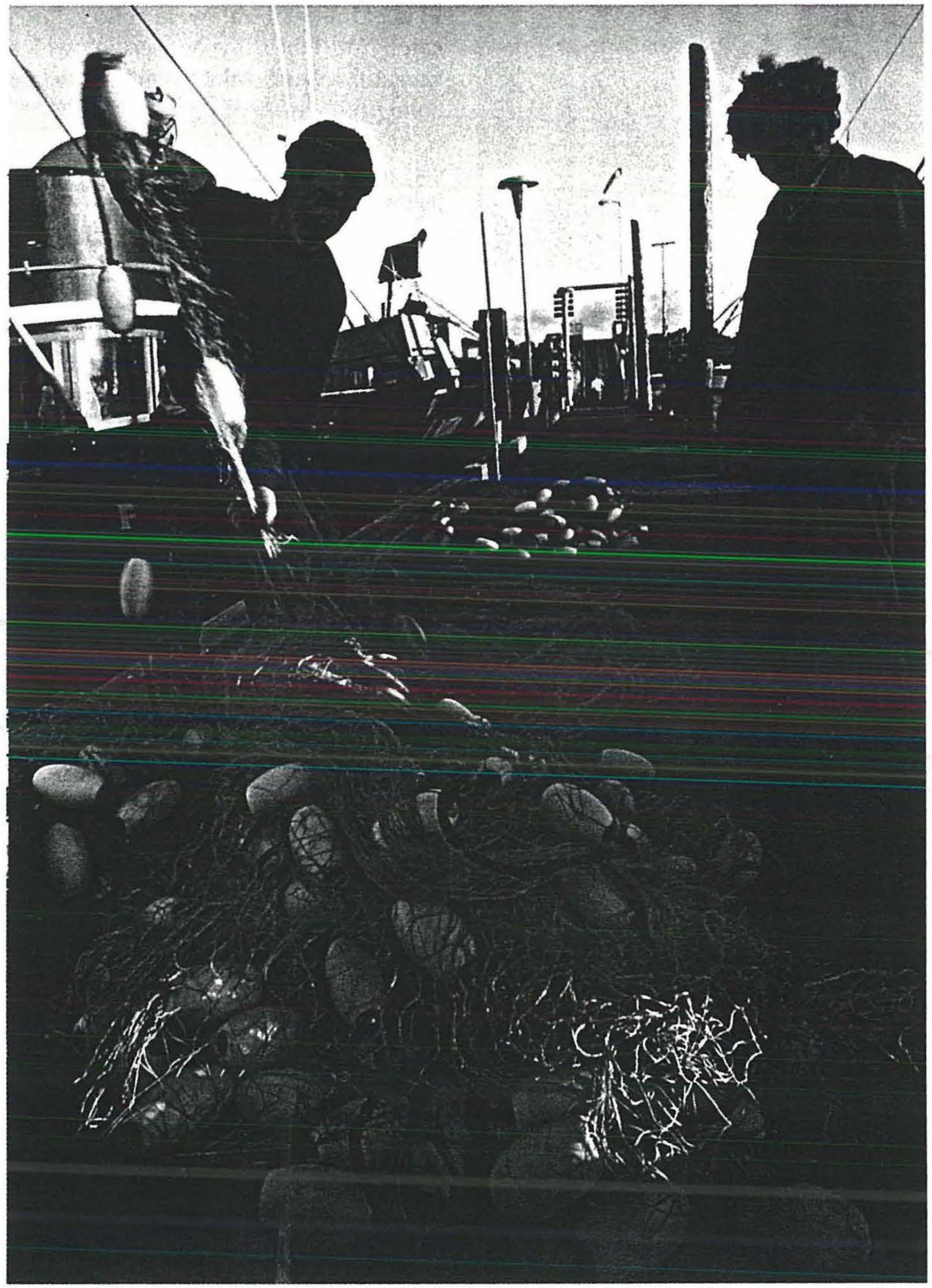
Chums are predominantly four-year fish in Cook Inlet, and they tend to have an even-year cycle.

For the gill-net fishery, the peak of the chum run occurs about a week after that of the sockeye — or sometime shortly after about July 20.

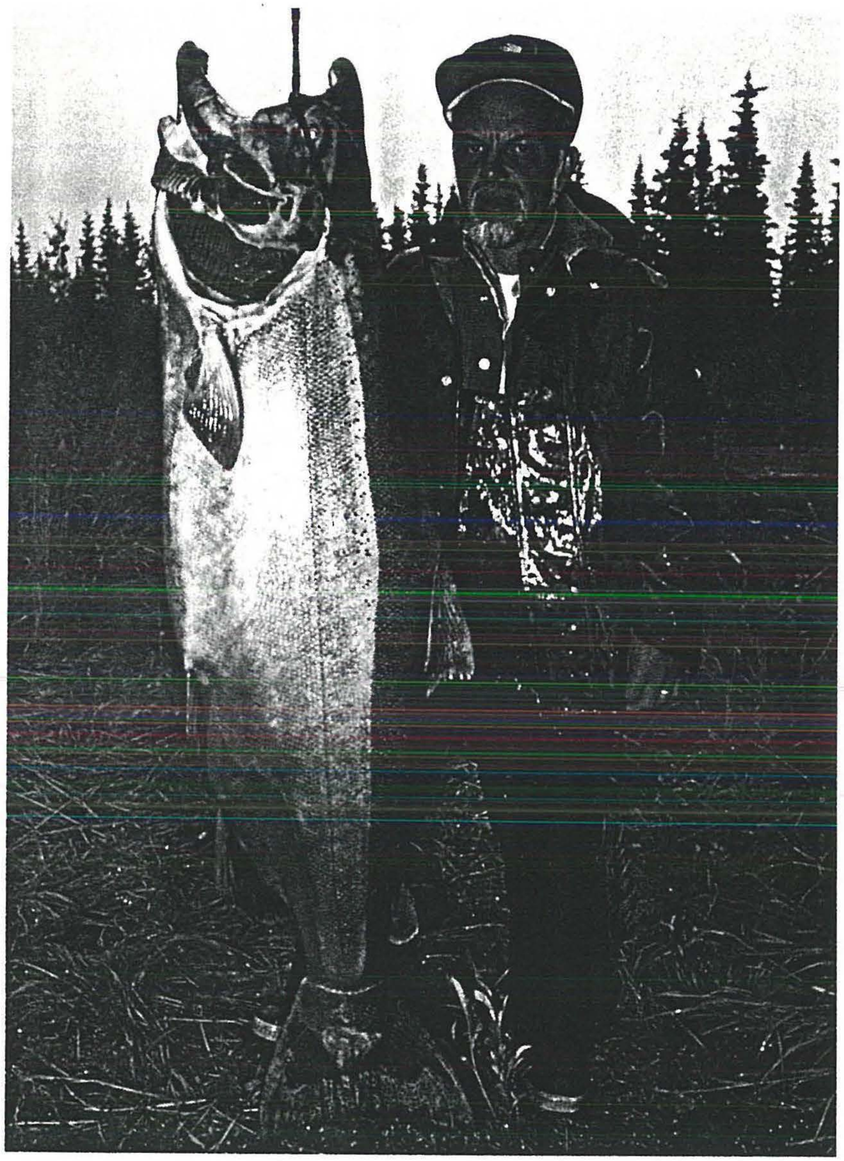
The vast Susitna basin produces about 90% of the chums of the gill-net fishery of the inlet. Chinitna Bay and Kamishak Bay, both on the west side of the lower inlet produce chums, as do certain bays of the lower Kenai Peninsula — Rocky, Windy, Port Dick, Seldovia, and Port Graham bays, among others.

Peak catches of chums in Cook Inlet occurred in 1964 (1.4 million), 1977 (1.3 million), and 1982 (1.5 million).

Coho salmon are another "me too" salmon in Cook Inlet that are caught mostly by fishermen who set their nets for the more valuable sockeye. The average annual coho catch for the inlet, 1973-82, was 30,400, or about 6.5% of the inlet's salmon catch. It was also



Paul Jones, of Homer, wrestles with his drift gill net, readying it for rolling it onto his gill-net reel.
(Jim Rearden, staff)



This 78½-pound king salmon was caught on sport tackle in the Kenai River by the late J.J. Smith, who stands behind the huge fish. Smith is 5' 6" tall. *(Jim Rearden, staff)*

11% of the total statewide coho salmon catch for that 10-year period, which says that Cook Inlet is an important coho producer.

At least 95% of the annual commercial coho catch is made by gill-net fishermen north of Anchor Point. Largely a four-year fish, the inlet coho tends to have an even-year cycle, but the cycle is not as pronounced as that of the pink salmon.

Coho salmon are found in almost every spawning system of the inlet, and they tend to be rather evenly distributed around the inlet — more so than any other species. They start arriving in mid July, and some coho are still arriving as late as October. The peak of the coho run for the upper inlet is in late July.

Because the coho arrives and enters streams in the fall when water tends to be high and murky from fall rains, fishery managers seldom have much information on the numbers that reach spawning grounds.

The smallest coho salmon catch in 50 years occurred in 1972 when only 83,000 were taken. Remarkably, the coho has made a tremendous recovery: the largest catch of coho ever for Cook Inlet was in 1982, when 765,400 of the silver-sided salmon were landed.

King salmon, silvery, black-spotted, huge, rich-fleshed, are now relatively unimportant to Cook Inlet's commercial fishermen. For the 10 years 1973-82, an annual average of 12,470 were caught — less than 1% of the inlet's salmon catch, and 1.8% of the statewide commercial catch of kings.

It was not always so. Greed almost destroyed Cook Inlet's kings. From 1924-40, commercial fishermen caught an average of 66,000 Cook Inlet kings each season. Then the catch increased: from 1941 to 1953, the catch averaged 109,000, with the largest catch ever in 1951 when 187,000 king salmon were caught.

After that it was all downhill, until shortly after statehood when a total closure for commercial and sport fishing for king salmon throughout the Cook Inlet basin allowed stocks to rebuild.

By 1977 more than 100,000 spawning king salmon were counted in the Susitna basin, and the species now seems secure.

Virtually all the king salmon caught by commercial fishermen in the inlet are taken by gill-netters north of Anchor Point. Kings enter the inlet in two separate runs: the early run is the big one, and it is bound for the Susitna basin. The bright strong sea-fresh fish arrive in the inlet about May 25, and by mid-June most have reached the silty Susitna and scattered to the many clear and not-so-clear streams where they spawn.

The second run, which arrives in June and continues through most of July, is bound mostly for the Kenai-Kasilof rivers. This is the run from which most of the commercial harvest is taken today. The current late June opening of commercial salmon season in the inlet comes well after the Susitna-bound kings have reached their spawning areas.

The Kodiak District

Kodiak Island, in the turbulent western Gulf of Alaska, 100 miles long, 60 miles wide, is Alaska's largest island. Thirty-mile-wide tide-and-storm-tossed Shelikof Strait separates lovely Kodiak Island from the Alaska Peninsula.

A spine of steep, rugged mountains runs the length of Kodiak; deep fjords and bays indent the coastline into which hundreds of short streams and rivers flow. Many small lakes and ponds are scattered across the glaciated surface of lush Kodiak and nearby spruce-covered Afognak Island. Only the northern end of Kodiak Island has spruce trees: the rest is grass, alder, and a wide variety of brush and forbes. The Karluk and Red rivers, both about 25 miles long, drain much of southwestern Kodiak Island. Karluk River, including 12-mile-long Karluk Lake, and Dog Salmon River, including 9-mile-long Frazer Lake, are among the most important salmon producing systems.

The annual average 60 inches of precipitation and the cool-to-mild maritime climate produce luxurious near-tropical plant growth. Severe storms with high winds are common. The temperate North Pacific waters that surround Kodiak are alive with a wide variety of marine life.

The Kodiak area is fished by purse seines, beach seines, and set nets. During the 10 years 1973-82 Kodiak's salmon fishermen caught an annual average of 10 million salmon of all five species — or about 15% of the total statewide catch of salmon. Most of these fish were pink salmon (85%), for the many short streams of Kodiak are ideal for this species. Chum salmon are the second most abundant salmon of the Kodiak area, and in recent years about 7.2% of the catch has been of chums.

The town of Kodiak (pop. 4,746) on the north end of Kodiak Island is the main human and trade center. Akhiok (105), Port Lions (215), Ouzinkie (173), Karluk (96), Old Harbor (334) and Larsen Bay (144), are villages on and around Kodiak Island. The Alaska Marine Highway (state ferry), and regular airline service provide transportation to and from the island. Few roads exist, and most local transportation is by small plane or boat.

Purse, hand purse, and beach seines are used to catch salmon in all Kodiak districts except for Olga and Moser bays, where only set gill nets are permitted. Set nets also fish in a few other areas on the west side of the island.

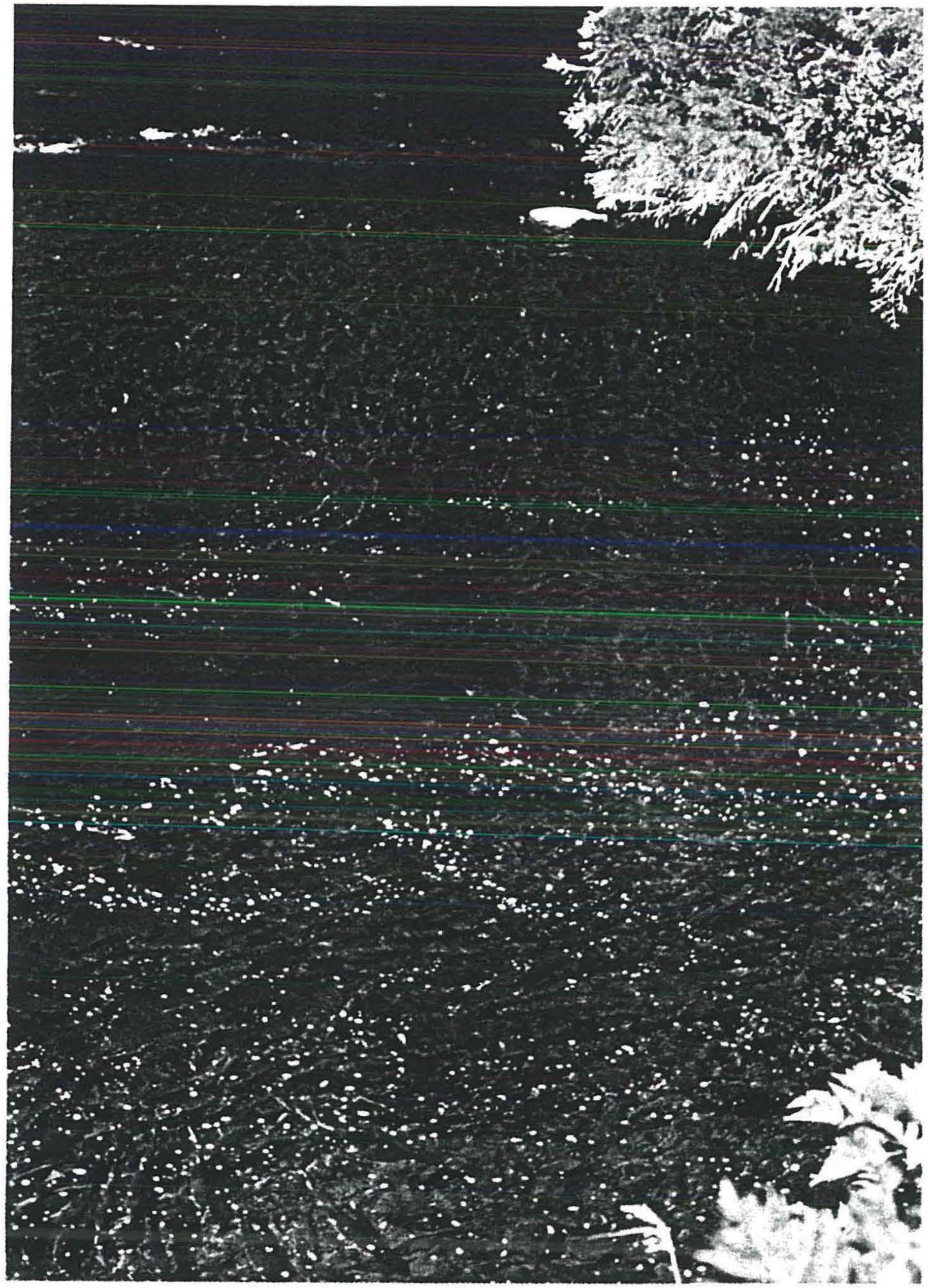
King salmon catches are minor in the Kodiak area, averaging about 1,100 fish a year during the 10 years 1973-82. The Karluk and Red rivers have the only natural king salmon runs. Kings were apparently successfully introduced into the Dog Salmon-Frazer Lake system in the mid-1960s.

Red salmon dominated the Kodiak fishery in the late 1890s and early 1900s, but today it is only the third most abundant species. Average annual sockeye catch 1973-82 was 683,500, making up 6.8% of the Kodiak catch. There are more than 30 sockeye-producing systems in the Kodiak fishing area, but only four of these —Karluk, Red River, Upper Station, and Frazer Lake are of real importance.

Frazer Lake, which drains into Olga Bay, is one of Kodiak's largest lakes. It had no salmon runs because of an impassable (to salmon) falls. In 1951 the Territorial Department of Fisheries introduced red salmon into the lake, and followed up the egg plant with introduction of live spawners over a period of several years. As sockeye returned to the Frazer they were netted and carried over the falls in backpack tanks. The run gradually increased. In 1962 fishways were built which put an end to backpacking salmon: they can now swim across the falls on their own. This run, one of the few successful man-established sockeye runs anywhere, is still increasing: in 1982, 400,000 eager, flipping and splashing sockeye swam through the fishway and into Frazer lake to spawn.

Karluk Lake, on the west side of Kodiak Island, once sustained the greatest red salmon fishery known for any single river and lake anywhere. The 12-mile-long lake and 24-mile-long river which flows through Karluk Lagoon and into Shelikof Strait, produced a catch of 4 million in 1901. Between 1887 and 1928, the average annual catch of sockeye from the Karluk was 1.9 million.

Salmon and crab fishing boats crowd the Kodiak harbor. Some boats are used for both, and rigging is changed seasonally. *(Sharon Paul, staff)*



Pink salmon in Portage Creek, Afognak Island. *(Dennis Gretsch)*

Since 1938, when 1 million were caught, the catch has declined. In 1982, although the escapement goal was 800,000 for the Karluk, only 132,000 red salmon arrived.

Despite years of research and good numbers of spawners over the years the Karluk red run hasn't increased: no one knows why. A large even-year run of pink salmon to the Karluk complicates the picture: how do you harvest large numbers of pinks without taking more sockeye than you want?

Each year, when regulations permit, Kodiak seiners run to Cape Igvak on the mainland, where they net good numbers of sockeye. A tagging study of these fish showed that most were bound for Chignik, to the south, and some were bound for Cook Inlet, to the north. If a weak run is expected at Chignik this fishery is curtailed.

The Alitak district, on the south end of the island, has historically been second only to the Karluk in producing large red salmon catches. Upper Station, Frazer, and Akalura are the major producers there.

The Kodiak red salmon catch for 1982 of 1.2 million was the second largest red salmon harvest in 34 years. The catch of 215,000 sockeye at Cape Igvak plus fair to good runs to Kodiak Island systems accounted for this.

Pink salmon eggs hatch and eventually the fry wriggle out of the gravel to almost immediately go to salt water. Stable water levels, clean gravel, cool summer and mild winter temperatures are major requirements for a pink salmon stream.

Most of the approximately 300 streams in the Kodiak management area meet these requirements, and most of them produce pinks. The bulk of Kodiak's pink salmon, however, are found in about 31 of the major rivers.

Today more than 90% of Kodiak's pink salmon are caught by purse seiners. Pink salmon were relatively unimportant in the Kodiak area until after about 1912. Catches from 1934 through about 1947 were especially good, averaging 8.5 million fish.

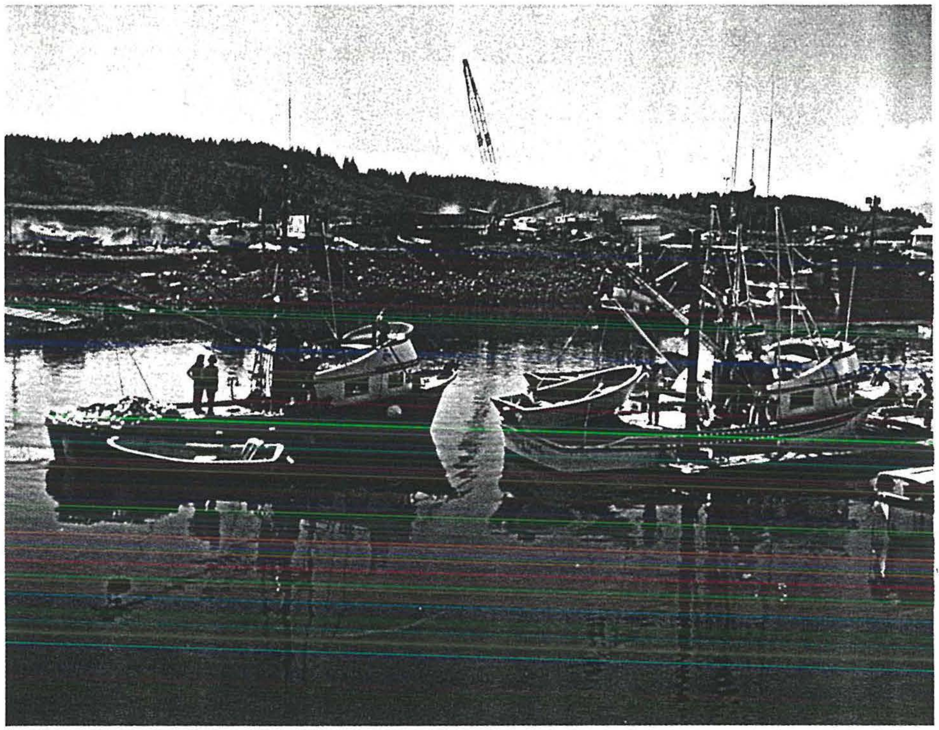
After a decline, catches again increased with the average annual catch from 1962 to 1970 being about 8.6 million.

The average annual catch for the 10-year period 1973-82 was 8.5 million. This was 22.5% of the statewide catch of pink salmon. Peak year was 1980 when 17.2 million were caught: other top years were 1937 with a catch of 16.7 million, 1962 with a catch of 14.1 million, and 1978, with 15 million.

In the past the odd-year cycle of pinks dominated. In the mid-1970s the even-year cycle was dominant, with weak runs in odd years. Since then both even- and odd-year catches have been good, averaging more than 12 million a year since 1976.

Important pink producers of Kodiak include Terror, Uganik, and Uyak rivers, on the west side of the island. The Karluk (of red salmon fame), Sturgeon and Red River districts on the west and southern end of the island are great pink producers — catches of 4 million or more in a season are not unusual.

A typical modern salmon seine type vessel (left) in the Kodiak harbor. Such boats are commonly also used for fishing for crab, shrimp, and herring. *(Staff)*

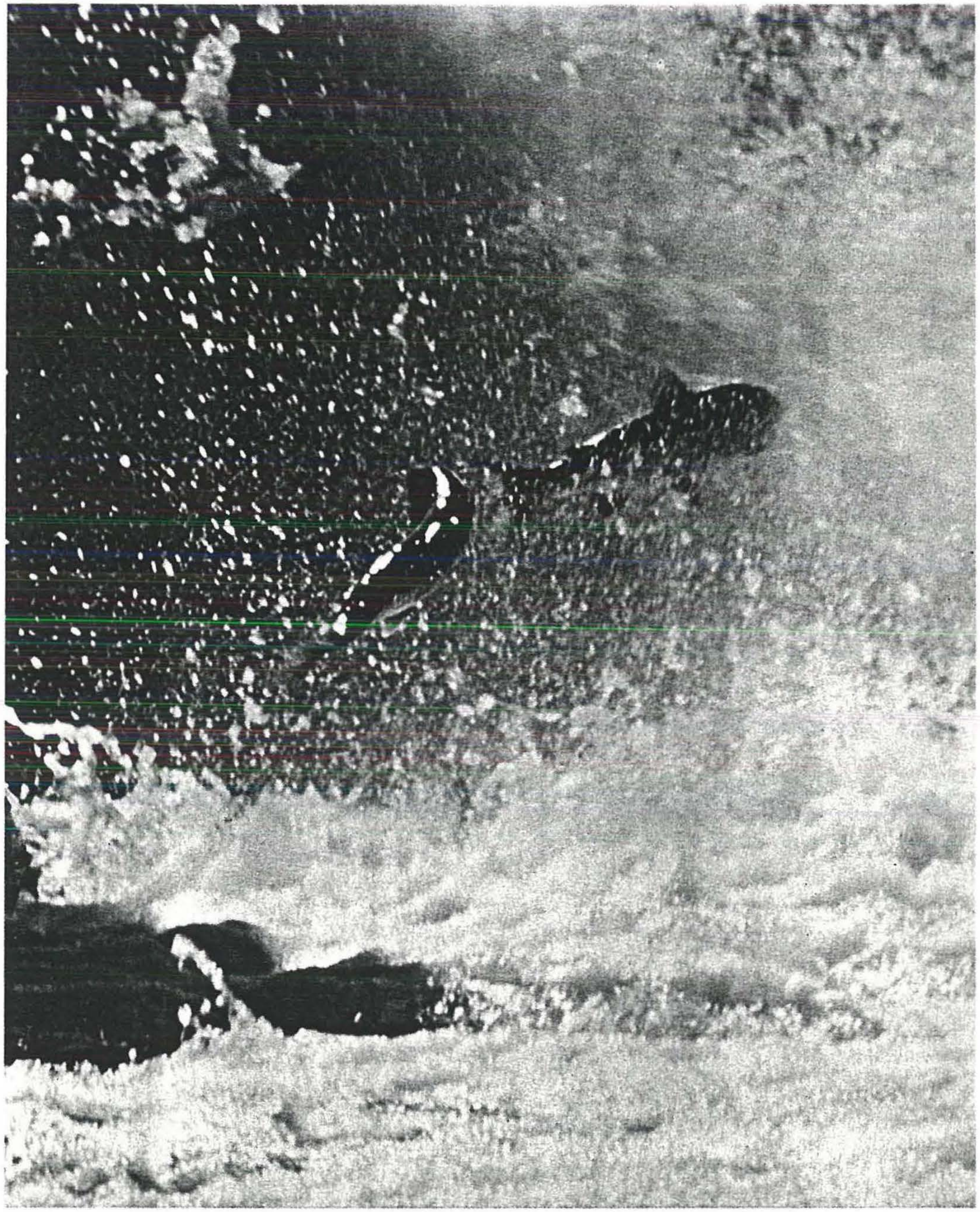


The Alitak district, on southern Kodiak, generally produces catches ranging from half a million to 2 million.

The east side of Kodiak Island, which faces the Gulf of Alaska, has many small pink salmon-producing streams and a few major rivers. There seiners commonly round-haul and brail board 2 to 4 million or more silvery splashing pinks during a season.

Afognak Island, just north of and across the channel from Kodiak Island, has a strong pink run, with yearly catches ranging from 50,000 to 2 million or more. A fishway built by the state on Perenosa River has made that system one of the best pink salmon producers on Afognak Island.

Chum salmon are second to pinks in abundance on Kodiak Island. For the 10-year period 1973-82, the annual average catch of chums in the Kodiak management district was 732,400 — which was only 7.2% of the total



Kodiak catch. It was also 10% of the total statewide catch of chums for that period.

Like most other salmon fisheries dominated by one species — in this case pink salmon — management decisions are based on when and where it is proper to catch pinks. If chums are present, they are also caught.

Kodiak chums generally use the same spawning systems as pinks. One slight difference between the two species is the different time of arrival in bays and estuaries: pinks arrive around July 1, chums around July 15. Both are present in salt water until about September 1.

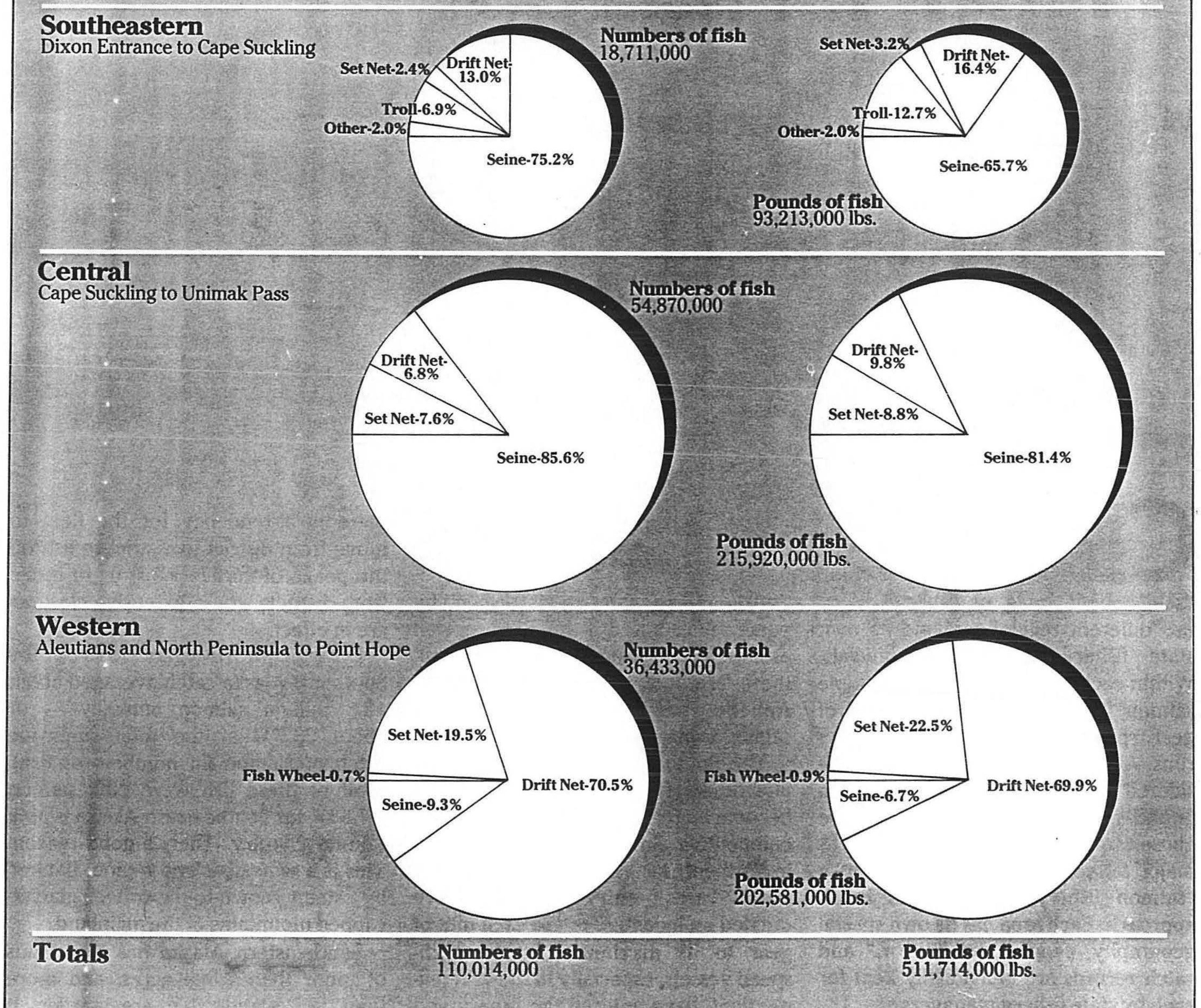
Chum catches appear on the increase in recent years: more than 1 million chums were annually caught each year 1980-82. Previously the only recent catches of 1 million or more were in 1960, 1971, and 1972. The 1982 chum catch of 1.2 million ranked as Kodiak's third largest (behind 1971 and 1981).

Coho salmon catches at Kodiak are generally small. For the 10-year period 1973-82 the annual average catch was only 88,610. This figure is somewhat distorted by the spectacular and unexpected catch of 343,000 in 1982 — the largest ever coho catch at Kodiak. For the nine years prior to 1982 the average annual catch of cohos for Kodiak was 53,600.

Red salmon struggle to overcome Fraser Falls to reach their spawning grounds in western Kodiak.
(Gerry Atwell, USF&WS, reprinted from ALASKA GEOGRAPHIC®*)*

Salmon Harvest by Gear, 1980

Figures supplied by the Alaska Department of Fish & Game



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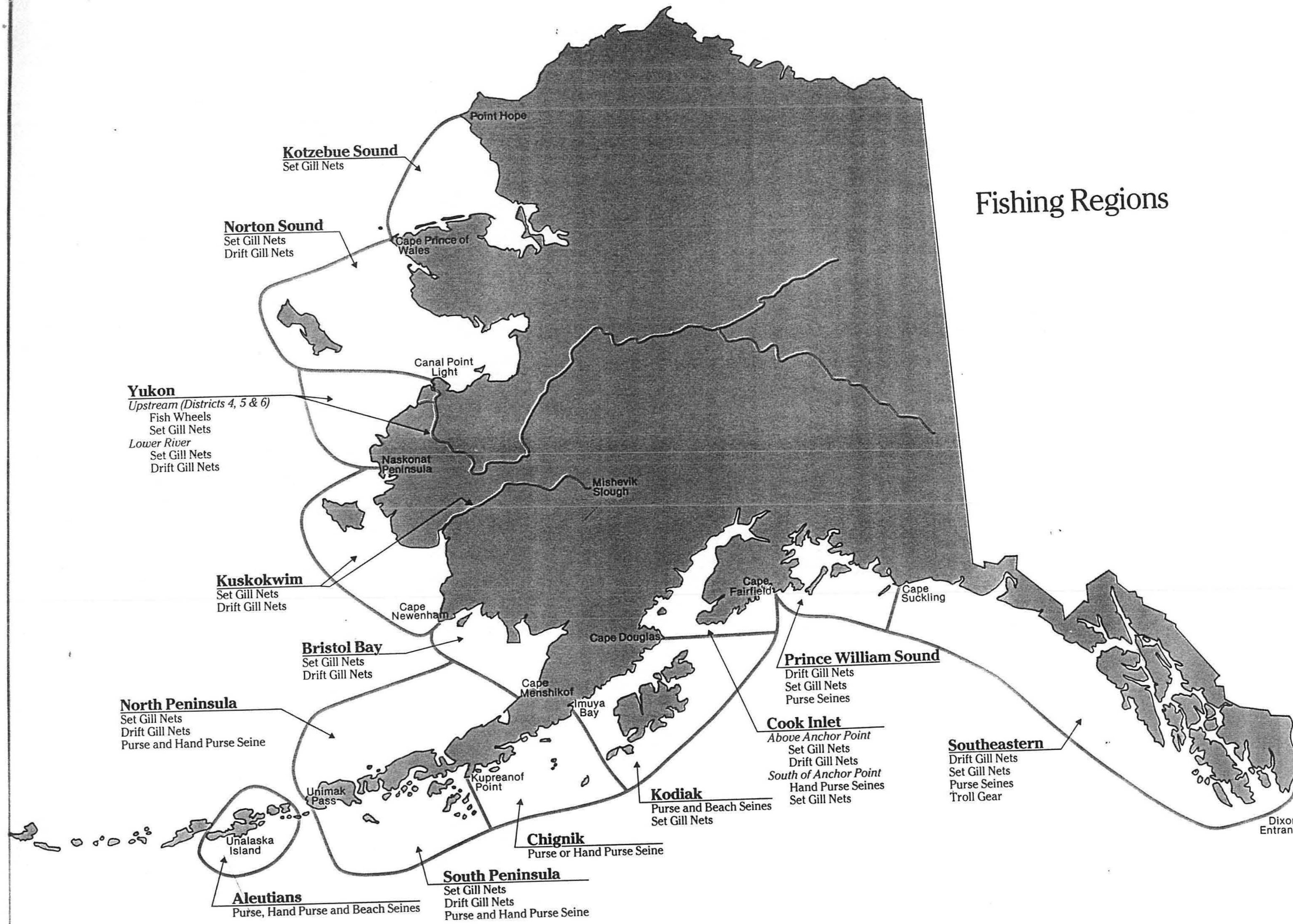
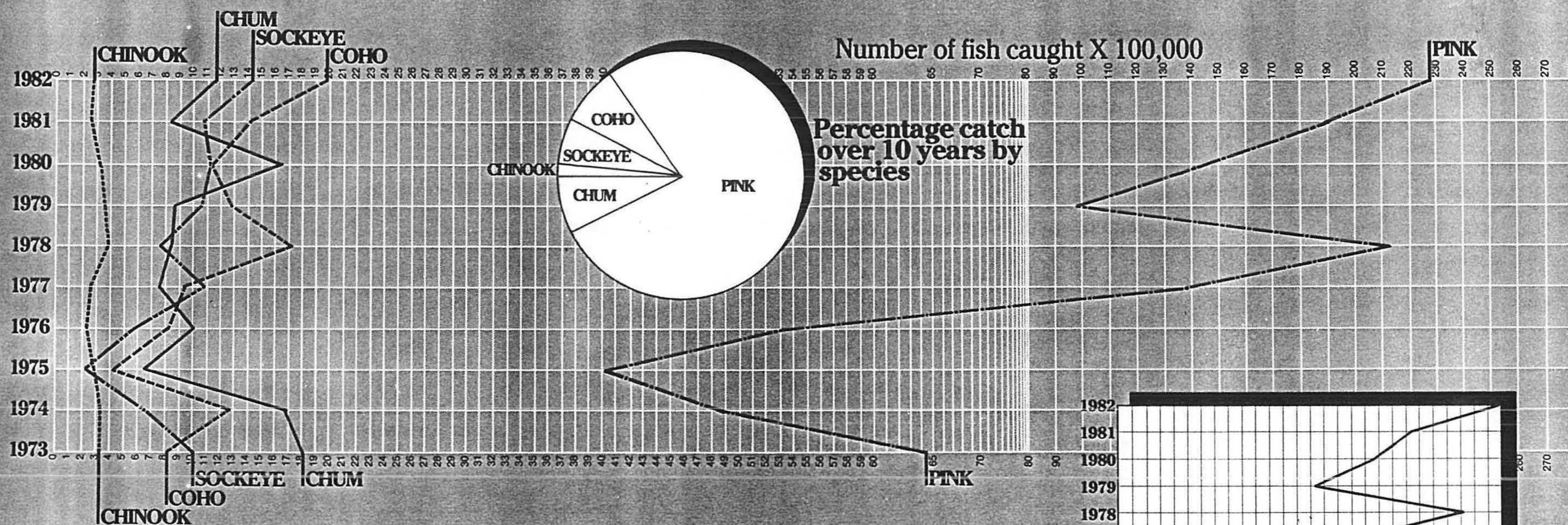
Fishing Regions

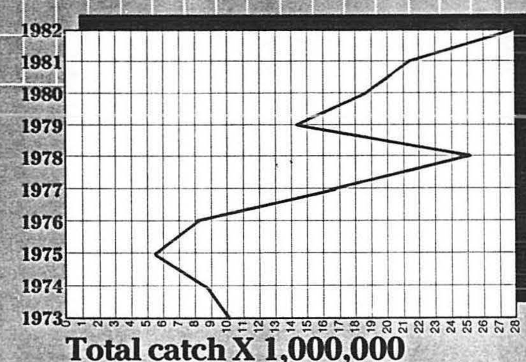


NA

Salmon catch for

Southeastern Alaska





Summary of Data

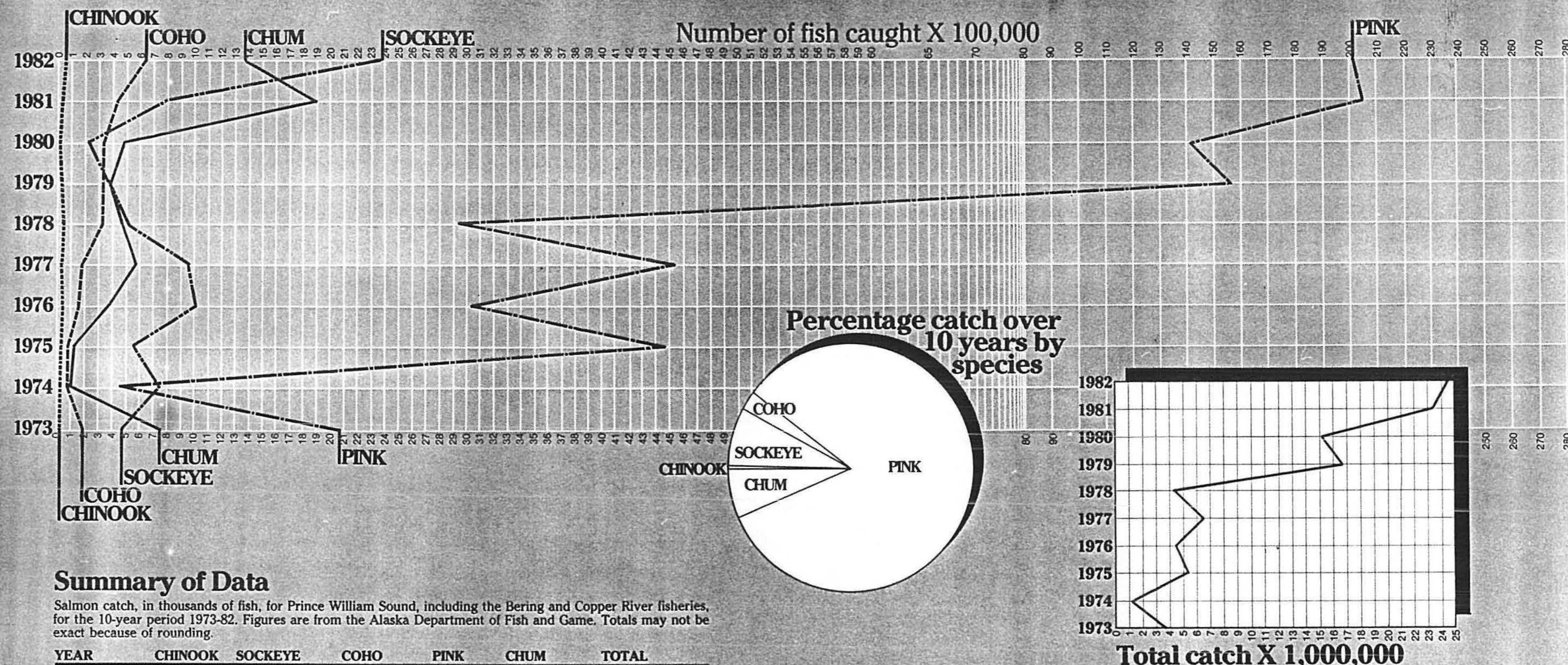
Salmon catch, in thousands of fish, for Southeastern Alaska, including Yakutat, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	285.9	1,428.2	1,991.1	22,868.7	1,187.4	27,761.3
1981	271.9	1,079.6	1,407.1	18,967.9	849.5	22,576.1
1980	323.2	1,120.4	1,136.7	14,478.3	1,651.2	18,709.9
1979	367.6	1,073.9	1,284.6	10,977.9	888.3	14,592.3
1978	401.4	788.3	1,714.5	21,243.4	869.0	25,016.6
1977	285.2	1,085.1	944.8	13,843.6	738.7	16,897.4
1976	241.8	595.3	823.7	5,329.6	1,030.9	8,021.2
1975	300.7	245.2	427.4	4,026.5	686.6	5,686.4
1974	346.6	687.4	1,278.2	4,888.8	1,682.6	8,883.5
1973	343.6	1,011.5	836.3	6,455.2	1,832.2	10,478.2
TOTAL	3,168.0	9,114.9	11,844.4	123,079.9	11,416.4	158,622.9
AVERAGE	3,168.0	911.4	1,184.4	12,307.9	1,141.6	15,862.2
% Each Species 10 Yrs.	1.9%	5.7%	7.4%	77.5%	7.1%	
% Of Statewide Catch For Species, 10 Yrs.	46.9%	4.8%	45.2%	32.0%	15.7%	ALL: 23.7%

Limited entry permits held for Southeastern Alaska (September 1982) included: 421 purse seine, 484 drift gill net, 2,150 hand troll, and 484 power troll.

Salmon catch for

Prince William Sound



Summary of Data

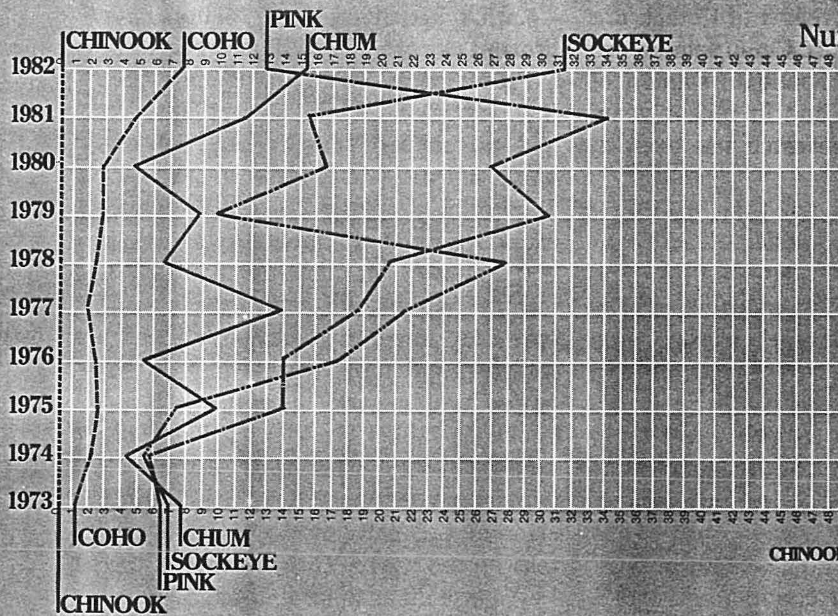
Salmon catch, in thousands of fish, for Prince William Sound, including the Bering and Copper River fisheries, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

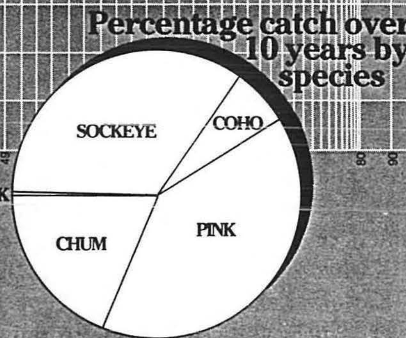
YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	49.2	2,372.3	615.0	20,262.7	1,345.7	24,645.1
1981	21.9	798.4	423.9	20,519.6	1,890.2	23,654.0
1980	8.6	208.7	337.1	14,161.0	482.2	15,197.7
1979	20.1	369.6	315.7	15,638.3	349.6	16,693.3
1978	30.4	505.5	312.9	2,917.5	489.8	4,256.1
1977	22.9	943.9	179.4	4,536.5	573.2	6,255.8
1976	32.8	1,009.1	160.5	3,022.4	370.7	4,595.4
1975	22.3	546.6	84.1	4,453.0	101.3	5,207.4
1974	20.6	741.3	76.0	458.6	89.2	1,385.8
1973	22.6	473.0	199.0	2,065.8	740.0	3,500.6
TOTAL	251.4	7,968.4	2,703.6	88,035.4	6,431.9	105,391.2
AVERAGE	25.1	796.8	270.3	8,803.5	643.2	10,539.1
% Each Species 10 Yrs.	.2%	7.5%	2.5%	83.5%	6.1%	
% Of Statewide Catch For Species, 10 Yrs.	3.7%	4.2%	10.3%	23.3%	8.8%	ALL: 15.7%

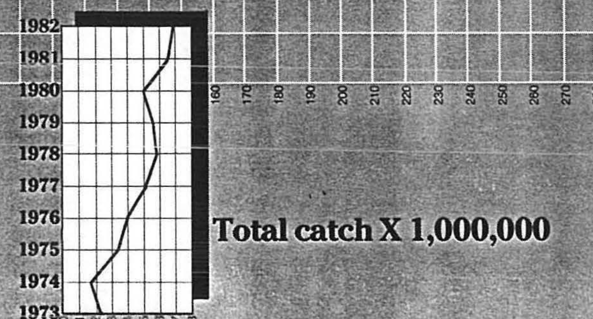
Limited entry permits held for Prince William Sound (September 1982) include: 270 purse seines, 543 drift gill net, and 30 gill net.

Salmon catch for

Cook Inlet







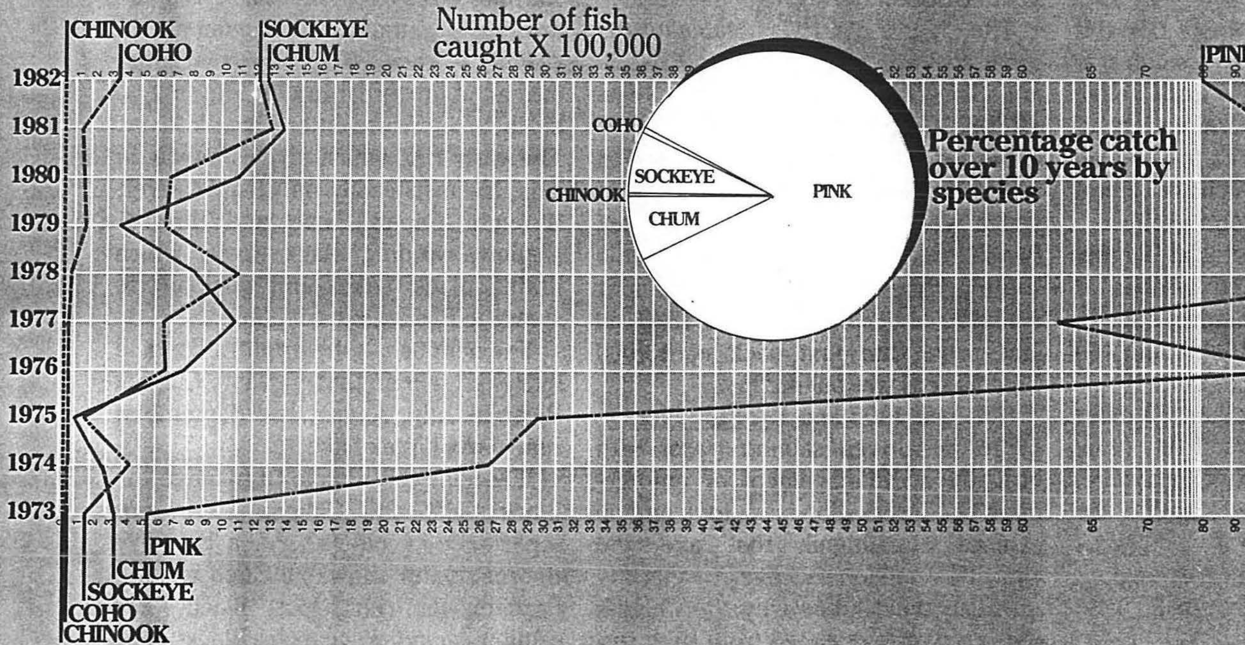
Summary of Data

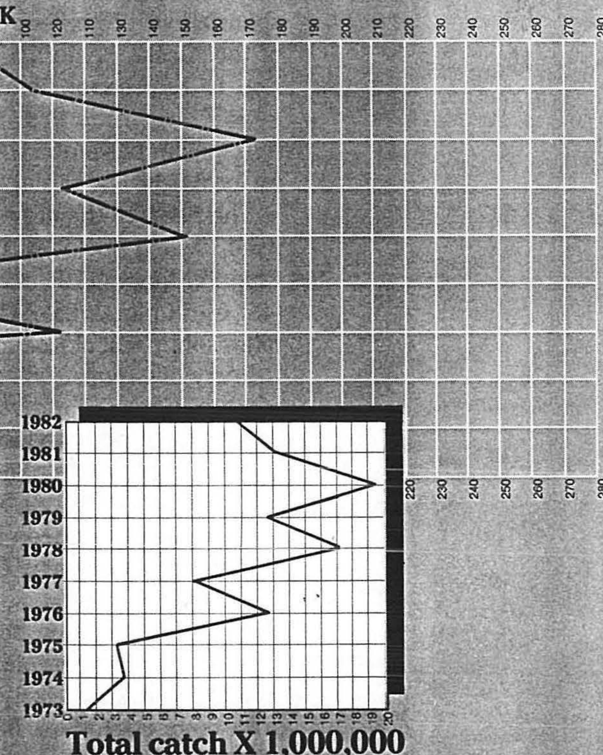
Salmon catch, in thousands of fish, for Cook Inlet for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	1.9	3,147.6	765.4	1,278.1	1,524.2	6,735.2
1981	13.3	1,549.5	495.9	3,406.4	1,169.6	6,634.7
1980	14.2	1,643.0	285.9	2,676.1	463.2	5,082.5
1979	15.0	988.8	287.8	3,049.2	873.4	5,214.1
1978	19.0	2,778.1	225.3	2,041.7	645.5	5,709.6
1977	15.0	2,154.1	195.8	1,846.3	1,379.5	5,590.8
1976	11.3	1,722.3	211.9	1,393.2	520.6	3,859.4
1975	4.9	713.0	233.6	1,399.8	973.4	3,324.7
1974	6.8	524.6	206.6	534.3	416.1	1,688.4
1973	5.3	699.2	106.5	633.6	783.1	2,227.8
TOTAL	124.7	15,920.2	3,014.7	18,258.7	8,748.6	46,067.2
AVERAGE	12.4	1,592.0	301.5	1,825.8	874.8	4,606.7
% Each Species 10 Yrs.	.2%	34.5%	6.5%	39.6%	18.9%	
% Of Statewide Catch For Species, 10 Yrs.	1.8%	8.5%	11.5%	4.4%	12%	ALL: 6.8%

Limited entry permits held for Cook Inlet (September 1981) included 590 drift gill net, 748 set gill net, and 84 hand purse seine.

Salmon catch for
Kodiak Commercial Fishing District





Summary of Data

Salmon catch, in thousands of fish, for the Kodiak Commercial fishing district, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

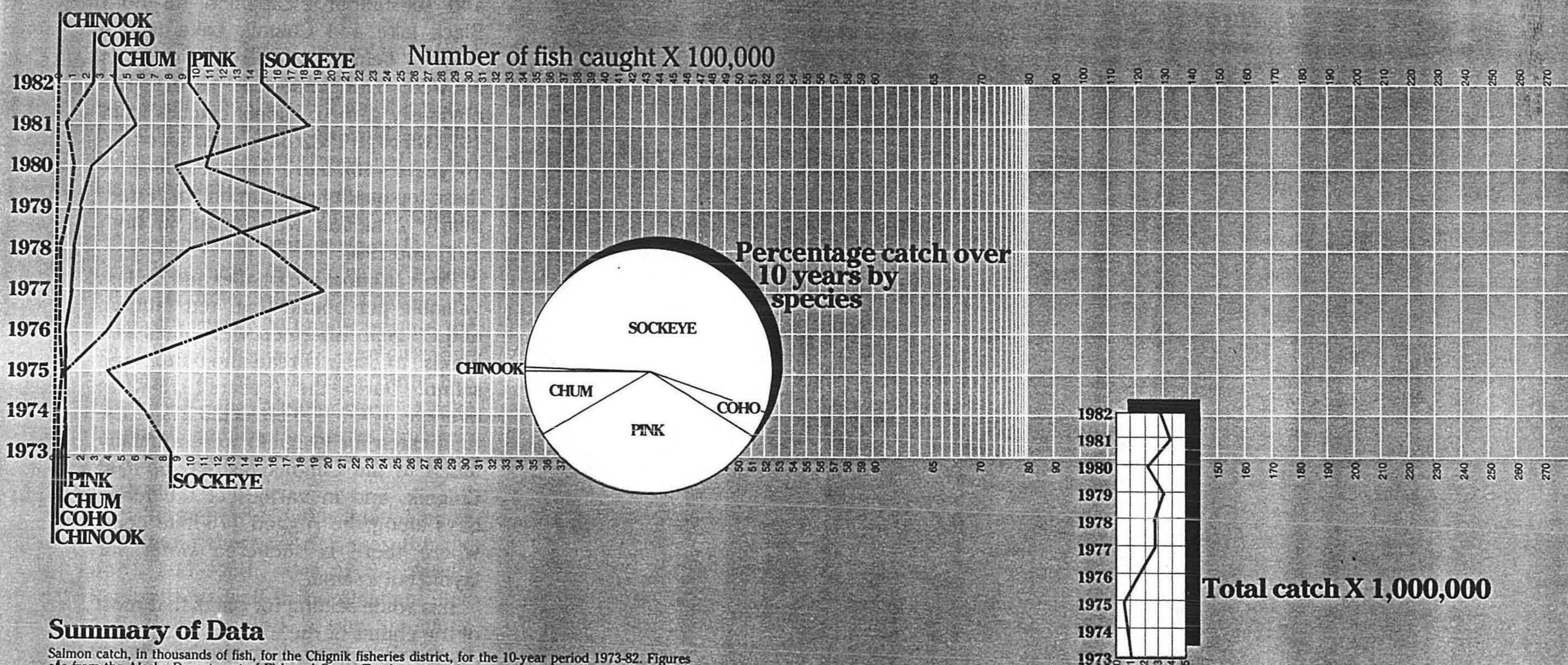
YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	1.2	1,204.8	343.5	8,076.2	1,266.2	10,891.9
1981	1.4	1,289.0	121.5	10,336.8	1,345.3	13,094.1
1980	.5	651.4	139.2	17,290.6	1,075.6	19,157.2
1979	1.9	630.8	140.6	11,285.8	358.3	12,417.4
1978	3.2	1,071.8	48.8	15,004.1	814.3	16,942.2
1977	.6	623.5	27.9	6,252.4	1,072.3	7,976.7
1976	.8	641.5	23.7	11,078.0	740.5	12,484.5
1975	.1	136.4	23.7	2,942.8	84.4	3,187.4
1974	.5	418.8	13.6	2,647.3	249.3	3,329.4
1973	.8	167.3	3.6	511.7	317.9	1,001.3
TOTAL	11.0	6,835.3	886.1	85,425.6	7,324.1	100,482.1
AVERAGE	1.1	683.5	88.6	8,542.5	732.4	10,048.2
% Each Species 10 Yrs.	.01%	6.8%	.8%	85.0%	7.2%	
% Of Statewide Catch For Species, 10 Yrs.	.16%	3.6%	3.3%	22.7%	10.0%	ALL: 15.0%

Limited entry permits held for Kodiak (September 1982) included 386 purse seine, 34 beach seine, and 187 gill net.

NA

Salmon catch for

Chignik Fisheries District



Summary of Data

Salmon catch, in thousands of fish, for the Chignik fisheries district, for the 10-year period 1973-82. Figures afe from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

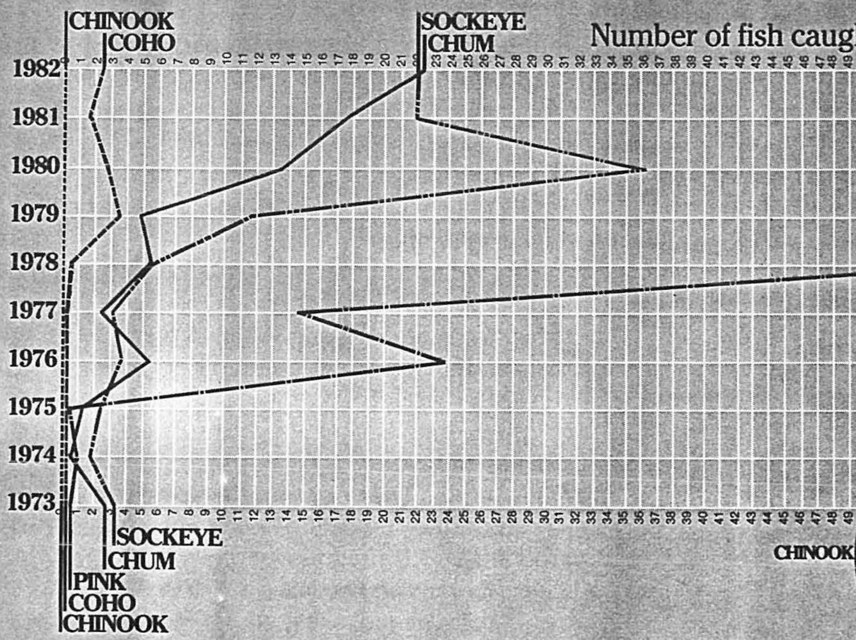
YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	5.2	1,509.2	289.2	942.7	403.5	3,149.8
1981	2.7	1,839.5	78.8	1,162.6	580.3	3,663.9
1980	2.3	860.0	119.6	1,093.2	252.5	2,327.6
1979	1.3	1,049.7	99.1	1,905.2	188.9	3,244.2
1978	1.6	1,576.3	20.2	985.1	120.9	2,704.1
1977	.7	1,972.2	17.4	604.8	110.5	2,705.6
1976	2.3	1,163.7	35.2	395.3	81.4	1,677.9
1975	.5	399.6	53.3	66.2	25.2	544.8
1974	.3	662.9	12.2	70.0	34.4	779.9
1973	.5	870.4	22.3	25.5	8.7	927.4
TOTAL	17.4	11,903.5	747.3	7,250.6	1,806.4	21,725.2
AVERAGE	1.7	1,190.3	74.7	725.0	180.6	
% Each Species 10 Yrs.	.08%	54.8%	3.4%	33.3%	8.3%	
% OF Statewide Catch For Species, 10 Yrs.	.25%	6.3%	2.8%	1.9%	2.4%	ALL: 3.2%

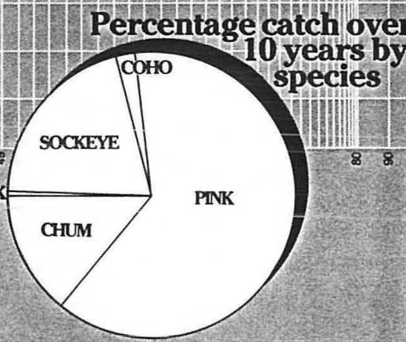
In September 1982 there were 101 limited entry permits for purse seine in the Chignik district.

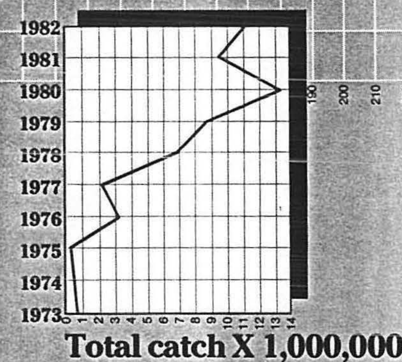
NA

Salmon catch for

South Peninsula District







Summary of Data

Salmon catch, in thousands of fish, for South Peninsula district, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	8.0	2,208.0	249.0	6,601.0	2,219.0	11,285.0
1981	11.0	2,191.8	162.2	5,030.8	1,757.5	9,153.3
1980	4.8	3,613.0	274.2	7,861.5	1,353.1	13,106.6
1979	2.1	1,149.9	356.9	6,564.9	482.9	8,556.8
1978	.8	579.4	60.8	5,590.1	546.2	6,777.3
1977	.6	311.7	2.1	1,448.6	243.2	2,006.2
1976	2.2	375.0	.2	2,366.8	532.5	3,276.8
1975	.1	243.5	.1	60.6	130.8	435.1
1974	.6	197.4	9.4	100.6	71.8	379.8
1973	.4	330.1	6.6	58.1	292.9	688.1
TOTAL	30.6	11,199.8	1,121.5	35,683.0	7,629.9	55,665.0
AVERAGE	3.0	1,119.9	1,12.1	3,568.3	762.9	5,566.5
% Each Species 10 Yrs.	.05%	20.1%	2.0%	64.1%	13.7%	
% Of Statewide Catch For Species, 10 Yrs.	.45%	5.9%	4.2%	9.4%	10.4%	ALL: 8.3%

Limited entry permits held for South Peninsula, North Peninsula, and Aleutian districts (all are open for the same permit) in September 1982 included 127 purse seine, 164 drift gill net, and 116 set gill net.

ALASKA'S SALMON FISHERIES

ALASKA GEOGRAPHIC®

Quarterly

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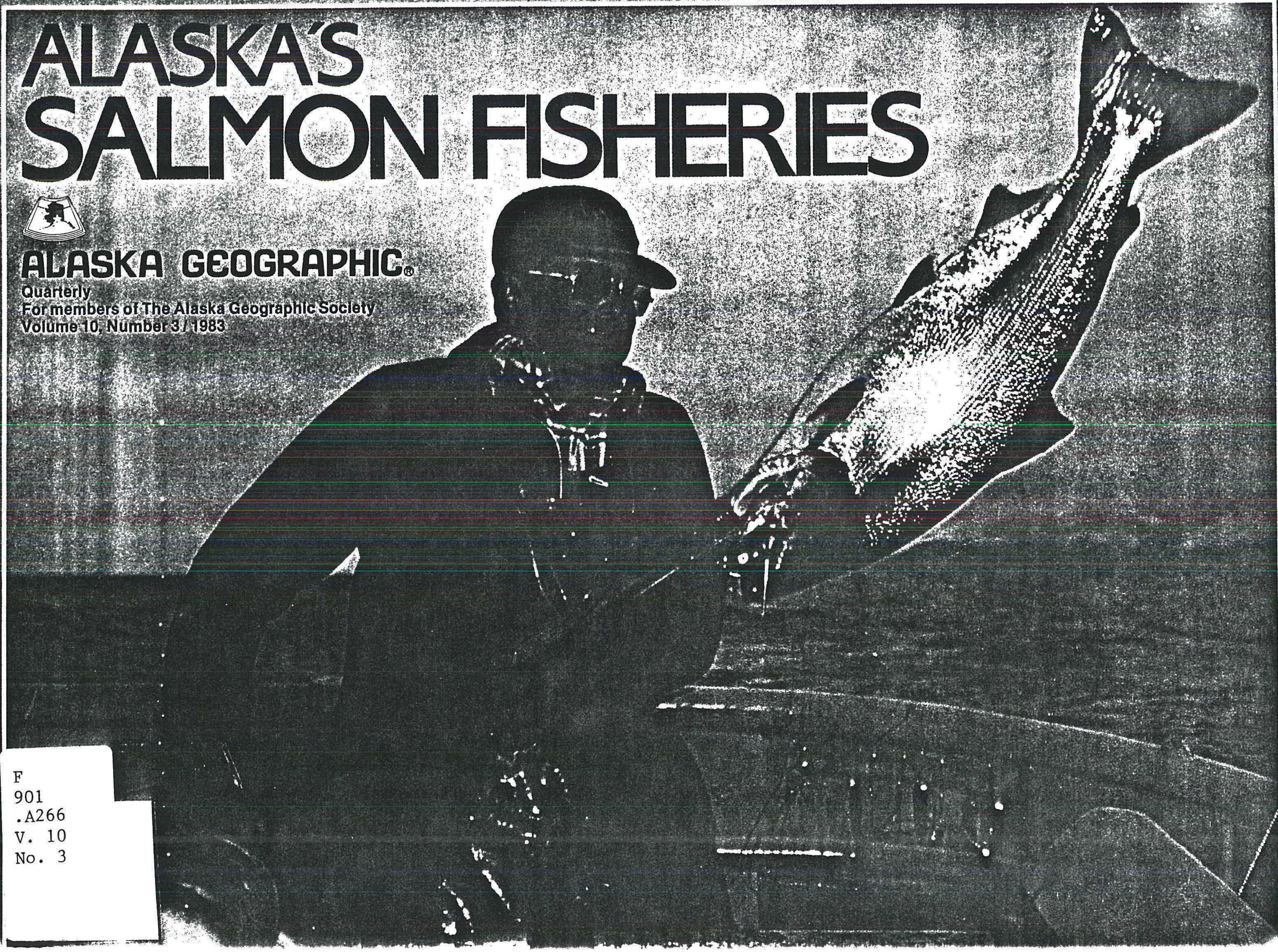
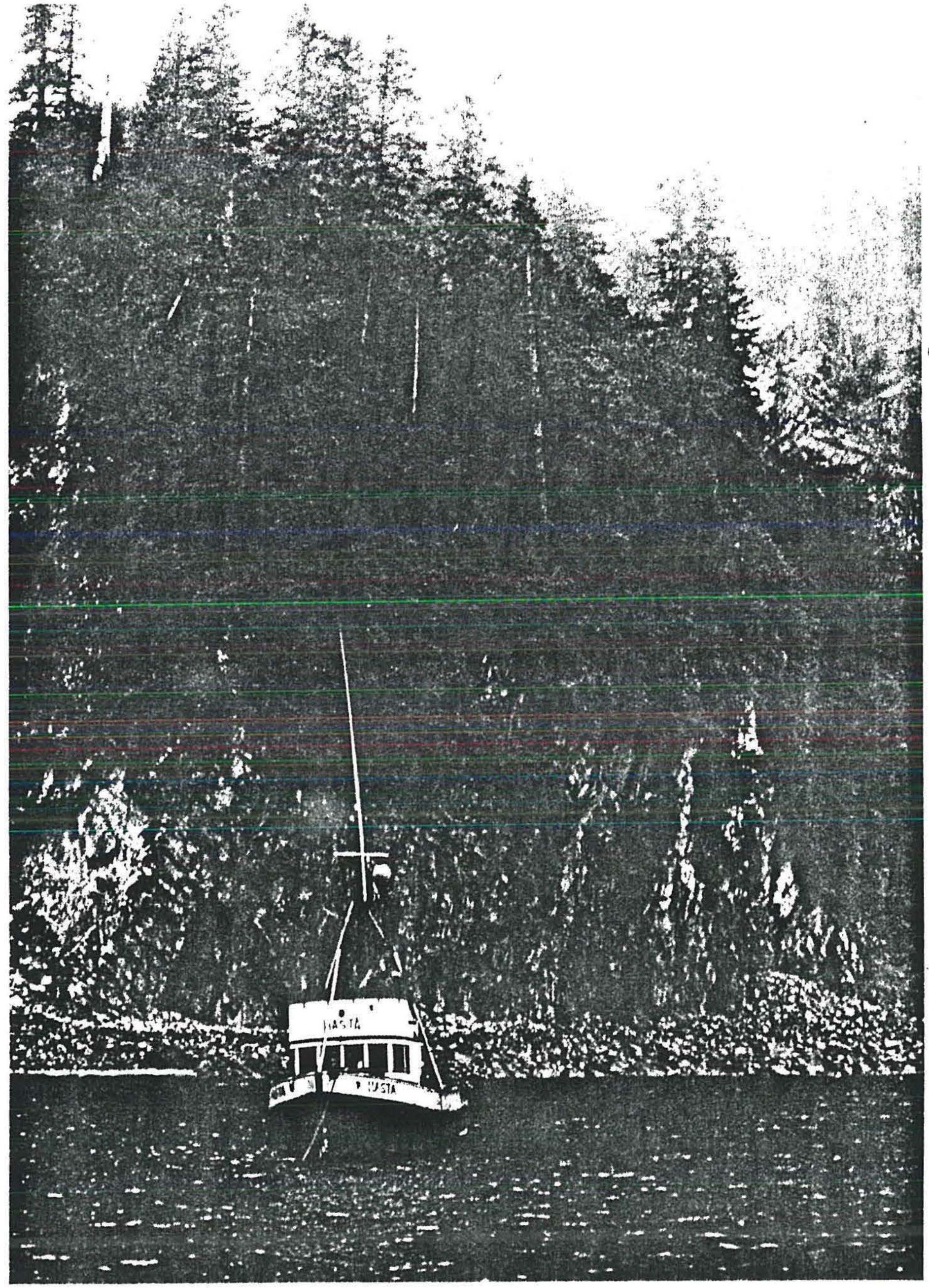


Prince William Sound

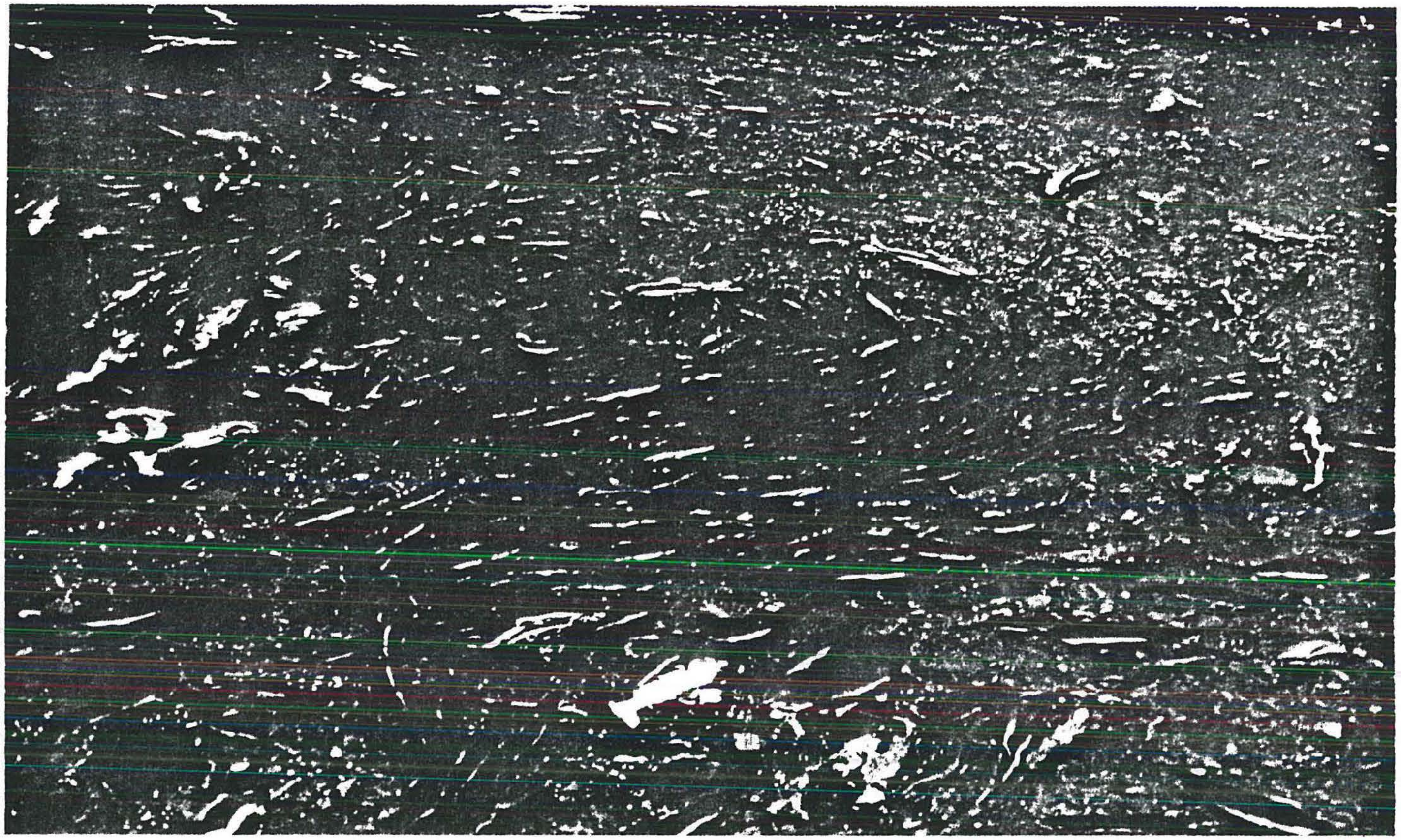
Prince William Sound is fished by purse seines, drift gill nets and set gill nets. As in all other areas of the state salmon fishermen of Prince William Sound have become increasingly more efficient in recent years. High investment in vessels, gear, and entry permits have created an incentive to use each boat and each net as effectively as possible. The fishing vessels are faster and can carry more fish and synthetic fiber nets are stronger and far more efficient than those of earlier decades.

During the 10 years 1973-82 Prince William Sound fishermen caught an annual average of 10.5 million salmon of five species, or 15.7% of the state's total salmon catch. Most of these salmon (83.5%) were pink salmon (an annual average of 8.8 million, 1973-82) for, like Southeastern Alaska, Prince William Sound is pink salmon country. In recent years (1973-82) Prince William Sound produced 23.3% of the pink salmon caught in Alaska.

Next numerous are sockeye salmon, with an annual average of 796,800 caught during the years 1973-82, 4.2% of the statewide sockeye catch. Also, during these years, an annual average of 643,190 chum salmon (8.8% of the statewide catch in recent years), 270,360 coho salmon (10.3% of the statewide catch), and 25,140 chinook



A small Prince William Sound seiner at anchor, awaiting a tide and time to go fishing. *(Jim Rearden, staff)*



Chum and pink salmon in fresh water, as they approach spawning, near Valdez. Dead, spawned-out fish lay on the bottom. The schooled fish have yet to break up into pairs. When paired and actively spawning, salmon scatter out. (Tom Walker)

salmon (3.7% of the statewide catch) were caught in Prince William Sound.

Prince William Sound proper is administratively divided into nine major fishery districts, six for the management of the purse seine fishery for pink and chum salmon, and three smaller districts for the management of sockeye salmon runs which are caught by set gill nets, drift gill nets, and purse seines.

In addition, the Copper River and Bering River districts are included in the Prince William Sound management area; both are restricted to drift gill-net fishing, mainly for sockeye and coho salmon.

Purse seiners, which catch most of the fish in the sound, fish all Prince William Sound districts, except Eshamy, usually beginning in early or mid-July (late July in some years), depending upon the strength of early pink salmon runs, and usually fish into the first or second week of August.

Mountain-surrounded, island-dotted, sheltered Prince William Sound is roughly 60 miles north and south, and 125 miles east and west at the northernmost point in the Gulf of Alaska. The sound is a huge bay containing many coves, bays, harbors, sheltered fjords, narrows and straits, lagoons and islands. Islands range down from 50-mile-long Montague, which lies between the violent Gulf of Alaska and the sound. The Copper River basin, which contributes most of the sockeye and chinook salmon to the Prince

William Sound catch, has long cold winters, and short hot summers. The great valley from which this turbulent giant flows has many clear streams and lakes which are ideal for spawning red and chinook salmon, where fry can grow and feed for the year or three they spend in fresh water, after which they descend the swift stream to the sea.

This is a region of great tectonic activity, with frequent severe earthquakes. One of the world's strongest recorded earthquakes occurred here on March 27, 1964, with shock waves over a 500-mile-wide area. It registered between 8.4 and 8.6 on the Richter scale with the primary epicenter in northern Prince William Sound. A vertical shift ranging from 32 feet of uplift to 6 feet of subsidence occurred in various pink and chum salmon streams of Prince William Sound, with a profound effect on salmon runs to those streams: the pink salmon catch for the sound decreased sharply immediately following the great earthquake.

The most pronounced effect of this uplift and subsidence was in the intertidal area where 35% to 77% of pink salmon spawning had occurred. Stream banks and beds became unstable and surface flows dropped or disappeared in the uplifted intertidal area. Channels were exposed to salt water and increased sedimentation in areas of subsidence. It seems that somehow nature can compensate for even great disasters: decreased numbers of spawning salmon occurred in streams where changes were observed, and increased spawning occurred on unchanged streams.

Between 1967 and 1971 the Alaska Department of Fish and Game attempted to improve Prince William Sound salmon spawning areas damaged by the great earthquake, using state and available federal money. The goal was to stabilize pink and chum salmon streams that had been uplifted or had subsided. Mechanical renovation of such streams included: 1. emplacement of drop structures, 2. channel extension, 3. bank stabilization, 4. channel excavation, and 5. construction of water deflectors on nine high value streams.

The work had to be done between the times when immature salmon left the stream and when spawning adults returned — from about early April until July. The ADF&G vessel *Shad* with a 24' x 60' barge, a tractor, a loader-backhoe, and a crew with hand tools performed the work.

In addition to mechanically improving streams, pink salmon spawners were also fenced into streams. Incubation boxes were used in an attempt to renew lost pink, chum, and sockeye salmon stocks, using eggs from streams with surviving stocks. Adult sockeye spawners were transplanted to Solf Lake from Eshamy Lake.

After several years of field work there was no evidence that the production of pink salmon was increasing, so mechanical renovation was stopped in 1972, and only limited restocking work continued.

Incubation boxes in a few locations produced good survival of pink salmon eggs, while several others failed, due primarily to inadequate water supply.

The natural evolution of streams eased the problem, and the bulldozing and other work speeded the process. Within about a decade of the big earthquake spawning areas had returned to near-normal, and the salmon fishery of Prince William Sound has essentially recovered from what, at the time, appeared to be severe damage.

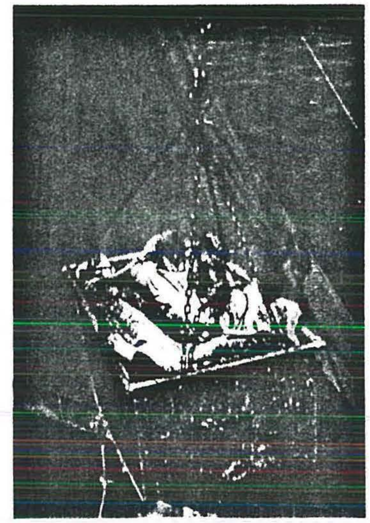
Volcanism shaped many of the peaks that surround the sound, and scientists keep a wary eye on many of these apparently dormant mountains. Glaciers provide source water for many of the mainland streams, including the great Copper River, one of Alaska's largest.

High peaks of the Chugach Mountains on the east and north, and the great Kenai Mountains on the west, form three walls around Prince William Sound. Moisture-laden air from the Gulf of Alaska dumps vast amounts of rain and snow on the steep and high mainland mountains to create a typical wet and windy maritime climate, with abundant snow and rain, varying between different parts of the sound. During fall and winter winds of the gulf commonly blow from 30-50 MPH, occasionally reaching 100 MPH.

Cordova's average annual temperature is about 38° F, with precipitation of about 92 inches: Valdez, farther from the sea, is cooler, averaging 36° F, with 59 inches of precipitation. For real precipitation, there is Whittier, at the base of the high weather-blocking

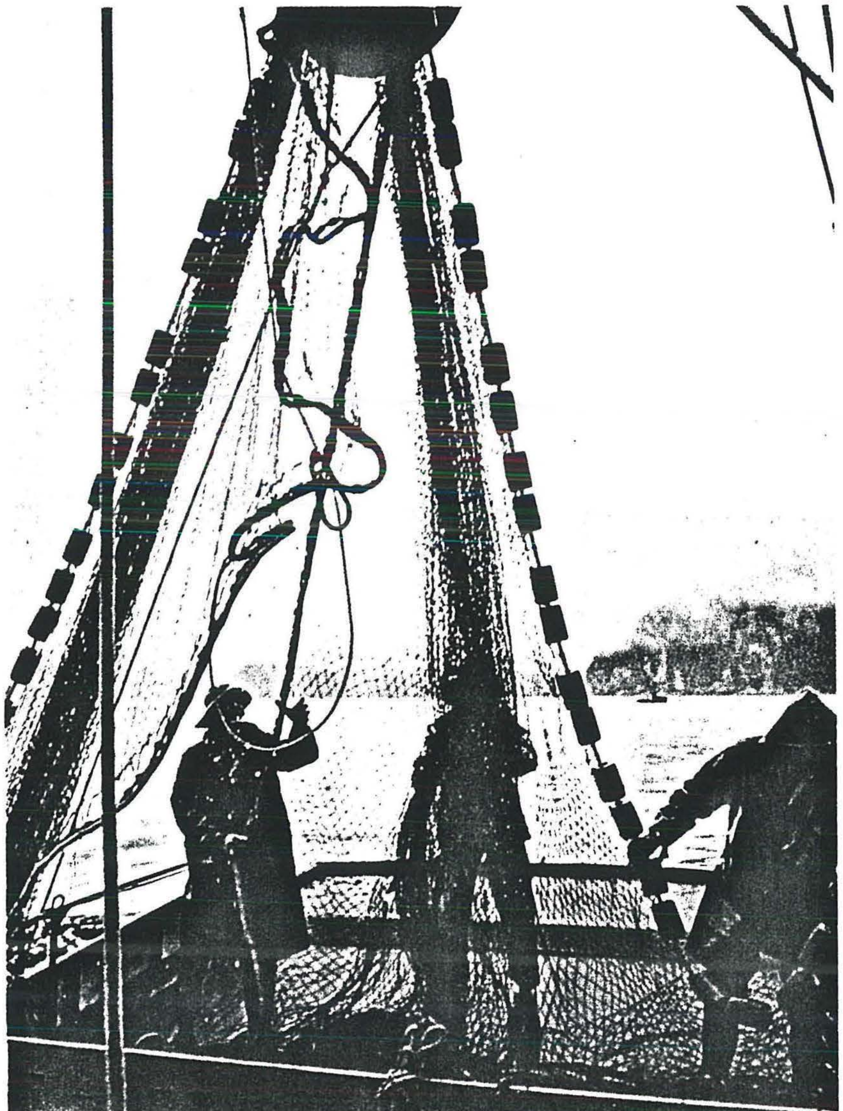
Opposite — ***Sheep Bay, Prince William Sound, with an anchored fishing boat.*** *(Jim Rearden, staff)*

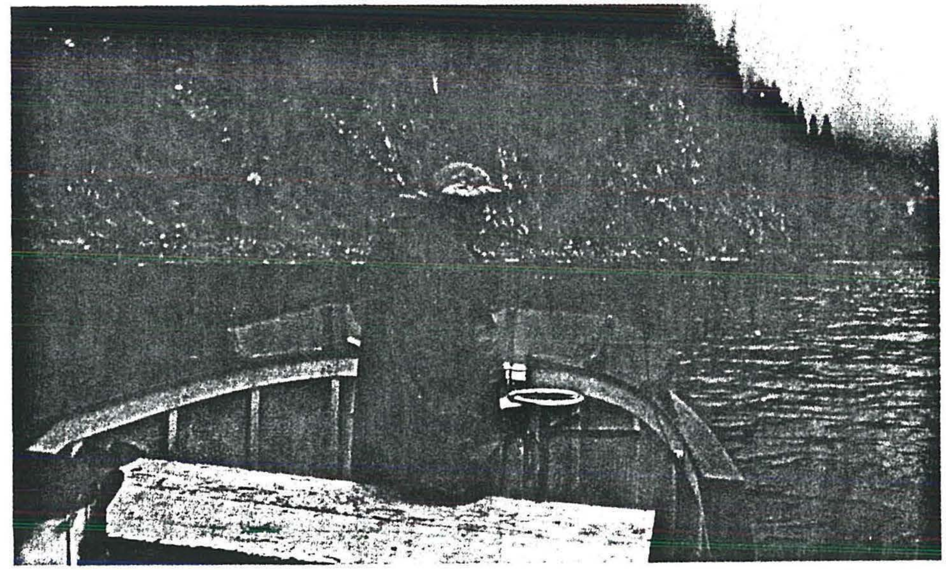
Below — ***A box of fresh-caught coho salmon is lifted from a salmon boat.*** *(Matt Donohoe)*



*Below — **Crewmen pile the purse seiner of the** Invader **during a set in Prince William Sound. Net is being pulled aboard by the hydraulically powered block at the top of this photo.*** *(Jim Rearden, staff)*

*Right — **Harry Hamilton, skipper of the seiner** Invader**, at Point Elrington, Prince William Sound, waiting his turn at the lead.*** *(Jim Rearden, staff)*





Chugach Range, with an average of 175 inches annually. These are the three major ports in Prince William Sound.

The pink salmon fishery of the sound has produced more than 1 billion pounds since 1896. Peak year for pinks in Prince William Sound was 1982 when about 20.3 million of the spotted, rich-fleshed swimmers were caught as they returned to their home spawning streams.

An abrupt increase in catch of Prince William Sound pink salmon, from an average of about 3 million, occurred in 1979 when 15.6 million were caught: each year since has seen catches above any previous year's back to 1910. The 1980 catch was 14.2 million, in 1981 it was 20.5 million, and the 1982 catch was 20.3 million. Since 1910, the pink catch of the sound has exceeded 10 million only eight times: four of those have been since 1979.

The abundant short streams and the high rainfall of Prince William Sound closely resemble those of Southeastern Alaska, and, as in Southeastern, pinks bound for widely distributed streams arrive at capes and passes and points in large schools as they reenter the sound. Fishermen meet them, and large numbers of the schooled fish are taken at these well-known concentration points or "cape fisheries."

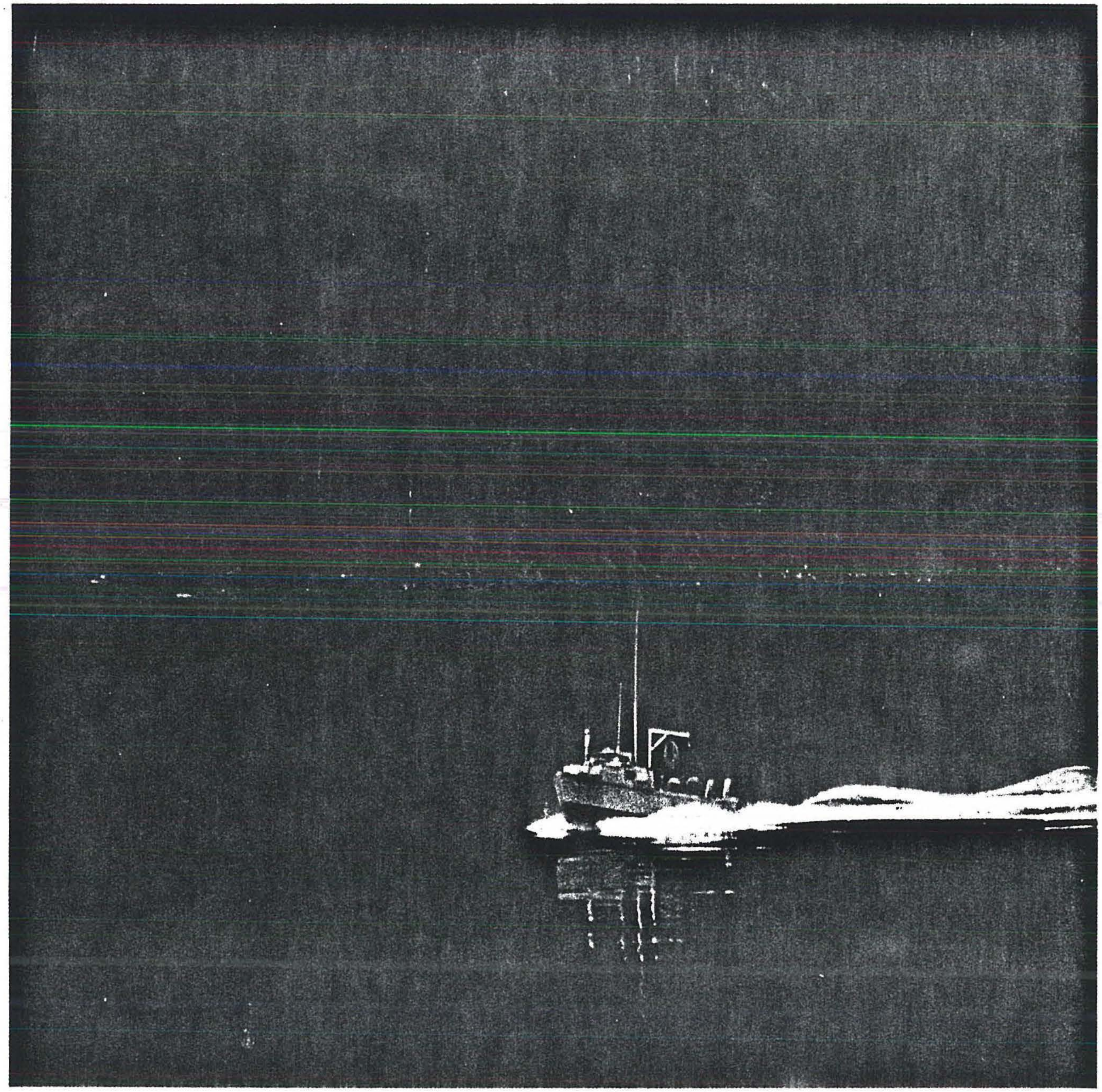
Sockeye salmon. The average catch of sockeye salmon from Prince William Sound (including the Copper and Bering rivers) averaged 796,800 annually during the 10 years 1973-82. Most of these fish were caught in the Copper River fishery.

The Copper River District opens for the fishing of sockeye salmon in mid-May, the earliest salmon fishery in Prince William Sound, and one of the earliest in the state. The Copper River fishery averages a catch of about 625,000 sockeye salmon annually. The 1982 catch of 1.2 million was the highest recorded in recent years.

The dry catch statistics don't show it, but the Copper River drift gill-net fishery is probably the most dangerous salmon fishery in Alaska. Fishing takes place off the mouth of the great, muddy, rapids-filled Copper River, which flows for 250 miles from the north side of the Wrangell Mountains through the Chugach Range into the Gulf of Alaska east of Prince William Sound.

Upon their return as approximately 7-pound ruby-fleshed, silver-sided, fat, vigorous adults, eager fishermen, with 24- to 30-foot mostly fiberglass bow-pickers (the net is layed and retrieved from the bow), with inboard-outboard power, brave the surging seas just outside the breakers where they lay out their 150 fathoms of drift gill net to catch these prime fish. During the 1950s through the 1970s Copper River flats fishermen used beamy, shallow-drift, rugged, outboard-powered "Cordova skiffs," with a tiny forward cabin and a gill net roller astern. Sudden storms and cranky slow-starting engines that allowed boats to drift into the violent surf both claimed many lives over the years in this rich fishery.

The Bering River District, adja-



A drift gill-netter speeds across Prince William Sound. *(Frank Bird)* cent to the Copper River, is a drift fishery mostly for coho and sockeye salmon: fishing starts in mid-June and may continue as late as mid-September. Coho salmon is the major species in the Bering River District, with average catches of around 60,000 annually.

The earliest salmon fishery in the sound proper is that of the Coghill-Unakwik district, which starts in late June and normally ends about mid-July for drift gill nets. Purse seine fishing in these districts coincide with drift gill-net fishing, but lasts beyond the mid-July gill net closing date in order to harvest later runs of pink and chum salmon.

A surprise run of sockeye hit the Coghill district in 1982. The 10-year average catch prior to 1982 was 108,000; but the 1982 catch was 942,000 sockeye, averaging 6.5 pounds. Further, at the Coghill weir 180,000 sockeye were counted into spawning areas: goal for that area was 50,000 to 60,000. For every parent spawner, about 40 fish returned in 1982, an almost unheard-of survival rate.

The Eshamy district, where there is a late red salmon run, usually begins in early July and extends into September. Purse seines fishing in the Southwestern district in July and August catch about 30% of the Eshamy reds before they reach the gill-net fishery.

Chum salmon, like the pink salmon, thrive in the short stream environment of Prince William Sound proper. Over the years chum catches have been less prone to great variations in run size: it is a relatively stable fishery. In the early 1970s the maximum sustained yield (MSY) for the chum fishery for the sound was estimated to be about 605,000 fish annually, based upon the catches of the years 1924-48.

Pink salmon piled in the hold of a cannery tender bound for the cannery, Prince William Sound. *(Jim Rearden, staff)*

The average catch of chums for the years 1973-82 was 643,190 — reasonably close to the estimated MSY.

Coho salmon are caught in Prince William Sound proper mostly incidentally to pink and chum salmon in the purse seine fishery. The Copper and Bering rivers gill-net fisheries produce far more cohos. The cohos are incidental to the sockeye during the early season, but later the catch is almost all cohos. The estimated maximum sustained yield for the Copper-Bering coho fishery is about 207,000 fish annually.

The total coho catch for Prince William Sound, including that of the Copper-Bering rivers, averaged 270,360 fish annually from 1973-82, with catches that ranged from 76,000 to 615,000 — the latter a record breaker in 1982.

King Salmon of Prince William Sound are mostly caught incidentally to the sockeye in the Copper River fishery. During the 10 years 1973-82 the annual average catch (for all Prince William Sound, including the Copper and Bering rivers) was 25,140 kings. The 1982 catch of kings, following the trend of other species for the sound, was also a record breaker, with 49,200 fish netted. The previous high catch of kings was 32,800 caught in 1976.

ment managed the Cook Inlet (and all of Alaska's) fishery was 1959. In that year inlet fishermen caught the fewest salmon taken since the earliest days of the fishery — only 1.3 million, about one-third the average of the previous five years' annual catch.

It was now the state's job to rebuild the salmon fishery.

Cook Inlet — How It Is Today

Cook Inlet is a tapered bay that extends north and east for about 220 miles from the northern Gulf of Alaska. During the 10 years 1973-82, Cook Inlet's commercial salmon fishermen caught an annual average of 4.6 million salmon, or about 6 % of the statewide catch.

Cook Inlet's waters, in common with the other great gill-net fishing districts of Alaska, are silty. Most major streams that pour into the inlet carry silt, much of it from glaciers. The biggest include the great Susitna River, at the head of the inlet, the nearby Little Susitna and Matanuska rivers, and, about halfway down the inlet on the east side, the Kenai and Kasilof rivers.

The northern 190 miles of the inlet are perpetually murky, and the line between clear and murky water is often abrupt. Usually this line is found at about the latitude of Ninilchik, but it moves north with large tides, and south with minus low tides. Above the Forelands — which is the sharp narrowing about two-thirds the way up the inlet — the inlet appears to be liquid mud.

The inlet is rimmed on the west by volcanic peaks: cone-shaped Mount Augustine, which last errupted in 1975, is an island in the lower inlet; Mounts Iliamna and Redoubt are perpetually snow-capped steam-venting peaks of around 10,000 feet in the Aleutian Range; and Mount Spurr, which last errupted in the early 1950s, is an 11,020-foot peak in the Alaska Range. The generally low shoreline of the Kenai Peninsula lies on the eastern side of the inlet.

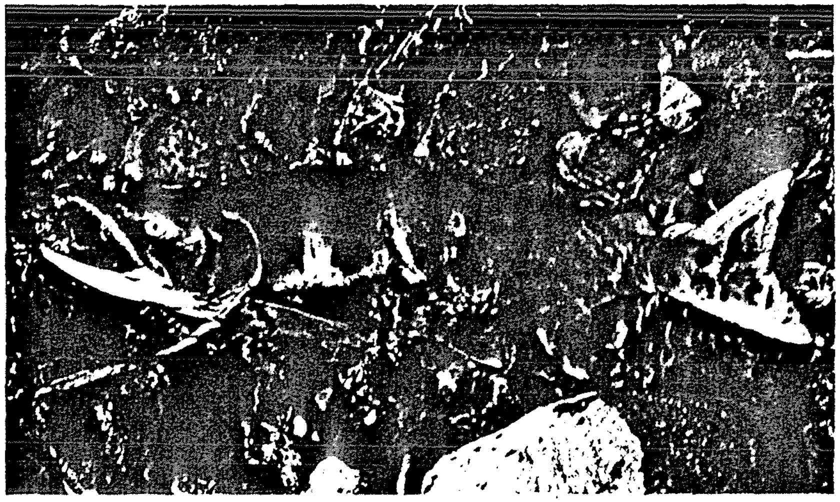
The climate is primarily northern maritime, although colder continental conditions prevail in the northern interior basins of the inlet. Cool cloudy summers, wet autumns, variable but typically cold winters, and relatively cool, dry springs are found.

About half of Alaska's human population lives in the Cook Inlet basin. Anchorage (pop. 173,000), Alaska's largest city, lies at the head of the inlet. Kenai (4,300), and Soldotna (2,320) are found on the upper Kenai Peninsula. Homer (2,211) and Seldovia (473) lie on opposite sides of Kachemak Bay, a 30-mile-long, deep, clear-water bay which juts easterly from Cook Inlet near the tip of the Kenai Peninsula. Ninilchik (336), Tyonek (239), English Bay (53), and Port Graham (162) are villages on the shores of the inlet.

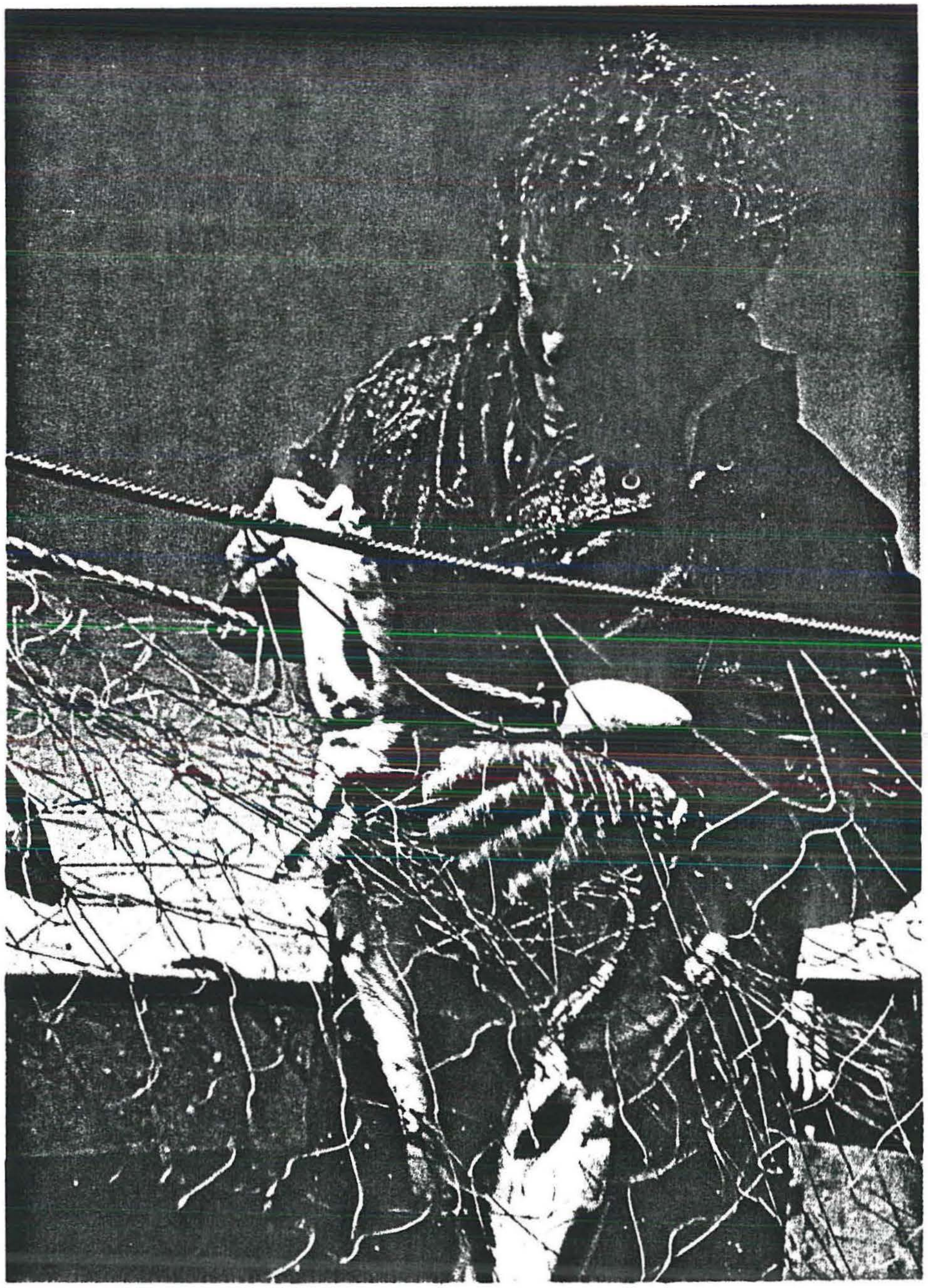
Cook Inlet has long been known for its stable salmon fishery: cycles of abundance and scarcity are not generally as severe as those of many other of Alaska's salmon fisheries. The great diversity of spawning streams and lakes that surround the inlet, with the broad range of climatic conditions, probably account for this: when severe weather causes mortality in streams and lakes of one part of the inlet, moderate conditions may be found elsewhere, with consequent higher salmon survival.

The inlet has the largest tides in Alaska, with maximum high tides reaching nearly 33 feet at the northern end. The inlet narrows to the north, compressing the incoming tide. At narrow points, as between the Forelands, and between Harriet Point and Kalgin Island, tides may flow at 8 knots or more. Tidal swirls and rips are common throughout the inlet, making small boat navigation interesting.

Fishermen pay a penalty for fishing in the gill net districts of Cook Inlet, for compared with many other fishing



A bear-killed red salmon. Alaska's coastal bears feast on spawning salmon. *(Tom Walker)*



Skipper Pete Islieb picking sockeye salmon from his drift gill net. Nylon fish gloves hold slippery fish. *(Freda Shen)*

districts, the inlet is rough and difficult to navigate. Distances are considerable — with about 70 miles of open water between the northern and southern boundaries of the drift gill net (Central) district and 30 to 40 miles between the eastern and western shores. The usually rough seas that build with strong southwest summer afternoon breezes whooping up the inlet toss the average 30- to 35-foot drift gill-netters about violently, often forcing a stop to fishing. The 20-foot set-net fishermen's skiffs are difficult to launch, and the, nets hard to pick.

Although the upper inlet is not considered important as a salmon feeding and rearing area, it is the route for the five species of salmon that leave their home streams and go to sea; they return as adults through the swift tides and murky turbulent waters to their home streams.

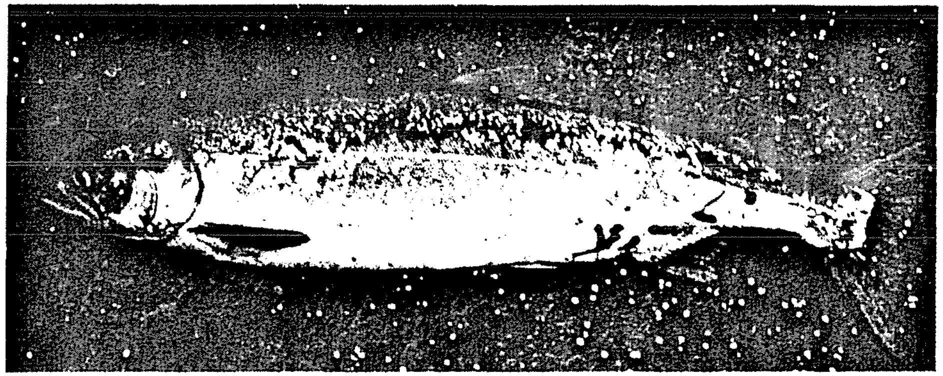
Sockeye salmon, with its ruby red flesh, was the lure that brought early salmon packers and fishermen to the inlet. It is still the main lure. The fish arrive in a great flood in July, pouring from the Gulf of Alaska through Shelikof Strait and the wind-and-tide-tossed waters between the Barren Islands and the tip of the Kenai Peninsula. Scientists who have tagged these fish in the lower inlet found that most arrived on the west side of the lower inlet to swim northeast, heading mostly for the great Kenai and Kasilof rivers. The Kenai River is the largest producer of sockeye salmon in the inlet, and the huge Susitna is second largest. Depending upon weather, Susitna-bound fish may follow the east or west shore of the inlet as they seek the mouth of the Susitna. Others home on numerous other streams around the inlet.

The multiplicity of streams connected to lakes that flow into all sides of Cook Inlet (sockeye generally spawn only in drainages where there are lakes) has resulted in a wide variety of races or types of sockeye salmon: some are big, deep, and heavy. Others are long and slim. A few are tiny, barely 2 or 4 pounds.

Cook Inlet's sockeye salmon catch, on average, is the second largest for that species in Alaska, coming only after that of Bristol Bay, although the inlet produced only about 8.5% of the sockeye caught in Alaska during the years 1973-82. Normally about 60% of returning Cook Inlet sockeye are five-year-olds; from 15% to 20% are four-year-olds; and less than 20% are six-year-olds.

Sockeye is the money fish in Cook Inlet, and during 1973-82 an annual average of 1.6 million sockeye were caught — about 8.5% of the statewide catch of sockeye for the period. Sockeye made up 34.5% of the total inlet catch. Major runs of sockeye swim into the Kenai, Kasilof, Susitna, and Crescent rivers — all in the Northern and Central districts. The peak of the sockeye fishery is usually between July 15 and 20.

Salmon traps caught most of the inlet's sockeye for many years. Since statehood, and the banning of salmon traps, gill nets have caught virtually all of the inlet's sockeye. By the early 1950s between 500 and 600 drift gill nets annually fished the silty waters of the inlet for reds — about the same number as today. However, fishing time allowed in those years was five 24-hour fishing periods a week: today the basic time is two 12-hour fishing periods a week.



A fresh-caught pink salmon, its scales as shiny as new dimes, lays on the deck of the seiner that caught it.
(Jim Rearden, staff)

From its start in 1893 the inlet's sockeye catch has reached or exceeded 2 million 10 times. Largest catch ever, of 3.1 million, was made in 1982.

While sockeye was the original attraction for packers and fishermen, in recent years the other four species have also become important.

Pink salmon are the most abundant salmon in Cook Inlet. For the years 1973-82 this species made up 39.6% of the total catch (numbers of fish), with an annual average catch of 1.8 million. This was about 4.4% of the statewide catch of pinks of those years.

Pink salmon in the gill net districts of the inlet (north of Anchor Point) have a distinct even-year cycle: catches range to perhaps 100,000 fish in odd years (although there was an inexplicable catch of 554,000 pinks in these districts in 1977 — the largest ever odd-year pink catch) but it ranges from 1 to 2 million in even years.

Major pink-producing streams include Kenai River and the Susitna River at the head of the inlet: the clear-water Talachulitna River, a tributary of the Susitna, is probably the most important pink producer, with as many as 1 million pink salmon spawners in some years.

Prior to about 1940 the smaller (average 3 to 4 pounds), spotted, and soft-fleshed pink salmon were incidentally caught by fishermen using large-mesh (5¼-inch or larger) gill nets seeking sockeye, chum, coho, and chinook salmon, but now pinks are of importance on their own, and pink gill nets with a 4-inch or slightly larger mesh are commonly fished after the bulk of the sockeye have passed.

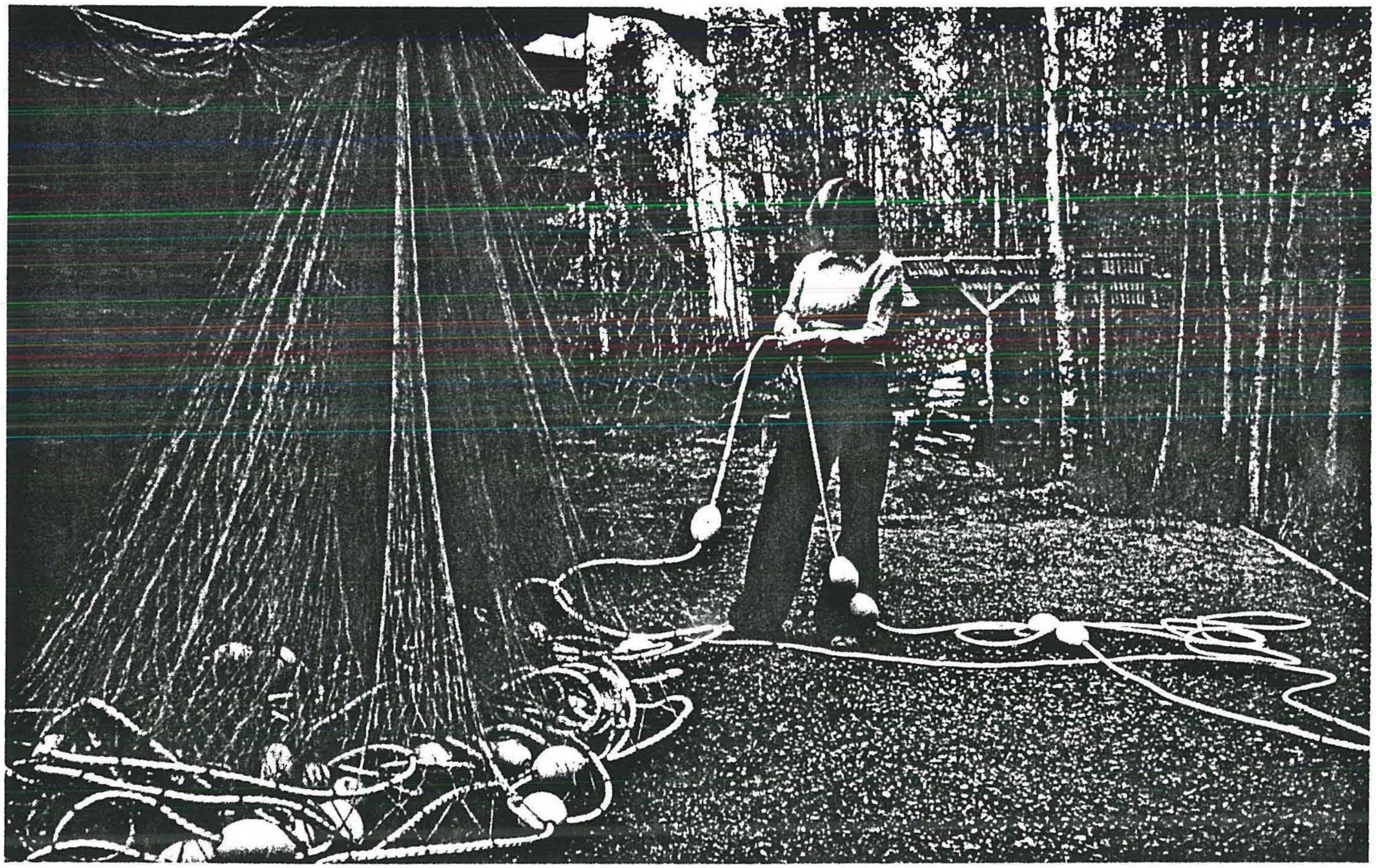
Pink salmon are the primary species caught by Cook Inlet's hand purse seine fishermen who fish south of Anchor Point. During the period 1948-61 the annual average catch here was around 480,000 pinks. Then, unexpectedly, in 1962, the catch soared to 2 million pinks. Two years later, in 1964, the catch was still high at 1 million.

From 1965 through the early 1970s the annual pink catch south of Anchor Point averaged 374,000. Catches during the early 1970s were poor. Then in the late 1970s a major change took place: the dominant even-year pink runs changed so that the odd-year pink runs became dominant. In 1979 the catch was 2.9 million, of which 375,000 were produced by a state hatchery in Tutka Lagoon — on the south side of Kachemak Bay.

The 1980 catch of 728,000 was well above the average. Then in 1981, the catch was 2.8 million pinks, of which 1 million were produced by the Tutka Lagoon hatchery. Instead of a 1% to perhaps 3% return of fry, biologists estimated that the return to the hatchery was perhaps 15% to 18% — an almost unheard-of survival rate for pink salmon. Credit was given to short-time rearing and feeding of the fry before they were released in Tutka Lagoon to make their way on to their 14-month sea-faring odyssey.

In 1982 the Tutka Lagoon hatchery return was only 231,800 pinks — far below that expected.

Chum salmon in upper Cook Inlet are a "me too" fish: they are caught



Susan Beeman hanging a set gill net (attaching lead and cork lines). She's working on the cork line. *(Tom Walker)* mostly by gill-net fishermen who are seeking the more valuable sockeye. They are about the same size as the sockeye and nets designed for sockeye are equally effective in taking chums. Chums made up about 19% of the Cook Inlet catch for the 10 years 1973-82, with an average annual catch for those years of about 871,000. Normally about 85% of these are caught by gill-net fishermen north of Anchor Point, and the balance by hand purse seiners fishing in the sheltered bay of the lower Kenai Peninsula, and in the often-stormy Kamishak Bay.

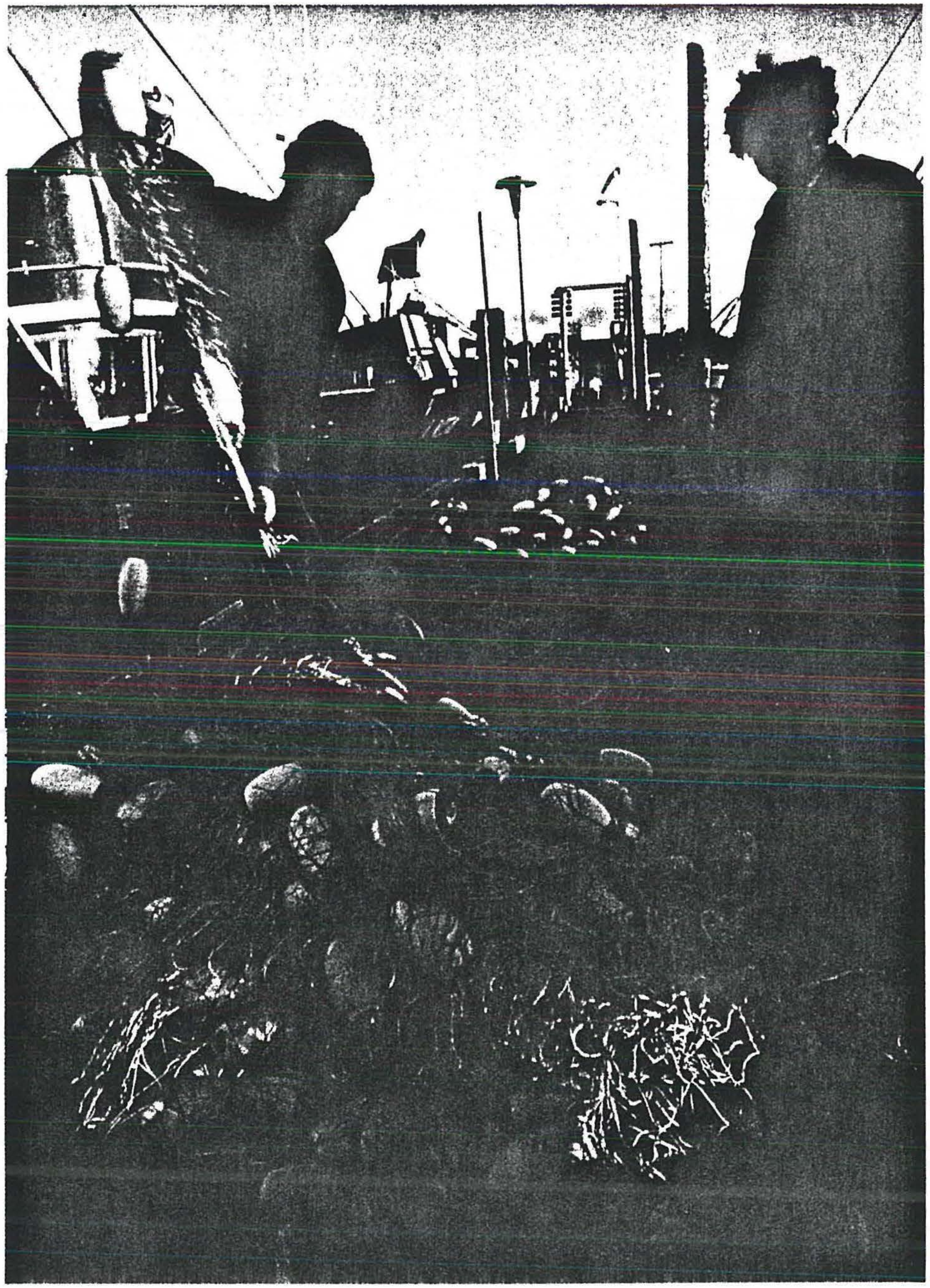
Chums are predominantly four-year fish in Cook Inlet, and they tend to have an even-year cycle.

For the gill-net fishery, the peak of the chum run occurs about a week after that of the sockeye — or sometime shortly after about July 20.

The vast Susitna basin produces about 90% of the chums of the gill-net fishery of the inlet. Chinitna Bay and Kamishak Bay, both on the west side of the lower inlet produce chums, as do certain bays of the lower Kenai Peninsula — Rocky, Windy, Port Dick, Seldovia, and Port Graham bays, among others.

Peak catches of chums in Cook Inlet occurred in 1964 (1.4 million), 1977 (1.3 million), and 1982 (1.5 million).

Coho salmon are another "me too" salmon in Cook Inlet that are caught mostly by fishermen who set their nets for the more valuable sockeye. The average annual coho catch for the inlet, 1973-82, was 30,400, or about 6.5% of the inlet's salmon catch. It was also



Paul Jones, of Homer, wrestles with his drift gill net, readying it for rolling it onto his gill-net reel.
(Jim Rearden, staff)

This 78½-pound king salmon was caught on sport tackle in the Kenai River by the late J.J. Smith, who stands behind the huge fish. Smith is 5′ 6″ tall. *(Jim Rearden, staff)*

11% of the total statewide coho salmon catch for that 10-year period, which says that Cook Inlet is an important coho producer.

At least 95% of the annual commercial coho catch is made by gill-net fishermen north of Anchor Point. Largely a four-year fish, the inlet coho tends to have an even-year cycle, but the cycle is not as pronounced as that of the pink salmon.

Coho salmon are found in almost every spawning system of the inlet, and they tend to be rather evenly distributed around the inlet — more so than any other species. They start arriving in mid July, and some coho are still arriving as late as October. The peak of the coho run for the upper inlet is in late July.

Because the coho arrives and enters streams in the fall when water tends to be high and murky from fall rains, fishery managers seldom have much information on the numbers that reach spawning grounds.

The smallest coho salmon catch in 50 years occurred in 1972 when only 83,000 were taken. Remarkably, the coho has made a tremendous recovery: the largest catch of coho ever for Cook Inlet was in 1982, when 765,400 of the silver-sided salmon were landed.

King salmon, silvery, black-spotted, huge, rich-fleshed, are now relatively unimportant to Cook Inlet's commercial fishermen. For the 10 years 1973-82, an annual average of 12,470 were caught — less than 1% of the inlet's salmon catch, and 1.8% of the statewide commercial catch of kings.

It was not always so. Greed almost destroyed Cook Inlet's kings. From 1924-40, commercial fishermen caught an average of 66,000 Cook Inlet kings each season. Then the catch increased: from 1941 to 1953, the catch averaged 109,000, with the largest catch ever in 1951 when 187,000 king salmon were caught.

After that it was all downhill, until shortly after statehood when a total closure for commercial and sport fishing for king salmon throughout the Cook Inlet basin allowed stocks to rebuild.

By 1977 more than 100,000 spawning king salmon were counted in the Susitna basin, and the species now seems secure.

Virtually all the king salmon caught by commercial fishermen in the inlet are taken by gill-netters north of Anchor Point. Kings enter the inlet in two separate runs: the early run is the big one, and it is bound for the Susitna basin. The bright strong sea-fresh fish arrive in the inlet about May 25, and by mid-June most have reached the silty Susitna and scattered to the many clear and not-so-clear streams where they spawn.

The second run, which arrives in June and continues through most of July, is bound mostly for the Kenai-Kasilof rivers. This is the run from which most of the commercial harvest is taken today. The current late June opening of commercial salmon season in the inlet comes well after the Susitna-bound kings have reached their spawning areas.

The Kodiak District

Kodiak Island, in the turbulent western Gulf of Alaska, 100 miles long, 60 miles wide, is Alaska's largest island. Thirty-mile-wide tide-and-storm-tossed Shelikof Strait separates lovely Kodiak Island from the Alaska Peninsula.

A spine of steep, rugged mountains runs the length of Kodiak; deep fjords and bays indent the coastline into which hundreds of short streams and rivers flow. Many small lakes and ponds are scattered across the glaciated surface of lush Kodiak and nearby spruce-covered Afognak Island. Only the northern end of Kodiak Island has spruce trees: the rest is grass, alder, and a wide variety of brush and forbes. The Karluk and Red rivers, both about 25 miles long, drain much of southwestern Kodiak Island. Karluk River, including 12-mile-long Karluk Lake, and Dog Salmon River, including 9-mile-long Frazer Lake, are among the most important salmon producing systems.

The annual average 60 inches of precipitation and the cool-to-mild maritime climate produce luxurious near-tropical plant growth. Severe storms with high winds are common. The temperate North Pacific waters that surround Kodiak are alive with a wide variety of marine life.

The Kodiak area is fished by purse seines, beach seines, and set nets. During the 10 years 1973-82 Kodiak's salmon fishermen caught an annual average of 10 million salmon of all five species — or about 15% of the total statewide catch of salmon. Most of these fish were pink salmon (85%), for the many short streams of Kodiak are ideal for this species. Chum salmon are the second most abundant salmon of the Kodiak area, and in recent years about 7.2% of the catch has been of chums.

The town of Kodiak (pop. 4,746) on the north end of Kodiak Island is the main human and trade center. Akhiok (105), Port Lions (215), Ouzinkie (173), Karluk (96), Old Harbor (334) and Larsen Bay (144), are villages on and around Kodiak Island. The Alaska Marine Highway (state ferry), and regular airline service provide transportation to and from the island. Few roads exist, and most local transportation is by small plane or boat.

Purse, hand purse, and beach seines are used to catch salmon in all Kodiak districts except for Olga and Moser bays, where only set gill nets are permitted. Set nets also fish in a few other areas on the west side of the island.

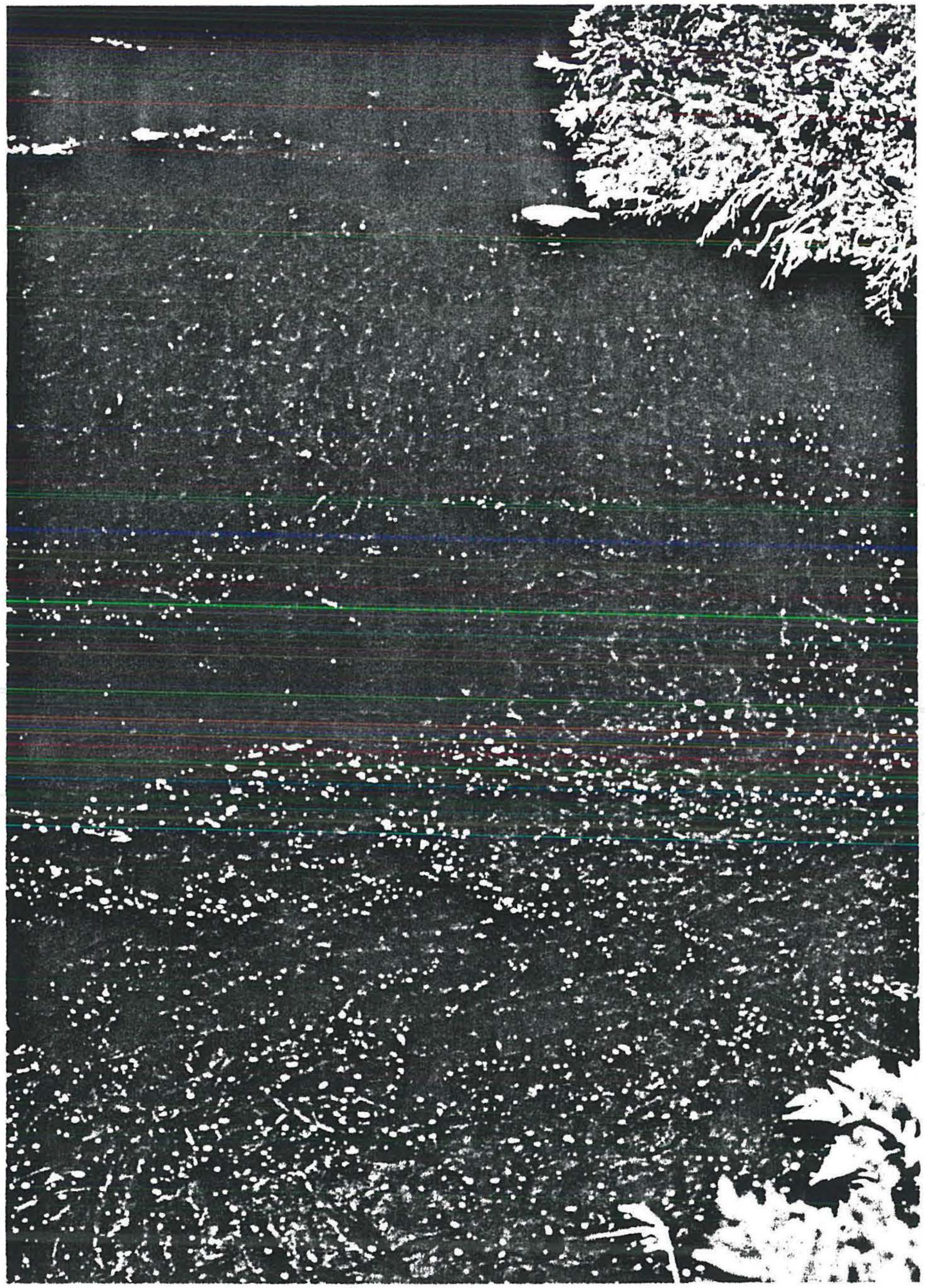
King salmon catches are minor in the Kodiak area, averaging about 1,100 fish a year during the 10 years 1973-82. The Karluk and Red rivers have the only natural king salmon runs. Kings were apparently successfully introduced into the Dog Salmon-Frazer Lake system in the mid-1960s.

Red salmon dominated the Kodiak fishery in the late 1890s and early 1900s, but today it is only the third most abundant species. Average annual sockeye catch 1973-82 was 683,500, making up 6.8% of the Kodiak catch. There are more than 30 sockeye-producing systems in the Kodiak fishing area, but only four of these —Karluk, Red River, Upper Station, and Frazer Lake are of real importance.

Frazer Lake, which drains into Olga Bay, is one of Kodiak's largest lakes. It had no salmon runs because of an impassable (to salmon) falls. In 1951 the Territorial Department of Fisheries introduced red salmon into the lake, and followed up the egg plant with introduction of live spawners over a period of several years. As sockeye returned to the Frazer they were netted and carried over the falls in backpack tanks. The run gradually increased. In 1962 fishways were built which put an end to backpacking salmon: they can now swim across the falls on their own. This run, one of the few successful man-established sockeye runs anywhere, is still increasing: in 1982, 400,000 eager, flipping and splashing sockeye swam through the fishway and into Frazer lake to spawn.

Karluk Lake, on the west side of Kodiak Island, once sustained the greatest red salmon fishery known for any single river and lake anywhere. The 12-mile-long lake and 24-mile-long river which flows through Karluk Lagoon and into Shelikof Strait, produced a catch of 4 million in 1901. Between 1887 and 1928, the average annual catch of sockeye from the Karluk was 1.9 million.

Salmon and crab fishing boats crowd the Kodiak harbor. Some boats are used for both, and rigging is changed seasonally. *(Sharon Paul, staff)*



Pink salmon in Portage Creek, Afognak Island. (Dennis Gretsch)

Since 1938, when 1 million were caught, the catch has declined. In 1982, although the escapement goal was 800,000 for the Karluk, only 132,000 red salmon arrived.

Despite years of research and good numbers of spawners over the years the Karluk red run hasn't increased: no one knows why. A large even-year run of pink salmon to the Karluk complicates the picture: how do you harvest large numbers of pinks without taking more sockeye than you want?

Each year, when regulations permit, Kodiak seiners run to Cape Igvak on the mainland, where they net good numbers of sockeye. A tagging study of these fish showed that most were bound for Chignik, to the south, and some were bound for Cook Inlet, to the north. If a weak run is expected at Chignik this fishery is curtailed.

The Alitak district, on the south end of the island, has historically been second only to the Karluk in producing large red salmon catches. Upper Station, Frazer, and Akalura are the major producers there.

The Kodiak red salmon catch for 1982 of 1.2 million was the second largest red salmon harvest in 34 years. The catch of 215,000 sockeye at Cape Igvak plus fair to good runs to Kodiak Island systems accounted for this.

Pink salmon eggs hatch and eventually the fry wriggle out of the gravel to almost immediately go to salt water. Stable water levels, clean gravel, cool summer and mild winter temperatures are major requirements for a pink salmon stream.

Most of the approximately 300 streams in the Kodiak management area meet these requirements, and most of them produce pinks. The bulk of Kodiak's pink salmon, however, are found in about 31 of the major rivers.

Today more than 90% of Kodiak's pink salmon are caught by purse seiners. Pink salmon were relatively unimportant in the Kodiak area until after about 1912. Catches from 1934 through about 1947 were especially good, averaging 8.5 million fish.

After a decline, catches again increased with the average annual catch from 1962 to 1970 being about 8.6 million.

The average annual catch for the 10-year period 1973-82 was 8.5 million. This was 22.5% of the statewide catch of pink salmon. Peak year was 1980 when 17.2 million were caught: other top years were 1937 with a catch of 16.7 million, 1962 with a catch of 14.1 million, and 1978, with 15 million.

In the past the odd-year cycle of pinks dominated. In the mid-1970s the even-year cycle was dominant, with weak runs in odd years. Since then both even- and odd-year catches have been good, averaging more than 12 million a year since 1976.

Important pink producers of Kodiak include Terror, Uganik, and Uyak rivers, on the west side of the island. The Karluk (of red salmon fame), Sturgeon and Red River districts on the west and southern end of the island are great pink producers — catches of 4 million or more in a season are not unusual.

A typical modern salmon seine type vessel (left) in the Kodiak harbor. Such boats are commonly also used for fishing for crab, shrimp, and herring. *(Staff)*

The Alitak district, on southern Kodiak, generally produces catches ranging from half a million to 2 million.

The east side of Kodiak Island, which faces the Gulf of Alaska, has many small pink salmon-producing streams and a few major rivers. There seiners commonly round-haul and brail board 2 to 4 million or more silvery splashing pinks during a season.

Afognak Island, just north of and across the channel from Kodiak Island, has a strong pink run, with yearly catches ranging from 50,000 to 2 million or more. A fishway built by the state on Perenosa River has made that system one of the best pink salmon producers on Afognak Island.

Chum salmon are second to pinks in abundance on Kodiak Island. For the 10-year period 1973-82, the annual average catch of chums in the Kodiak management district was 732,400 — which was only 7.2% of the total

Kodiak catch. It was also 10% of the total statewide catch of chums for that period.

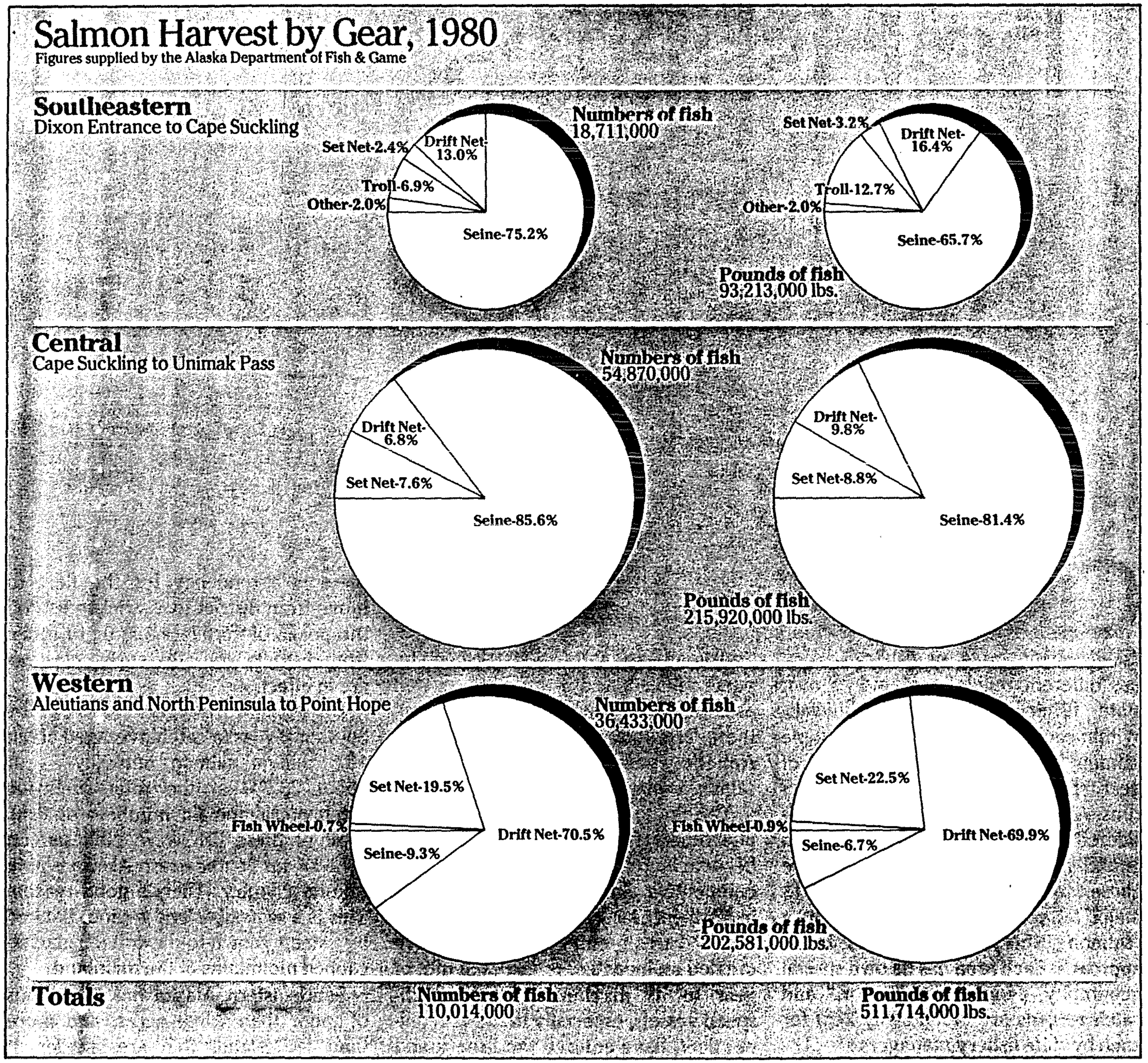
Like most other salmon fisheries dominated by one species — in this case pink salmon — management decisions are based on when and where it is proper to catch pinks. If chums are present, they are also caught.

Kodiak chums generally use the same spawning systems as pinks. One slight difference between the two species is the different time of arrival in bays and estuaries: pinks arrive around July 1, chums around July 15. Both are present in salt water until about September 1.

Chum catches appear on the increase in recent years: more than 1 million chums were annually caught each year 1980-82. Previously the only recent catches of 1 million or more were in 1960, 1971, and 1972. The 1982 chum catch of 1.2 million ranked as Kodiak's third largest (behind 1971 and 1981).

Coho salmon catches at Kodiak are generally small. For the 10-year period 1973-82 the annual average catch was only 88,610. This figure is somewhat distorted by the spectacular and unexpected catch of 343,000 in 1982 — the largest ever coho catch at Kodiak. For the nine years prior to 1982 the average annual catch of cohos for Kodiak was 53,600.

Red salmon struggle to overcome Fraser Falls to reach their spawning grounds in western Kodiak.
(Gerry Atwell, USF&WS, reprinted from ALASKA GEOGRAPHIC®*)*



Salmon Harvest by Gear, 1980
Figures supplied by the Alaska Department of Fish & Game
Southeastern
Dixon Entrance to Cape Suckling
Numbers of fish
18,711,000
Set Net-2.4%
Drift Net-13.0%
Troll-6.9%
Other-2.0%
Seine-75.2%
Set Net-3.2%
Drift Net-16.4%
Troll-12.7%
Other-2.0%
Seine-65.7%
Pounds of fish
93,213,000 lbs.
Central
Cape Suckling to Unimak Pass
Numbers of fish
54,870,000
Drift Net-6.8%
Set Net-7.6%
Seine-85.6%
Drift Net-9.8%
Set Net-8.8%
Seine-81.4%
Pounds of fish
215,920,000 lbs.
Western
Aleutians and North Peninsula to Point Hope
Numbers of fish
36,433,000
Set Net-19.5%
Fish Wheel-0.7%
Seine-9.3%
Drift Net-70.5%
Set Net-22.5%
Fish Wheel-0.9%
Seine-6.7%
Drift Net-69.9%
Pounds of fish
202,581,000 lbs.
Totals
Numbers of fish
110,014,000
Pounds of fish
511,714,000 lbs.

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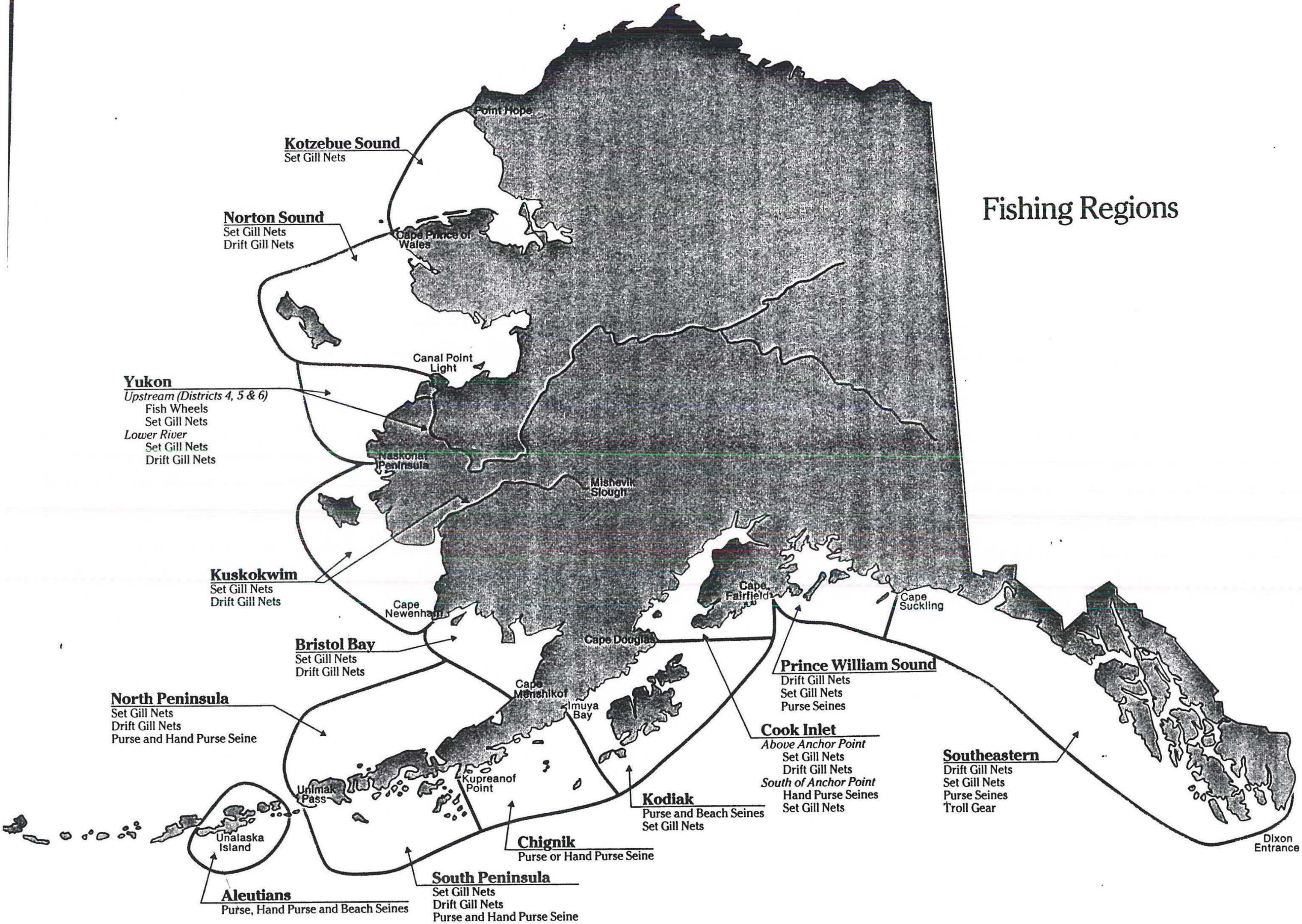
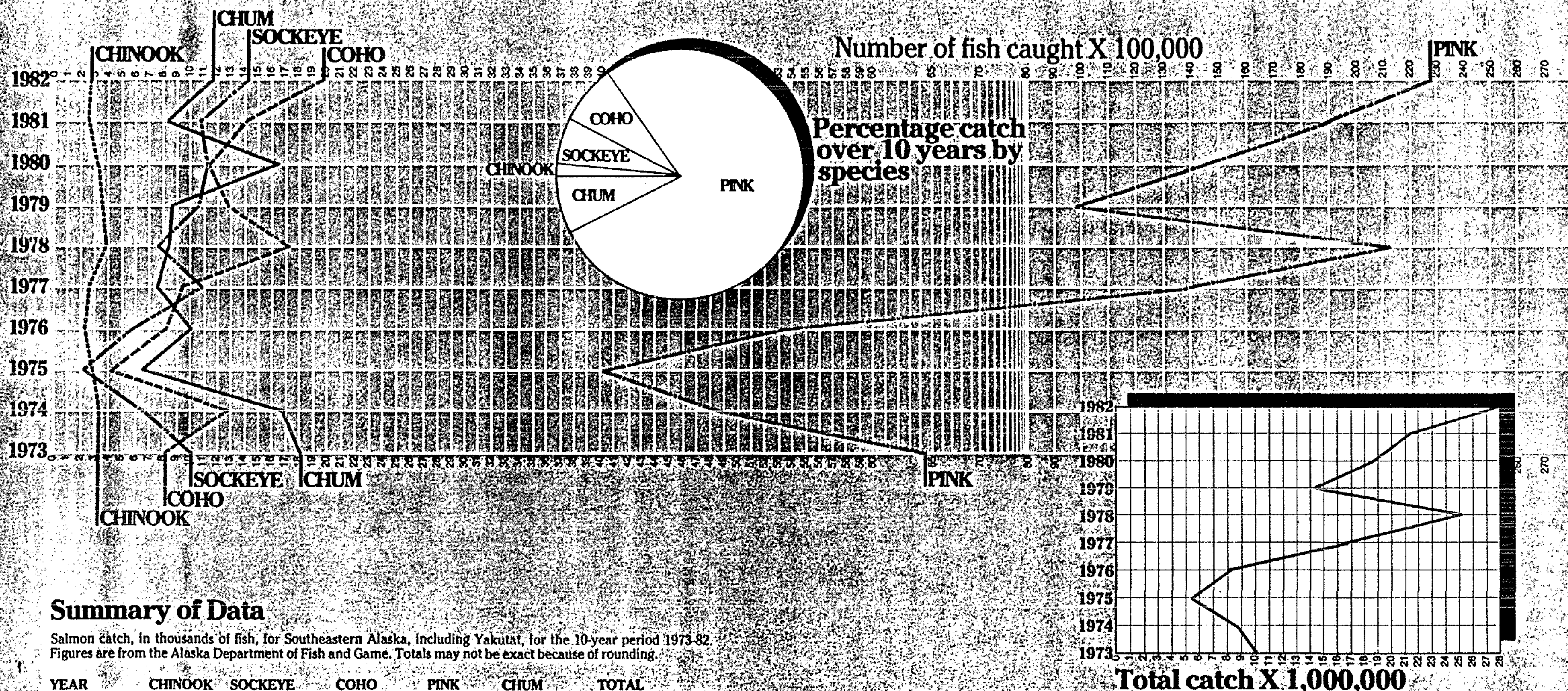
Fishing Regions



NA

Salmon catch for
Southeastern Alaska



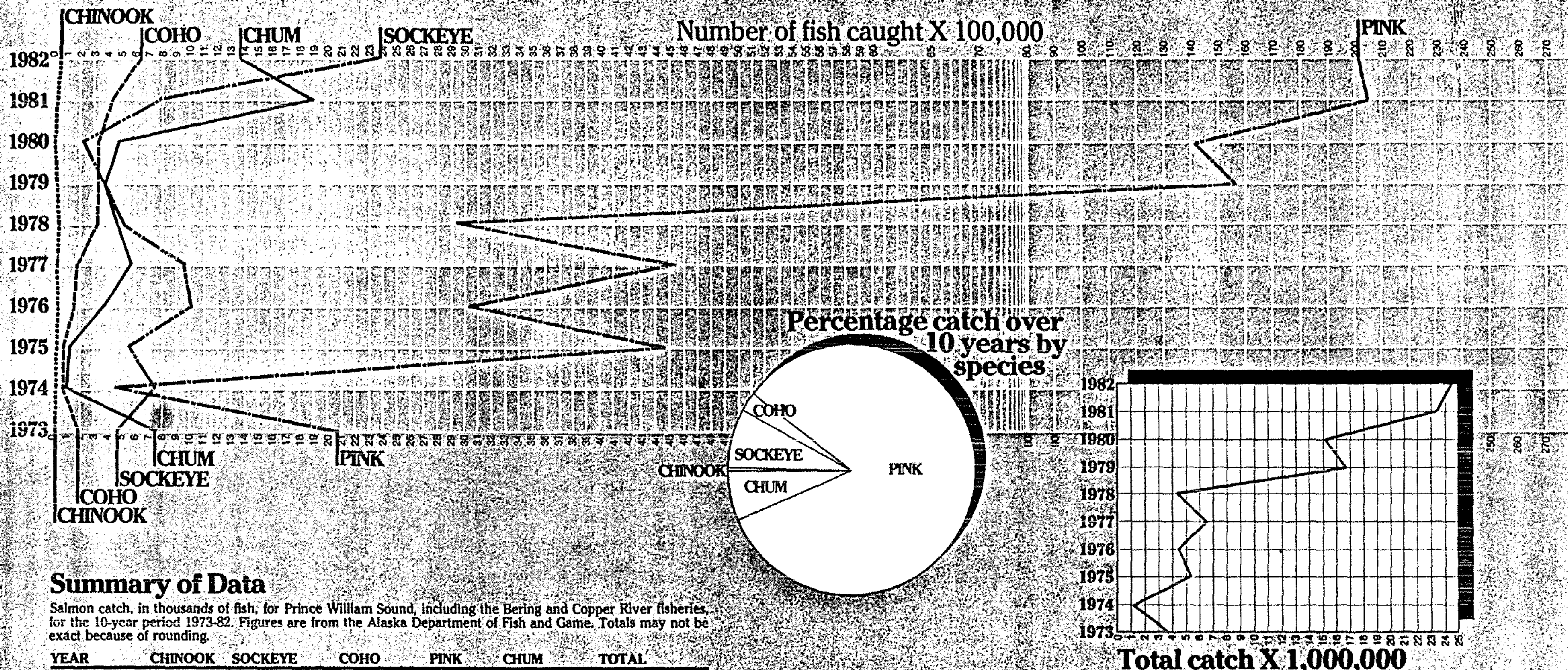
Summary of Data

Salmon catch, in thousands of fish, for Southeastern Alaska, including Yakutat, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	285.9	1,428.2	1,991.1	22,868.7	1,187.4	27,761.3
1981	271.9	1,079.6	1,407.1	18,967.9	849.5	22,576.1
1980	323.2	1,120.4	1,136.7	14,478.3	1,651.2	18,709.9
1979	367.6	1,073.9	1,284.6	10,977.9	888.3	14,592.3
1978	401.4	788.3	1,714.5	21,243.4	869.0	25,016.6
1977	285.2	1,085.1	944.8	13,843.6	738.7	16,897.4
1976	241.8	595.3	823.7	5,329.6	1,030.9	8,021.2
1975	300.7	245.2	427.4	4,026.5	686.6	5,686.4
1974	346.6	687.4	1,278.2	4,888.8	1,682.6	8,883.5
1973	343.6	1,011.5	836.3	6,455.2	1,832.2	10,478.2
TOTAL	3,168.0	9,114.9	11,844.4	123,079.9	11,416.4	158,622.9
AVERAGE	3,168.0	911.4	1,184.4	12,307.9	1,141.6	15,862.2
% Each Species 10 Yrs.	1.9%	5.7%	7.4%	77.5%	7.1%	
% Of Statewide Catch For Species, 10 Yrs.	46.9%	4.8%	45.2%	32.0%	15.7%	ALL: 23.7%

Limited entry permits held for Southeastern Alaska (September 1982) included: 421 purse seine, 484 drift gill net, 2,150 hand troll, and 484 power troll.

Salmon catch for
Prince William Sound



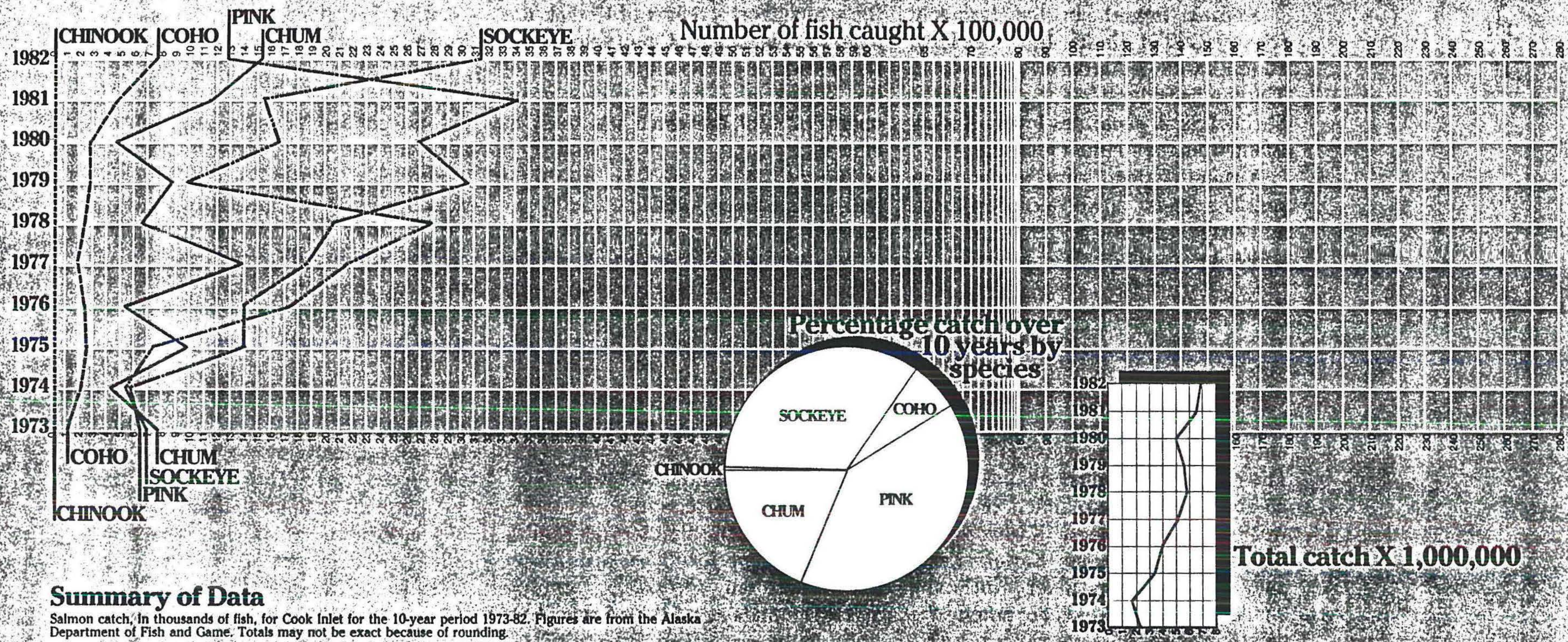
Summary of Data

Salmon catch, in thousands of fish, for Prince William Sound, including the Bering and Copper River fisheries, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	49.2	2,372.3	615.0	20,262.7	1,345.7	24,645.1
1981	21.9	798.4	423.9	20,519.6	1,890.2	23,654.0
1980	8.6	208.7	337.1	14,161.0	482.2	15,197.7
1979	20.1	369.6	315.7	15,638.3	349.6	16,693.3
1978	30.4	505.5	312.9	2,917.5	489.8	4,256.1
1977	22.9	943.9	179.4	4,536.5	573.2	6,255.8
1976	32.8	1,009.1	160.5	3,022.4	370.7	4,595.4
1975	22.3	546.6	84.1	4,453.0	101.3	5,207.4
1974	20.6	741.3	76.0	458.6	89.2	1,385.8
1973	22.6	473.0	199.0	2,065.8	740.0	3,500.6
TOTAL	251.4	7,968.4	2,703.6	88,035.4	6,431.9	105,391.2
AVERAGE	25.1	796.8	270.3	8,803.5	643.2	10,539.1
% Each Species 10 Yrs.	.2%	7.5%	2.5%	83.5%	6.1%	
% Of Statewide Catch For Species, 10 Yrs.	3.7%	4.2%	10.3%	23.3%	8.8%	ALL 15.7%

Limited entry permits held for Prince William Sound (September 1982) include: 270 purse seines, 543 drift gill net, and 30 gill net.

Salmon catch for
Cook Inlet



Summary of Data

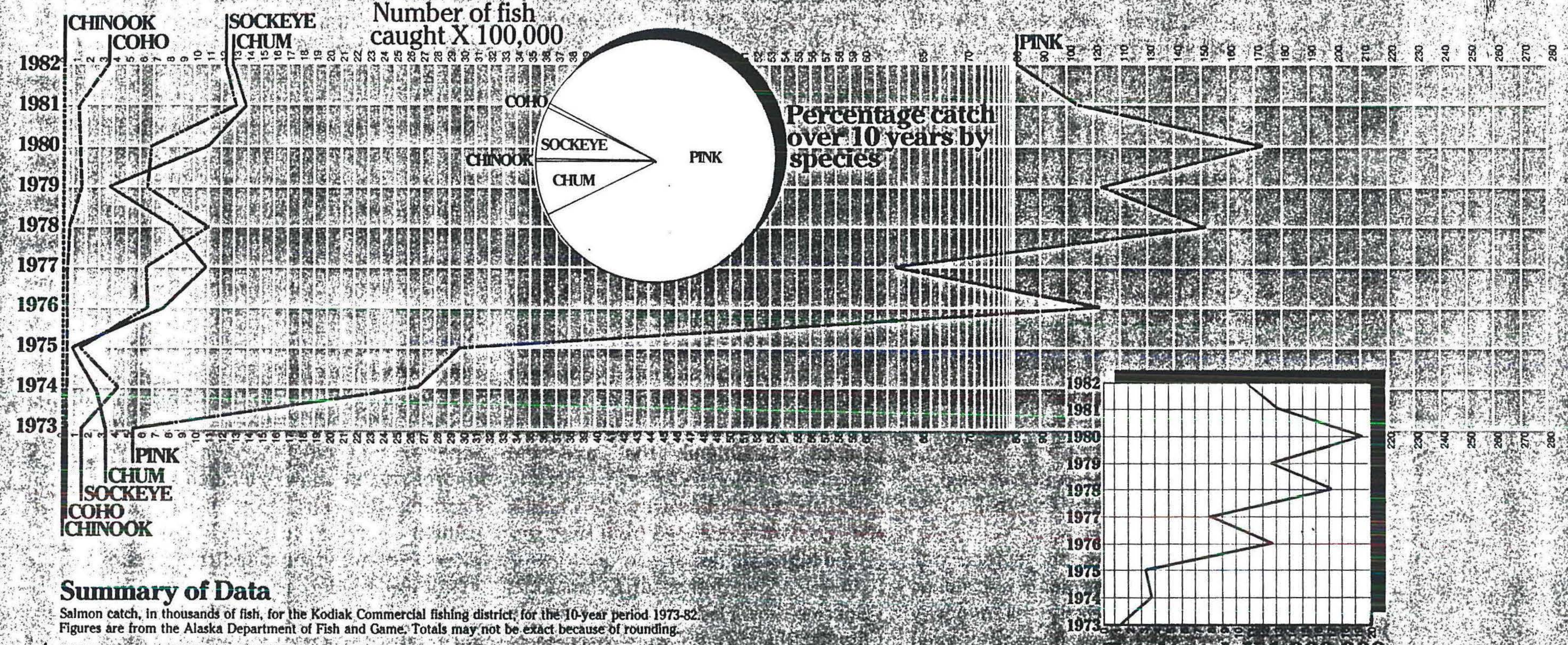
Salmon catch, in thousands of fish, for Cook Inlet for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	1.9	3,147.6	765.4	1,278.1	1,524.2	6,735.2
1981	13.3	1,549.5	495.9	3,406.4	1,169.6	6,634.7
1980	14.2	1,643.0	285.9	2,676.1	463.2	5,082.5
1979	15.0	988.8	287.8	3,049.2	873.4	5,214.1
1978	19.0	2,778.1	225.3	2,041.7	645.5	5,709.6
1977	15.0	2,154.1	195.8	1,846.3	1,379.5	5,590.8
1976	11.3	1,722.3	211.9	1,393.2	520.6	3,859.4
1975	4.9	713.0	233.6	1,399.8	973.4	3,324.7
1974	6.8	524.6	206.6	534.3	416.1	1,688.4
1973	5.3	699.2	106.5	633.6	783.1	2,227.8
TOTAL	124.7	15,920.2	3,014.7	18,258.7	8,748.6	46,067.2
AVERAGE	12.4	1,592.0	301.5	1,825.8	874.8	4,606.7
% Each Species 10 Yrs.	.2%	34.5%	6.5%	39.6%	18.9%	
% Of Statewide Catch For Species, 10 Yrs.	1.8%	8.5%	11.5%	4.4%	12%	ALL: 6.8%

Limited entry permits held for Cook Inlet (September 1981) included 590 drift gill net, 748 set gill net, and 84 hand purse seine.

Salmon catch for

Kodiak Commercial Fishing District



Total catch X 1,000,000

Summary of Data

Salmon catch, in thousands of fish, for the Kodiak Commercial fishing district, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

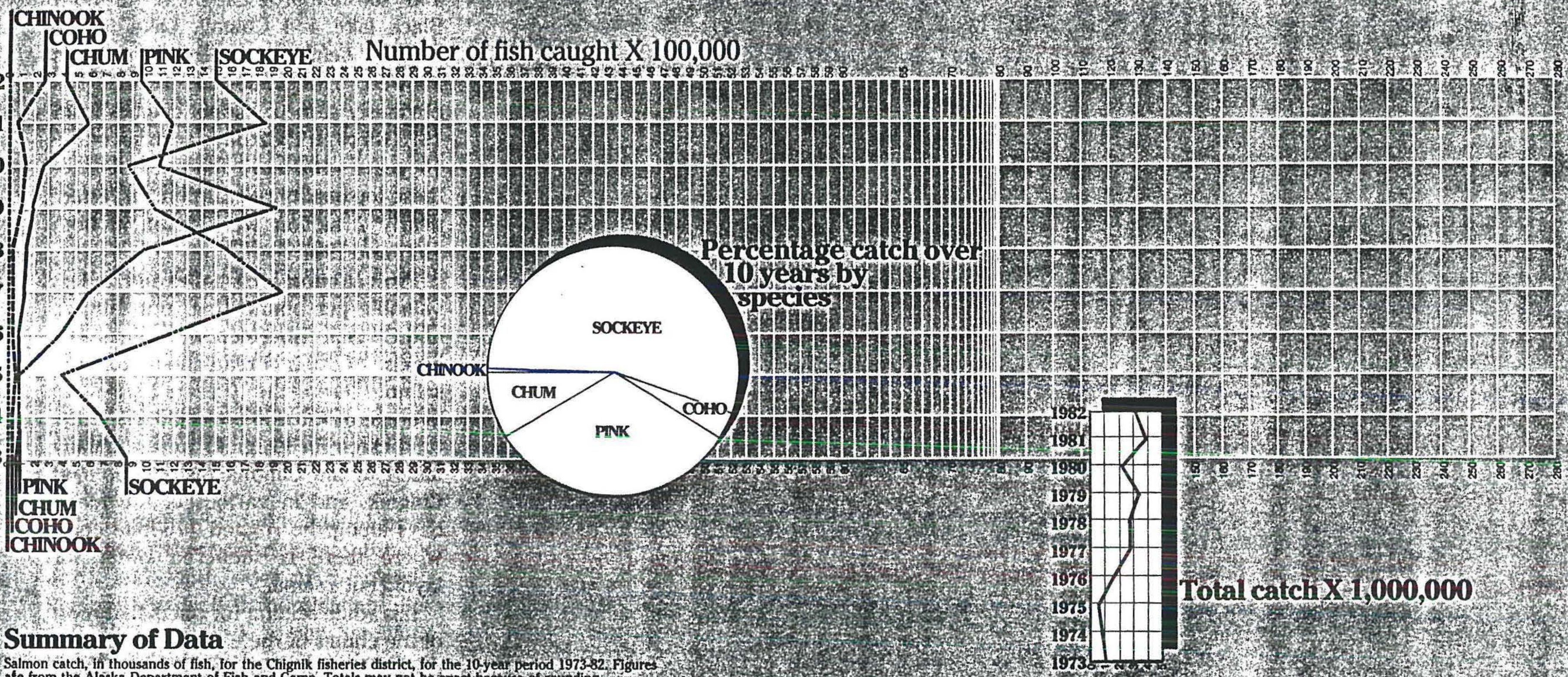
YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	1.2	1,204.8	343.5	8,076.2	1,266.2	10,891.9
1981	1.4	1,289.0	121.5	10,336.8	1,345.3	13,094.1
1980	.5	651.4	139.2	17,290.6	1,075.6	19,157.2
1979	1.9	630.8	140.6	11,285.8	358.3	12,417.4
1978	3.2	1,071.8	48.8	15,004.1	814.3	16,942.2
1977	.6	623.5	27.9	6,252.4	1,072.3	7,976.7
1976	.8	641.5	23.7	11,078.0	740.5	12,484.5
1975	.1	136.4	23.7	2,942.8	84.4	3,187.4
1974	.5	418.8	13.6	2,647.3	249.3	3,329.4
1973	.8	167.3	3.6	511.7	317.9	1,001.3
TOTAL	11.0	6,835.3	886.1	85,425.6	7,324.1	100,482.1
AVERAGE	1.1	683.5	88.6	8,542.5	732.4	10,048.2
% Each Species 10 Yrs.	.01%	6.8%	.8%	85.0%	7.2%	
% Of Statewide Catch For Species, 10 Yrs.	.16%	3.6%	3.3%	22.7%	10.0%	ALL: 15.0%

Limited entry permits held for Kodiak (September 1982) included 386 purse seine, 34 beach seine, and 187 gill net.

NA

Salmon catch for

Chignik Fisheries District



Summary of Data

Salmon catch, in thousands of fish, for the Chignik fisheries district, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

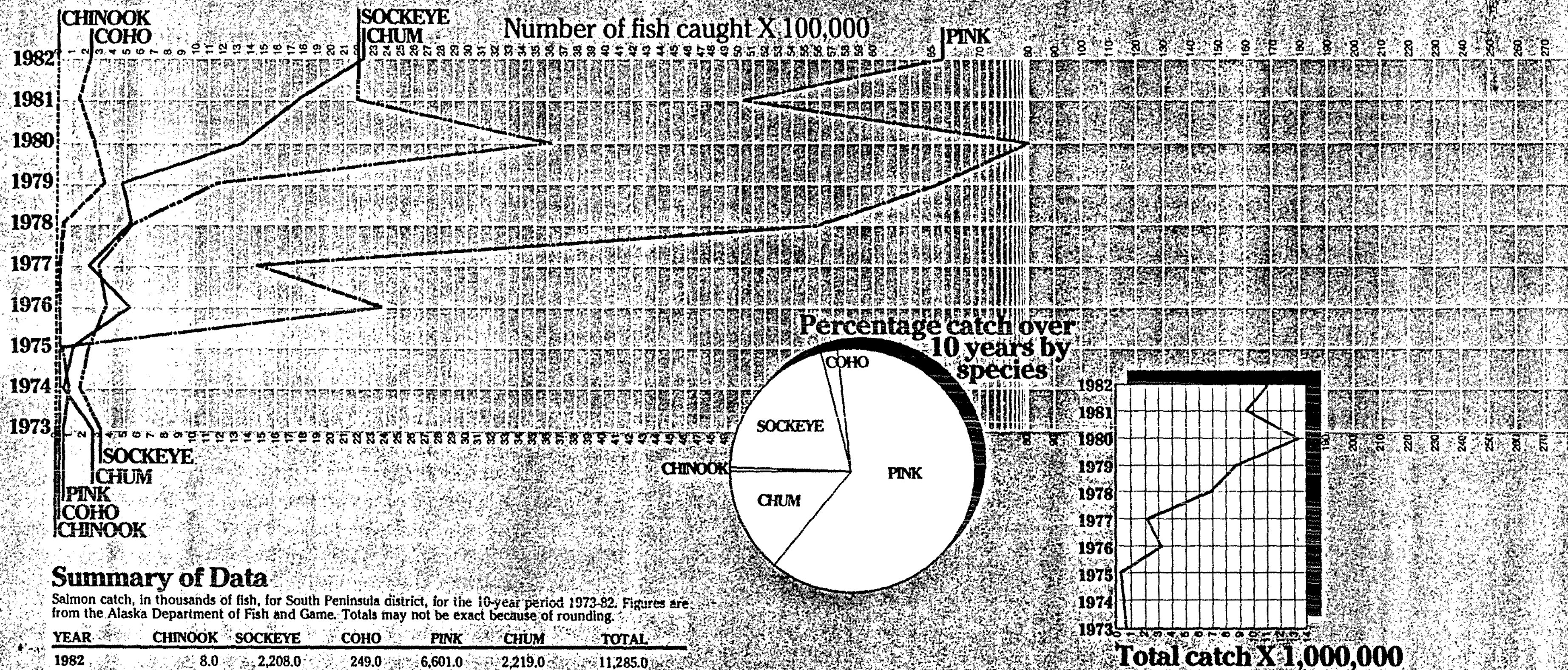
YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	5.2	1,509.2	289.2	942.7	403.5	3,149.8
1981	2.7	1,839.5	78.8	1,162.6	580.3	3,663.9
1980	2.3	860.0	119.6	1,093.2	252.5	2,327.6
1979	1.3	1,049.7	99.1	1,905.2	188.9	3,244.2
1978	1.6	1,576.3	20.2	985.1	120.9	2,704.1
1977	.7	1,972.2	17.4	604.8	110.5	2,705.6
1976	2.3	1,163.7	35.2	395.3	81.4	1,677.9
1975	.5	399.6	53.3	66.2	25.2	544.8
1974	.3	662.9	12.2	70.0	34.4	779.9
1973	.5	870.4	22.3	25.5	8.7	927.4
TOTAL	17.4	11,903.5	747.3	7,250.6	1,806.4	21,725.2
AVERAGE	1.7	1,190.3	74.7	725.0	180.6	
% Each Species 10 Yrs.	.08%	54.8%	3.4%	33.3%	8.3%	
% OF Statewide Catch For Species, 10 Yrs.	.25%	6.3%	2.8%	1.9%	2.4%	ALL: 3.2%

In September 1982 there were 101 limited entry permits for purse seine in the Chignik district.

NA

Salmon catch for

South Peninsula District



Summary of Data

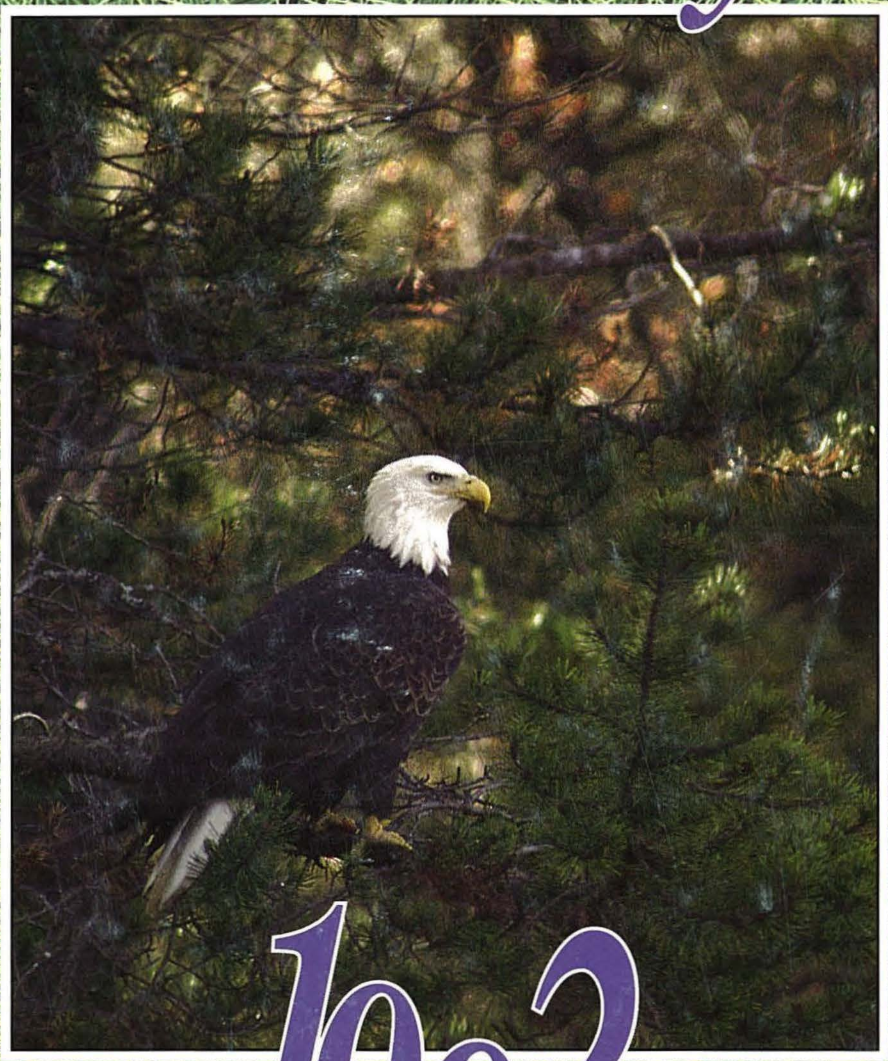
Salmon catch, in thousands of fish, for South Peninsula district, for the 10-year period 1973-82. Figures are from the Alaska Department of Fish and Game. Totals may not be exact because of rounding.

YEAR	CHINOOK	SOCKEYE	COHO	PINK	CHUM	TOTAL
1982	8.0	2,208.0	249.0	6,601.0	2,219.0	11,285.0
1981	11.0	2,191.8	162.2	5,030.8	1,757.5	9,153.3
1980	4.8	3,613.0	274.2	7,861.5	1,353.1	13,106.6
1979	2.1	1,149.9	356.9	6,564.9	482.9	8,556.8
1978	.8	579.4	60.8	5,590.1	546.2	6,777.3
1977	.6	311.7	2.1	1,448.6	243.2	2,006.2
1976	2.2	375.0	.2	2,366.8	532.5	3,276.8
1975	.1	243.5	.1	60.6	130.8	435.1
1974	.6	197.4	9.4	100.6	71.8	379.8
1973	.4	330.1	6.6	58.1	292.9	688.1
TOTAL	30.6	11,199.8	1,121.5	35,683.0	7,629.9	55,665.0
AVERAGE	3.0	1,119.9	1,12.1	3,568.3	762.9	5,566.5
% Each Species 10 Yrs.	.05%	20.1%	2.0%	64.1%	13.7%	
% Of Statewide Catch For Species, 10 Yrs.	.45%	5.9%	4.2%	9.4%	10.4%	ALL: 8.3%

Limited entry permits held for South Peninsula, North Peninsula, and Aleutian districts (all are open for the same permit) in September 1982 included 127 purse seine, 164 drift gill net, and 116 set gill net.

National Wildlife Federation

Conservation Directory



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Editor's Note: The state abbreviations which are used throughout this publication are the two-letter form

Alabama	AL	Kentucky	KY	Ohio	OH
Arizona	AZ	Louisiana	LA	Oklahoma	OK
Arkansas	AR	Maine	ME	Oregon	OR
California	CA	Maryland	MD	Pennsylvania	PA
Colorado	CO	Massachusetts	MA	Puerto Rico	PR
Connecticut	CT	Michigan	MI	Rhode Island	RI
Delaware	DE	Minnesota	MN	South Carolina	SC
District of Columbia	DC	Mississippi	MS	South Dakota	SD
Florida	FL	Missouri	MO	Tennessee	TN
Georgia	GA	Montana	MT	Texas	TX
Guam	GU	Nebraska	NE	Utah	UT
Hawaii	HI	Nevada	NV	Vermont	VT
Idaho	ID	New Hampshire	NH	Virgin Islands	VI
Illinois	IL	New Jersey	NJ	Virginia	VA
Indiana	IN	New Mexico	NM	Washington	WA
Iowa	IA	New York	NY	West Virginia	WV
Kansas	KS	North Carolina	NC	Wisconsin	WI
		North Dakota	ND	Wyoming	WY

RESTORATION PLANNING
FOLLOWING THE
EXXON VALDEZ OIL SPILL

Draft Technical Workshop Report

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EXECUTIVE SUMMARY

This report documents the findings and recommendations of participants in the Technical Workshop (3-5 April 1990) for restoration planning held in response to the Exxon Valdez oil spill. This workshop explored a broad range of actions that could be implemented to restore injured ecological, cultural, and recreational resources in Prince William Sound (PWS) and the Gulf of Alaska and suggested restoration feasibility studies to test the potential for success of some of these actions. The workshop, sponsored by the multiagency Restoration Planning Work Group, included federal, state, and private sector scientists and resource managers. Potential restoration projects were identified and evaluated based on information provided by the first year of the Natural Resource Damage Assessment studies, which focused on the impacts to coastal habitats and fish/shellfish, bird, and mammal resources. This report also provides a brief review of the state-of-the-art in restoration for northern latitudes with special emphasis on species or habitats similar to those in the PWS-Gulf of Alaska area.

Restoration planning requires knowledge of baseline conditions, and the nature and extent of the damages to the resources. The lack of specific baseline data on the resources affected by the spill, the paucity of fundamental information about natural recovery rates of potentially impacted habitats or species, and incomplete damage assessment information available at the time of the workshop made the task of identifying appropriate restoration alternatives difficult. In addition, relatively few restoration programs have been implemented under the climatic conditions experienced in Alaska, eliminating a potential source of knowledge pertaining to the degree of improvement in recovery rates that might result from attempted restoration in PWS and the Gulf of Alaska. Participants clearly recognized the limitations imposed by the lack of information and strongly recommended a continuation and, in some cases, an expansion or redirection of damage assessment efforts. The general consensus of the workshop participants was that more information is needed to develop an effective, comprehensive restoration plan for resources impacted by the Exxon Valdez oil spill. In addition, for those natural resources that are exploited (fish/shellfish) or otherwise regulated (some birds and mammals), more precise, real-time information is needed to manage these resources in a manner that will protect them from further damage and promote recovery, while minimizing the adverse economic and social impacts that would result from a very conservative management strategy. The recommendations for

"restoration" actions or feasibility studies reflect this need for additional information.

The most frequently recommended "restoration" alternatives were those that reduced or eliminated other stresses affecting impacted resources and their recovery. Activities such as logging and mineral extraction were identified as controllable perturbations to species and habitats potentially impacted by the spill. Workshop participants expressed the view that management alternatives may be the only practical intervention that could encourage natural recovery. For some resources, such as coastal habitats in general, management was seen to be impractical. Various participants suggested that no specific restoration alternatives be exercised, cautioning that restoration intervention may itself introduce further damage. Clearly, the general lack of information on baseline conditions, natural recovery rates, and actual damage, introduced much uncertainty as to what restoration alternatives were warranted.

A relevant point indirectly reflected by the three-day workshop was that based upon the predicted and actual impacts of this acute oil spill in PWS and the Gulf of Alaska, greater anticipatory planning of restoration alternatives was needed. In this way resource managers may be able to assess the need for restoration and the likelihood of success of a variety of human interventions more rapidly and efficiently than was possible in this situation.

The restoration planning program will be a precedent-setting effort and will influence the future of PWS and the Gulf of Alaska resources and the people and economies of the region. This Technical Workshop outlined a range of restoration alternatives and information requirements that will help focus the restoration process.

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GLOSSARY OF ACRONYMS

ADEC	Alaska Department of Conservation
ADFG	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
ARPA	Archaeological Resources Protection Act
ARTFO	Alaska Restoration Task Force Office
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CWA	Clean Water Act
DOI	Department of Interior
DOJ	Department of Justice
NHPA	National Historic Preservtion Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
NRHP	National Registry of Historic Places
NRDA	Natural Resources Damage Assessment
OAR	Oceanic Atmospheric Research
OSPCO	Oil Spill Project Coordination Office
PWS	Prince William Sound
RPWG	Restoration Planning Work Group
UAF	University of Alaska at Fairbanks
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service

I. INTRODUCTION

The oil spill that resulted from the grounding of the Exxon Valdez in Prince William Sound, Alaska on March 24, 1989 was the largest in U.S. history. Approximately 11 million gallons of North Slope crude oil were released and moved through the south-western portion of the Sound and along the northern coast of the Gulf of Alaska. Less than 1 million gallons of the oil were recovered; approximately 3 million gallons are believed to have evaporated (ADEC 1990). The remaining spilled oil was deposited on the shoreline or sank through the water column. The oil slick spread over an area of 10,000 square miles and affected over 700 miles of coastline (Piatt and Lensink 1989; Trustee Council 1989). A wide variety of natural resources are at risk from the spill. These public resources have significant ecological, economic, and social value. The extent of damage actually caused to natural resources is currently being investigated as part of the Natural Resource Damage Assessment (NRDA) program.

The Alaska Departments of Fish and Game, Natural Resources, and Environmental Conservation, the Federal Departments of Agriculture, Commerce, and Interior, and the U.S. Environmental Protection Agency formed the Restoration Planning Work Group (RPWG) to identify and report on a broad range of actions that can be taken to restore injured natural resources in Prince William Sound (PWS) and the Gulf of Alaska. The general goal for restoration is to return degraded biological communities to their pre-spill state, through direct human intervention (Jordan et al. 1988). The objective of the restoration planning effort described in this report was to explore ways to restore the ecological, cultural, and recreational resources that were injured or damaged as a result of the Exxon Valdez oil spill.

As part of this ongoing effort to develop a restoration strategy, the interagency RPWG sponsored a Technical Workshop during 3-5 April 1990, in Anchorage, Alaska to exchange ideas among damage assessment principal investigators, peer reviewers, scientists, and resource managers. The purpose of the workshop was to identify and evaluate the feasibility and effectiveness of potential restoration projects. The identification of candidate restoration projects was based on the results of the damage assessment studies available at the time of the workshop, the state-of-the-art in restoration technology, and the environmental and logistic conditions in the impacted areas. Due to the necessity of discussing damage assessment information that was considered confidential at the time, this workshop was closed to the public.

Participants in the Technical Workshop were selected by the RPWG and included members of the RPWG, damage assessment investigators, other federal and state scientists and resource managers, academic and private sector scientists and peers. The workshop began with a statement of objectives, a definition of the scope of restoration actions to be considered, and a summary of the preliminary results of the ongoing NRDA studies. Participants then formed separate work sessions to address the specific restoration requirements for coastal habitats, fish and shellfish, birds, and marine and terrestrial mammals during the first two days of the workshop. Following these sessions on ecological resources, separate sessions on cultural and recreational resources were held on the third day of the workshop. All sessions were conducted independently and reflected the opinions of participants and the state of knowledge regarding the resource under consideration.

Definition of Restoration

A wide range of environmental restoration efforts may be appropriate following the Exxon Valdez oil spill; however, the definition of restoration used in this report is based on the provisions of the governing Federal Acts. The Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and the Clean Water Act (CWA), as amended, provide the basis for determining injury to natural resources and assessing damages for restoring these resources to pre-spill conditions. The scope of "restoration" as incorporated into these Acts was used as a working definition of this term during the workshop:

> "'Restoration' includes actions undertaken to return an injured resource to its baseline condition as measured in terms of the injured resource's physical, chemical, and biological properties or the services previously provided." (Trustee Council 1989).

Under the authority of the federal laws cited above, funds obtained from responsible parties for environmental restoration are to be used to restore, replace, or acquire the equivalent of injured natural resources. "Restoration" includes direct attempts to return an injured resource to its baseline condition. This might include, for example, efforts to rehabilitate an oiled marsh ecosystem by augmenting natural plant and animal populations on-site after clean-up activities. "Replacement" provides a substitute for an injured resource. The application of hatchery-based stocking to establish a new source of fish in lieu of one that was severely damaged is an example of replacement. "Acquisition of equivalent resources" provides for the purchase, trade, other acquisition, or protection, of resources that are similar or related to the injured resource in terms of value, functions, or services provided. Equivalent resources may be outside the direct spill area and could include the purchase of undamaged and currently unprotected wildlife habitats, as an alternative to direct restoration of the injured resource.

Organization of this Report

This report summarizes the information, opinions, and recommendations presented by the participants at the first Technical Workshop. The restoration program is an ongoing process, and additional workshops are anticipated. This document describes the initial effort to identify a broad range of candidate restoration alternatives for each of the resource categories discussed. Participants also identified potential feasibility studies for the summer of 1990 to test hypotheses about candidate restoration approaches or to provide information necessary to develop effective restoration approaches. The report reflects the scope of the workshop, augmented with references to draft damage assessment reports from the NRDA principal investigators and available literature on restoration technology. To some extent, the participants went beyond the expected scope of the workshop to emphasize the need for additional damage assessment or resource management information. Therefore, some of the "restoration" recommendations described herein are actually recommendations for the acquisition of additional data and more complete information. Furthermore, many of the candidate restoration alternatives proposed are contingent, to varying degrees, upon future information to be supplied by continuing or expanded damage assessment studies.

The remainder of this report is organized into five chapters. Chapter II presents a summary of the general fate of oil in the marine environment, information presented by the NRDA investigators on the fate of the oil in PWS and the Gulf of Alaska, and the effects and/or impacts to natural resources. Chapter II also describes the perceived need for additional damage assessment information to support future efforts in the restoration process. Chapter III presents a brief review of the state-of-the-art for ecological restoration for the northern latitudes. Chapter IV documents specific restoration alternatives reviewed and recommended by the individual work sessions for ecological, cultural, and recreational resources. In addition, Chapter IV summarizes several central themes that seemed to reflect the consensus of participants across work sessions. Descriptions of suggested feasibility studies identified for potential implementation during the summer of 1990 are included in Chapter V, and the literature cited is presented in Chapter VI.

Appendices include workshop agendas and guidance provided to the participants, including fact sheets describing the Restoration Planning Program, a list of suggested questions prepared to guide presentations by damage assessment principal investigators, and information requirements for fishery management. Additional appendices include a list of participants by work session and a list of some supplemental references pertaining to the state-of-the-art for restoration, fate and effects of oil spills, bioremediation, and restoration ecology, and a bibliography of archaeological site stabilization.

II. OVERVIEW OF DAMAGE ASSESSMENT INFORMATION

Ongoing NRDA studies continue to provide information about natural resources damaged by the effects of oil released from the *Exxon Valdez*. This process will continue for years due to the scale of the impacted area and the complexity of quantifying impacts in a heterogeneous environment, through trophic food webs. The overview of the damage assessment information presented at the Technical Workshop highlighted some of the initial results from the NRDA studies, as well as some of the problems encountered in mounting such a large scale and complex assessment project.

This chapter describes the general findings presented at the plenary session of the workshop and selected preliminary results described by the principal investigators who participated in the individual sessions. These findings were augmented or refined, where possible, by reference to draft NRDA reports for 1989. The reader is referred to the NRDA reports for additional details on these findings.

A. FATE OF OIL

Information concerning the fate of oil released from the *Exxon Valdez* is being collected by state and federal agencies as a part of NRDA efforts. Much of this information had not been synthesized and was not available at the time of the workshop. Therefore, an approximate description of the fate of the oil was developed from qualitative information presented by members of the damage assessment teams and published information concerning the fate of oil from other tanker accidents.

General

The fate and behavior of petroleum hydrocarbons in the marine environment has received considerable attention ever since the *Torry Canyon* accident of 1967. Many studies were initiated in response to oil spills such as the *Torry Canyon*, the *Amoco Cadiz*, and the *Argo Merchant*. These studies have contributed to a general understanding of how physical, chemical, and biological processes interact to determine the overall fate and behavior of oil in the marine environment. These processes are summarized in Fig. II-1. Although this general view is applicable to all spills, experience suggests that every spill incident is unique, a conclusion consistent with both oil fate studies and studies of

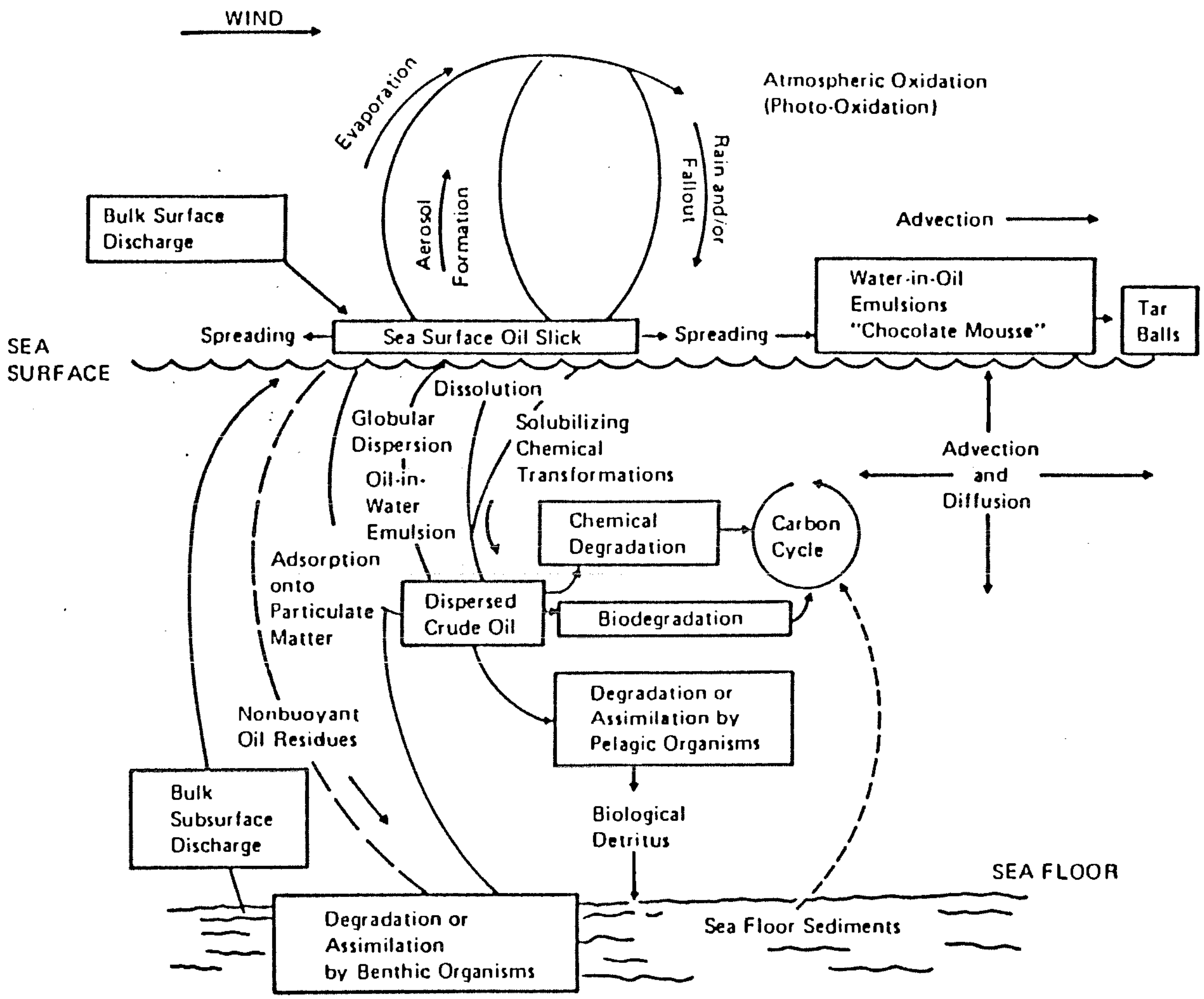

Figure II-1. Schematic describing the processes acting on oil spilled in the marine environment (from NAS 1985) environmental recovery following oil spills (Butler and Levy 1978).

The following general view of the behavior of spilled oil is based upon reviews (Hardy et al. 1977; Jordan and Payne 1980; NAS 1985) as well as studies of specific spills. Immediately upon entering the marine environment, oil spreads out along the surface of the water. Lighter, more volatile fractions begin to evaporate as the oil covers more surface area. Wave action enhances oil evaporation by promoting the formation of aerosols. Evaporated oil is transformed further by photo-oxidation and deposited over a potentially very broad area. Estimates of the atmospheric losses of spilled oil are difficult to make and are typically modeled, not measured directly. Depending upon the type of oil released, atmospheric losses can be significant.

The oil slick continues to spread out and thin as the oil interacts with wind and wave energy at the sea surface. As the oil surface area increases during dispersal, it becomes more susceptible to chemical and biological degradation. Chemical degradation occurs primarily through photo-oxidative processes. However, direct biodegradation of oil is probably the most significant process for degrading petroleum hydrocarbons to carbon dioxide. Despite significant background populations of oil-degrading bacteria, yeasts, and fungi in marine environments (Stewart and Marks 1978), few of these microorganisms can utilize the full range of hydrocarbons present in crude oils. Rates of biodegradation generally are related to temperature, and believed to be slow in cold environments (Atlas et al. 1978), and may be limited by nutrient availability (Stewart and Marks 1978). However, under optimal conditions microorganisms can degrade a significant proportion of spilled crude oil (60-80%, Gutnick and Rosenberg 1977).

Spilled oil spreads vertically as well as laterally, with vertical dispersion promoted by wave action and adsorbtion on to sinking particles. Initially, a water-in-oil emulsion, commonly referred to as "mousse", is formed at the surface. As further vertical mixing occurs, oil concentrations decrease and an oil-in-water emulsion forms. Once mixed into the water column, some of the oil is degraded by microorganisms, assimilated by pelagic organisms, or becomes directly adsorbed onto particulate matter. Ingestion of oil and subsequent incorporation into fecal pellets can be a significant mechanism for conveying oil to sublittoral sediments (Conover 1971). However, most oil reaches the sediment following adsorbtion onto sinking particles. Once incorporated into sediments, oil may persist for years, even decades (Teal and Howarth 1984; Boehm et al. 1982; Atlas et al. 1978; Cretney et al. 1978).

Ultimately, most spilled oil is removed from the water column through evaporation, degradation to carbon dioxide, sinking and deposition to sublittoral sediments, and deposition on surrounding intertidal regions, beaches, and rocky coasts. Collectively, these processes reduce the overall concentration of oil and, in some cases, promote a decrease in the more toxic fractions of spilled oil (Ganning et al. 1984). Therefore, beaches and coasts closest to the origin of the spill and first exposed to spilled oil generally receive a greater quantity of the more toxic fractions of the oil (Jordan and Payne 1980). Except for localized bays and inlets where oil or clean-up efforts are concentrated, it is generally those beaches and coasts closest to the origin of the spill that receive the greatest impact (Baker et al. 1989). Oil washed ashore often receives the most public attention, scrubbing, and clean-up efforts. Oil deposited on shore is affected by processes similar to those affecting oil in the water column (i.e., evaporation, biodegradation, and dispersal). This natural weathering can remove oil from certain levels on rocky shores in less than a year, even in non-tidal areas (Jonsson and Broman 1989). Mechanical energy in the form of wave action disperses the oil into the atmosphere, into upland regions, and deep into beach sediments. Mechanical energy is also an important mechanism by which much stranded oil eventually is removed from fouled shores.

Specific

Information concerning the grounding of the Exxon Valdez and work conducted by the Alaska Department of Environmental Conservation (ADEC 1990) provides some specific background on the fate of spilled oil shortly after the accident. On the night of 29 March 1989, the Exxon Valdez ran aground on Bligh Reef at or near sea speed, violently ripping a 650′ by 80′ hole in the 987′ tanker. Oil poured out of the hull, reportedly forming a wave of oil 3′ high, and started to spread through PWS. Eventually, 257,000 barrels (10.8 million U.S. gallons) were spilled from the tanker. With time, currents moved much of the oil from Bligh Reef through PWS and into the Gulf of Alaska (Fig. II-2), spreading through an area of 10,000 square miles (Piatt and Lensink 1989).

In order to minimize the amount of oil that might reach environmentally sensitive areas within the Sound, two days after the spill attempts were made to burn the oil floating at the sea surface. These attempts resulted in the removal of only 350 barrels (14,700 gallons, ADEC 1990).

The amount of oil recovered from a spill is difficult to estimate. Recovered oil is in an oil/water emulsion state, and the water content of the emulsion must be accurately determined before the quantity of oil recovered can be estimated. The current estimate is that between 14,000 and 20,000 barrels of oil

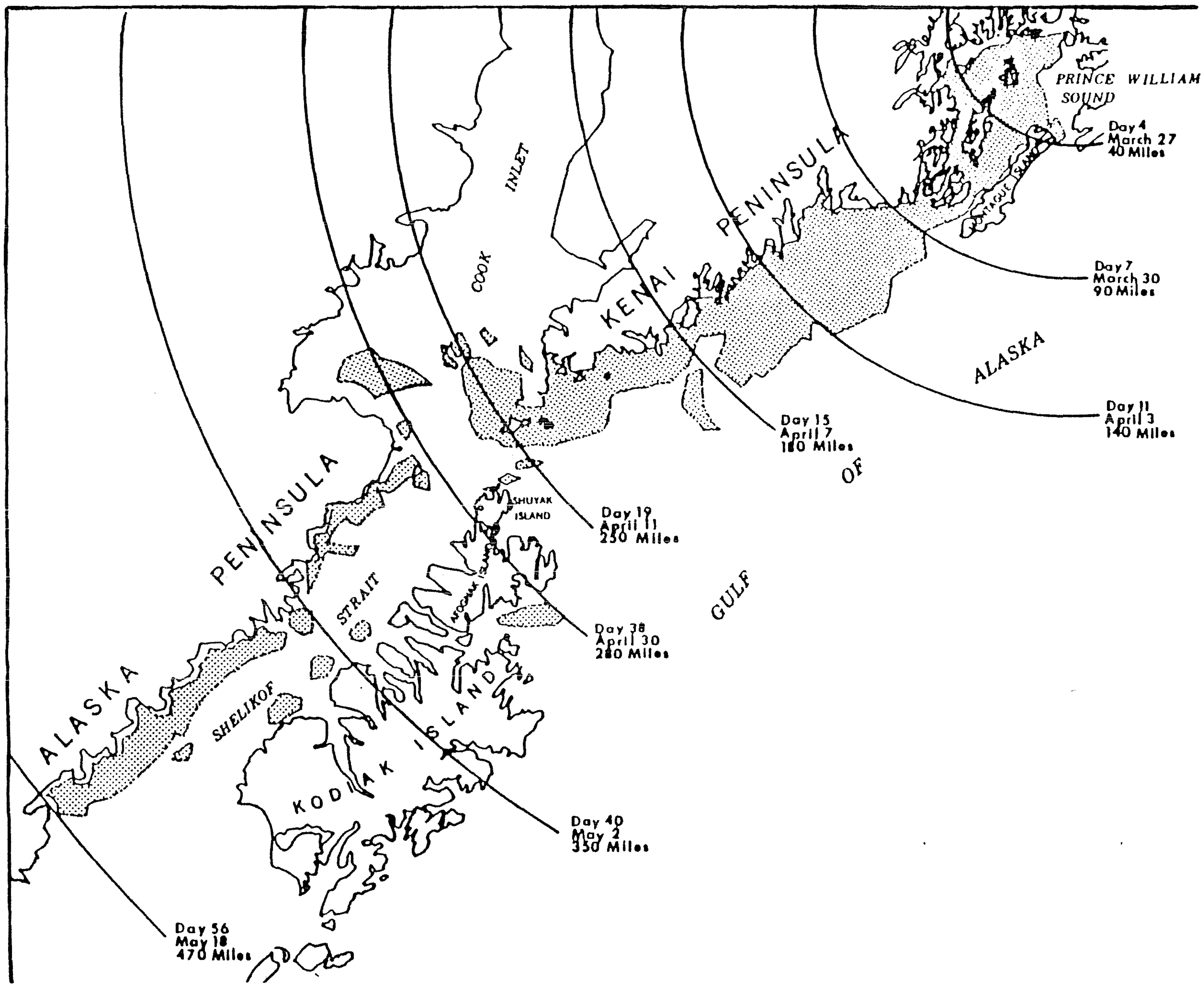

Figure II-2. Movement of the oil from the Exxon Valdez spill (March 24-May 18, 1989) (from Trustee Council 1989) have been recovered (ADEC 1990). The mid-point of this range (17,000 barrels) is assumed to be the best estimate, constituting 7% of the total amount spilled. By comparison, less than 8% of the oil spilled from the Amoco Cadiz was recovered (Teal and Howarth 1984).

Finally, estimates of how much oil has evaporated directly range between 20 and 40% of the spilled oil. Using the mid-point of this range, 77,100 barrels (more than 3.2 million gallons) evaporated (ADEC 1990). This estimate of the loss of spilled oil to the atmosphere presumably does not include additional losses of oil fractions following weathering (photodegradation) and biodegradation.

The fate of approximately 6.8 million gallons of unrecovered oil is largely uncertain. Some of the oil was washed ashore, and at least some portion settled to the bottom of PWS and the Gulf of Alaska. Preliminary data suggest that the hydrocarbon concentration in subtidal sediments generally decreases with increasing distance from the spill site (Wolfe et al. 1990). Damage assessment teams also have speculated that the amount of oil reaching subtidal regions might be small "since, at the time of the spill, little suspended matter was present in the waters of PWS to transport oil to the seabed" (Shaw 1990).

As an introduction to the restoration planning workshop, principal investigators from the Alaska Department of Environmental Conservation (ADEC) summarized their available results of general physical, chemical, and microbiological response related studies of the fate and effects of the spilled oil. The information presented was mostly qualitative and focused on specific areas of PWS, rather than providing a comprehensive assessment of the size and status of the impacted area. Much of the information obtained in these studies had not been analyzed or synthesized at the time of the workshop. The highlights of the DEC presentation are summarized below.

It was stated that detailed geomorphological profiles have been conducted throughout the impacted area; however, no quantitative information about the total area impacted or the percentage and degree of oiling of each type of habitat in PWS was made available. Three qualitative points were emphasized: 1) high energy shorelines in PWS were significantly cleaner in March 1990 than in November 1989; 2) "hot spots" of persistent, heavy oiling remain in low energy areas, where there was little or no natural oil removal or treatment; 3) asphalt mats are common throughout PWS.

Shoreline surveys conducted periodically from March through December 1989 indicated gross contamination of areas nearest Bligh Reef; however, by March 1990, high energy beaches had been virtually stripped of oil by a combination of wave action and a variety of response treatments. In March 1990, there was no observable oil penetration at a depth of 40 to 50 cm on some high energy beaches previously contaminated to this depth. Nevertheless, low lying crevices and protected areas, such as the areas beneath and behind frozen gravel bermes deposited by winter tides and storms, retained oil and tar. Despite their location on high energy beaches, crevices and storm bermes were outside the influence of most tides and remained relatively inactive. When the storm bermes are redistributed, mobile oil retained beneath and behind them may be dispersed and recontaminate the beaches.

Some low energy and untreated areas remained heavily oiled in March 1990. One year after the spill, beaches on Point Herring were reported to look just as they did after initial oiling. Significant oil penetration was detected 30 to 50 cm deep on these beaches. Bay of Isles (Knight Island), a high tide marsh determined to be "too sensitive" for clean-up treatment, was covered with oiled driftwood and debris, oil-matted grass, and asphalt pavement in March 1990. Oil penetrated to only about eight centimeters here, where the substrate becomes fine and densely compacted just beneath the surface. Marsha Bay, an area used by anadromous fish, where cleaning was discontinued to prevent interference with migration, showed a clear line of demarcation between cleaned and uncleaned areas. A continuous asphalt mat 10 cm thick covered the area past the point of treatment, while there was little or no asphalt in cleaned areas. It has been suggested that a portion of these asphalt mats may actually be oil and gravel mixtures that are held together by ice (ADEC 1990).

Naturally occurring hydrocarbon degrading bacteria (HDB) were the subject of a response study conducted in November of 1989. HDB were enumerated in the intertidal interstitial pore water and sediment and in the subtidal sediment of selected moderately and heavily oiled areas (Short and Lindstrom 1990). The ability of these bacteria to oxidize the petroleum hydrocarbons naphthalene and phenanthrene was measured by radiorespirometry. In Herring Bay, a heavily oiled, low energy area, there were 10^6 HDB per gram dry weight of sediment. Bacteria from 3 m subtidal sediments were able to oxidize the petroleum hydrocarbons, while bacteria from the same depth in an unoiled site did not degrade them. The ability of the Herring Bay bacteria to degrade petroleum hydrocarbons can be considered a surrogate for chemical measures of exposure to petroleum products because the specific enzyme system for petroleum hydrocarbon oxidation must be induced to enable HDB to degrade these substances. Because phenanthrene and napthalene are relatively uncommon in marine sediments, the principal investigator of this study suggested that the HDB at a depth of 3 m in Herring Bay must have been exposed to a substantial amount of these substances to cause induction of the appropriate enzyme system.

Recolonization of clean versus oiled rocky substrate was studied by placing cobbles, cleaned with methylene chloride on one side and uncleaned, and oil covered on the opposite side, in the intertidal zone at selected unoiled (control), moderately oiled, and heavily oiled sites. The experimental substrate remained in the field over the winter. Green algae recolonization occurred extensively on the cleaned halves of the cobbles. There was some recolonization in irregular areas of the weathered tar halves of the cobbles, but this occurred to a markedly lesser degree than recolonization of cleaned areas. It was noted that reoiling of cleaned cobbles occurred in some lower energy areas.

Available damage assessment information specific to six categories of natural resources (coastal habitats, fish/shellfish, birds, mammals, cultural, and recreational) is summarized in the following section.

B. GENERAL OVERVIEW OF EFFECTS

COASTAL HABITATS

Definition of Coastal Habitats

Coastal habitats include all communities and species from terrestrial vegetation at the high end of the shoreline, to the deepest sub-tidal marine regions. This zone includes a variety of distinct ecological communities and habitats, each of which is likely to have been exposed to different concentrations of oil. These different concentrations have different impacts on ecological structure and function (Ganning et al. 1984) and different restoration alternatives were identified for each community and habitat (see Chapter IV).

Session participants initially decided that both damage assessment information and restoration options could be discussed more easily if the broadly defined area encompassing coastal habitats was subdivided. Subdivisions were based upon community structure and related to the degree of oil exposure. The resulting four subdivisions of the coastal zone were:

- Supratidal Region
- Intertidal Region
- Shallow Subtidal Region
- Deep Subtidal Region.

These regions were defined by tide and water depth, with boundary definitions taken from the damage assessment reports (Table II-1). Depending upon tidal range and topographic slope,the size of these regions varies from fairly wide (tens to hundreds of meters), to very narrow. Regions are widest in gently sloping, low energy, protected environments, such as fine textured beaches, and narrowest in steep, high energy, exposed environments, such as rocky cliffs. Preliminary damage assessment information presented at the workshop indicated that ecological effects were more pronounced and longer lasting in low energy environments compared with high energy environments, a conclusion supported by previous oil spill studies (Ganning et al. 1984). Consequently, the four regions were also classified into low and high energy environments.

Available Damage Assessment Information

Quantitative information concerning ecological damage caused by the spill was generally unavailable at the time of the restoration planning technical workshop. The minimal information available was largely qualitative and based on descriptions of specific sampling sites. Unbiased estimates of how closely conditions at sampled sites represented conditions throughout the exposed area were unavailable. Therefore, it was difficult to judge whether the available damage assessment information characterized the entire region exposed to oil, or only characterized specific sites.

There is considerable variation among estimates of total area and miles of coastline impacted by the oil spill. For example, an EPA publication (EPA 1989) estimated that oil from the Exxon Valdez had spread over 3000 square miles and had reached over 1000 miles of shoreline, including 350 miles in PWS, while the public review draft of the NRDA plan included estimates of 10,000 square miles and 700 miles of coastline affected (Trustee Council 1989). A later estimate suggested that 4000 miles of shoreline were exposed to oil (Turner 1990). Due to the continuous movement of oil, the final area exposed to the spill will probably be even larger. An oil tanker spill affecting an area this large and impacting this much shoreline is unprecedented. Even the Amoco Cadiz spill of 1978, which released more than six times the amount of oil spilled from the Exxon Valdez, affected only 186 miles of coastline.

Damage assessment of coastal habitats was conducted with a stratified random sampling design so that information gathered at sampled sites could be used to estimate exposure and effects at locations that were not sampled. Thus, the entire PWS region was treated as a single statistical population from which samples were drawn to infer information about the population. Using a

Table II-1. Coastal habitat regions as defined by tide and depth

Region	Upper Boundary	Lower Boundary
Supratidal	Commencement of terrestrial vegetation	Mean high high water
Intertidal	Mean high high water	0 elevation tidemark
Shallow Subtidal	0 elevation tidemark	-20 m water depth
Deep Subtidal	-20 m water depth	no limit

geographic information system (GIS) and the Environmental Sensitivity Index (Sundberg 1990), the coastline was divided into 100,000 segments, of which 111 were selected randomly for sampling (Sundberg 1990; Turner 1990). The approach was statistically straightforward and has been proposed for other environmental programs dealing with ecological information on regional scales (EPA 1990). The damage assessment sampling design treated the oil impacted area as three geographic regions (PWS, Gulf of Alaska, and Kenai Peninsula), each of which was characterized by five different habitat types exposed to three degrees of oiling (Table II-2, Gibbons et al. 1990). The parameters sampled were oil in water, oil in sediments, intertidal fish, subtidal benthos, contaminants in shellfish, and intertidal flora and fauna. At the time of the workshop, sample processing was incomplete or had not yet begun for many parameters.

Damage assessment information available at the time of the restoration planning workshop was inadequate to provide quantitative estimates of the degree of oiling, or the ecological effects caused by exposure to oil. A significant problem noted by damage assessment researchers was the inadequate location of control sites with which to compare oiled vs. unoiled areas. Similar problems have been noted in other oil spill studies (Mann and Clark 1978). To minimize the likelihood of exposure to the spilled oil over the long term, control sites generally were located in mainland coastal areas. However, use of mainland control sites confounded comparisons between oiled and unoiled sites because these sites were not necessarily representative of the more exposed coastlines of the islands in the PWS area. Specifically, mainland stations generally were more affected by freshwater sources (Gibbons et al. 1990) and supported communities more likely to be tolerant of lower salinities and broader salinity ranges. Such communities characteristically are not species rich (Remane and Schlieper 1971). Thus, faunal abundance and species diversity were generally lower at control sites than at exposed sites supporting more stenohaline communities (communities tolerating a narrow range of salinity). Damage assessment teams suggested that in the future, control sites should be located closer to oiled sites (Gibbons et al. 1990), and the 1990 damage assessment sampling plan was altered to reflect this suggestion (Gibbons, person. comm.). A further limitation of the available damage assessment information mentioned by session participants was the lack of long-term baseline data about the ecological resources within PWS and the Gulf of Alaska. Without such information, it was difficult to estimate how natural interannual variability (e.g., an unusually harsh winter) may have influenced the assessment of the effects of the spilled oil.

Table II-2. Damage assessment sampling design: samples classified according to the following types of strata

Geographic Areas	Habitat Types	Oiling
Prince William Sound	Exposed rocky	Control (no oil)
Kodiak/Alaska Peninsula	Fine textured	Lightly oiled*
Lower Cook Inlet /Kenai Peninsula	Coarse textured	Heavily oiled
	Sheltered rocky	
	Sheltered estuarine	

* Strata not used since control and lightly oiled sites could not be adequately differentiated (Gibbons et al. 1990).

Supratidal Habitats

Ecological damages to supratidal habitats were perceived to be considerable, although not as severe as those for intertidal habitats. Supratidal habitats were affected by oil carried upland by extreme high tides and wave spray. Weathered oil formed tar and asphalt mats, suffocating vascular plants and preventing new growth. Clean-up operations also impacted this habitat, as access to beaches in some areas was gained by transversing supratidal zones.

Based upon observations made by damage assessment principal investigators participating in the workshop, the session assumed that damage in low-energy supratidal regions was confined to vascular plants, principally rye grass (*Elymus* spp.). Members of the damage assessment team indicated that within PWS proper, coasts are generally rocky and supratidal vegetation is of minor importance; however, in the Gulf of Alaska and on the Alaska Peninsula, more vascular plants occur. Despite intensive clean-up efforts, pools of oil are still present in some supratidal regions and weathered oil has formed layers of hard asphalt, severely impeding recolonization by vascular plants. No areal estimates of damaged supratidal vegetation were available at the time of the restoration workshop.

The effects of oiling on vascular plants are believed to be highly dependent upon exposure. Vegetation exposed to low or moderate oil concentrations may be affected only minimally and may actually have benefited from the spill initially (Gibbons et al. 1990). These plants are thought to have greater productivity compared to plants at unoiled sites. Similar observations have been made during studies of previous oil spills (Hershner and Moore 1977; Baker 1971). The reason for enhanced productivity by some vascular plants exposed to oil is not well understood. Small concentrations of oil and associated degradation products might act to fertilize vegetative stands. Alternatively, the higher production might simply be due to reduced grazing pressure from animals avoiding oiled vegetation and heavily populated beaches. Vegetation completely covered with high concentrations of oil for extensive periods of time probably experienced near total die-back.

Workshop participants mentioned that increased erosion brought on by the removal of oiled driftwood and dead brush was a related effect of the spill that potentially contributed to the loss of supratidal vegetation. Driftwood normally stabilizes the higher reaches of many beaches, allowing delicate plants to become established. As part of the clean-up efforts, oiled driftwood and dead brush were completely removed from many contaminated beaches, exposing plants to erosion from heavy rains and extreme high tides. Thus, although the production of some shoreline vegetation may have been enhanced by exposure to oil, clean-up efforts led to the loss of some vegetative stands by enhancing erosion. In addition to enhancing the loss of resources in the supratidal, erosion potentially contributed to a loss of resources in intertidal and subtidal habitats. Increased suspended loads that may have resulted from enhanced erosion could have adversely affected suspension and filter feeding organisms such as barnacles, mussels, and clams. Such potential losses could not be evaluated with the information available.

High energy supratidal habitats include steep, rocky faces and cliffs. Plant and animal communities within these habitats are extremely limited. Accessibility to this habitat from the water generally was limited due to strong currents and large waves, and from land due to steep cliffs. Descriptive reports given during the workshop suggest that in some areas these high energy regions are still covered with oil, mostly in the form of a sticky asphalt tar. The high energy supratidal areas may have suffered more aesthetic damage than long-lasting biological injury, as residual oil formed black bands on the rocky faces of the supratidal zone. Continuing NRDA studies are investigating further effects to this habitat. Even though biological impacts may be short-term, residual oil in the high energy supratidal zone may continue to impact recreational uses and archaeological resources.

Intertidal Habitats

Based on the damage assessment information available, the coastal habitats session concluded that, within the coastal zone, intertidal habitats received the greatest exposure to oil and suffered the most detrimental effects. Intertidal habitats were repeatedly exposed, as winds, waves, and currents moved oil around PWS and onto the shore. Clean-up operations also focused on intertidal habitats, potentially causing damages equal to or exceeding those damages caused by exposure to oil (Broman et al. 1983; Ganning et al. 1983; Foster et al. in press).

It was generally believed that of all of the habitats considered by the coastal habitats session, low energy intertidal habitats suffered the greatest damage. Past studies have shown that these habitats are particularly vulnerable to ecological damage from oil spills (Baker et al. 1989). Quantitative damage assessment information for this spill is not yet available to verify this view, but general support was provided by qualitative descriptions given by damage assessment principal investigators participating in the workshop.

The low energy intertidal habitats of the PWS area received high concentrations of oil in various stages of weathering and degradation, as winds and currents moved slicks of oil throughout the Sound. Once in the intertidal region, the oil generally stayed in low energy habitats, gradually working its way deeper into sediments, cracks and crevices. Plants and animals within this habitat were exposed to high concentrations of oil for long periods of time. Although high energy intertidal environments were cleaned to some extent by swift currents and pounding waves, oil within low energy intertidal environments generally was not moved from this zone and plants and animals were exposed to oil continuously. Because natural clean-up mechanisms were slow, clean-up crews concentrated efforts within low energy intertidal habitats. Thus, damage to ecological resources due to direct exposure to the spilled oil was further exacerbated by the disturbance caused by clean-up crews. Although oiling was most common in the mid to high intertidal zone, clean-up efforts at low tide were thought to have caused lower areas to be contaminated by flushed oil and sediment. Similar results have been demonstrated from previous oil spills (Foster et al. in press).

The dominant community type in the low energy intertidal region of PWS area is the rocky intertidal. The structure of the rocky intertidal community is dominated by macrophytic algae, principally the rock weed (Fucus). It is unclear from the descriptions which species were most heavily impacted by the oil. Further, the general lack of specific baseline information about the ecology of intertidal communities in the region made it difficult to select which species, if impacted, would be most in need of restoration.

Descriptive information provided by damage assessment principal investigators participating in the workshop suggested that the intertidal community was almost entirely eliminated in areas receiving prolonged, high concentrations of fresh oil, and in those areas where clean-up techniques were harsh. Principal investigators remarked that even in those regions where Fucus and the associated invertebrate fauna were not eliminated entirely, attached invertebrates are suspected to be heavily impacted. Although data are not yet available to verify this view, members of the damage assessment team suspect that specific grazers (limpets: Diadora aspera, Acmaea mitra, and snails: Littorina sp.) and predators (dog whelks: Nucella lamellosa) were especially hard hit by exposure to oil. These species generally are not important for commercial or subsistence uses; however, their ecological role in high latitude environments may be important (Gibbons person. comm.). These preliminary descriptions of the effects of oil in intertidal habitats are consistent with descriptions from previous oil spills (Clark and Finley 1977).

As in supratidal habitats, vascular plants in intertidal habitats exposed to low concentrations of oil were little damaged and perhaps even thrived. Plants receiving larger concentrations of oil are likely to have been more extensively damaged. Damage assessment teams indicated that in some of these more heavily oiled intertidal areas, asphaltic layers have formed from the weathered remains of oil.

Although communities within high energy intertidal habitats were exposed to high concentrations of oil, vigorous wave action during the winter of 1989 helped to wash oil out of these areas, promoting natural recovery. Preliminary damage assessment information indicates that recolonization of some species in these high energy environments is beginning to occur and that communities are beginning to return to pre-spill conditions. Because of this, and the problems of working in a high energy environment, where any restoration efforts might be quickly washed away, the coastal habitats session advised that no direct restoration projects should be considered for high energy intertidal habitats.

Subtidal Habitats

At the time of the workshop, the least amount of damage assessment information was available for shallow and deep subtidal habitats. Reports for subtidal habitats were largely descriptive and based upon data collected at specific sites that could not yet be extrapolated to the entire region to assess overall effects. Due to the large area over which sedimented oil may have spread, workshop participants generally agreed that subtidal environments were probably least affected by the spill. However, since sedimented oil can persist in the environment for years, session participants cautioned that some effects to selected subtidal populations may persist, as has been found in previous oil spill studies (Sanders et al. 1980; Dauvin and Gentil 1990). Damage assessment principal investigators described a "dead zone" in the subtidal region of Herring Bay, a silled embayment, where large numbers of flora and fauna were found dead, suggesting considerable localized damage (Gibbons et al. 1990). Researchers noted that there may have been an unusual concentration of oil, resulting from a booming operation intended to restrict the spread of oil. They emphasized that the "dead zone" was not considered indicative of conditions throughout subtidal areas in PWS. Further preliminary data analyses indicated no immediate or acute adverse effects of the oil spill on benthic algae, invertebrates, or fishes for shallow subtidal habitats (Gibbons et al. 1990). Sublethal, chronic effects are still being evaluated.

Additional Damage Assessment Information Needs

Throughout the discussion of restoration alternatives, session participants identified specific damage assessment information that would be useful in identifying restoration options and priorities appropriate for coastal habitats in PWS. At the time of the workshop, the most basic damage assessment information lacking was a quantitative description of the extent and magnitude of the spill. In addition, information regarding the spreading rate of the oil is required to identify those shores that were potentially exposed to more toxic oil fractions. Coasts receiving oil shortly after the spill were exposed to less weathered and potentially more toxic components of the oil than beaches that were exposed after the oil had been altered by evaporation, photodegradation, biodegradation, and settling (Jordan and Payne 1980). The members of the Coastal Habitats session strongly suggested that damage assessment studies be long-term, to document present and future effects as well as recovery.

Session participants thought that the damage assessment information should identify the areal extent and types of habitats in the PWS area, as well as the proportion of each habitat that was exposed to spilled oil. This information may be forthcoming from damage assessment teams but was unavailable at the time of the workshop. It was emphasized that the partial loss of a rare habitat is potentially as important as an extensive loss of a more common habitat, since the former may be the critical habitat for certain species. For example, although supratidal vascular plants are generally not common in PWS, they may be extremely important to foraging terrestrial mammals as a source of food during severe winters. Restoration efforts might be required if such areas were particularly heavily impacted. The group strongly encouraged damage assessment teams to separate oil induced effects from the effects of the various clean-up methods. Case histories have demonstrated that long-term ecological damage from some clean-up techniques may be greater than if the oil was left to degrade naturally (Smith 1968; Foster and Holmes 1977; Ganning et al. 1984; Baca et al. 1987).

The session strongly recommended an evaluation of which clean-up technique used in each habitat removed the most oil while producing the least amount of additional environmental damage. Session participants advised that the evaluation of any restoration efforts should take into account the history of clean-up activities at the site. Such an evaluation must include a comparison of habitat types that were cleaned with similar habitats that were oiled but not cleaned (Foster et al. in press). Despite years of oil pollution studies, such comparisons are rare (Ganning et al. 1984, but see also Wilson 1981).

Damage assessment team members cautioned that the evaluation and assessment of restoration efforts in specific habitats as a function of clean-up history might be difficult because information is generally not available at sufficient spatial scales to identify which clean-up techniques were employed in specific areas. Restoration research teams may need to review archived photographs of the clean-up efforts to identify which areas and beaches received specific clean-up treatments.

FISH AND SHELLFISH

The damage assessment for fish and shellfish was incomplete at the time of the workshop due to the ongoing nature of some of the NRDA studies and the apparent lack of an ecological approach in the study program. This situation is exacerbated by the lack of baseline biological or ecological information on many species of fish/shellfish potentially at risk as a result of the Exxon Valdez oil spill. This paucity extends to some of the most basic ecological information and life requirements of many of the species and is not unique to this area of Alaska (MBC Applied Environmental Sciences 1988).

Unlike most of the other biological resources (except some mammals, sea ducks, gulls, and colonial seabirds) potentially affected by the oil spill, a number of the fisheries resources are subject to exploitation by commercial, recreational, and subsistence fisheries. These fisheries are regulated and have direct and indirect social and economic benefits. As a result of the uncertainty in future resource availability introduced as a result of the spill, more precise and real-time information will be needed to manage these stocks effectively in the near future.

The directly observable impacts to fisheries resources or their habitats are described briefly below for important targeted species or groups. These resources are targeted due to their utilization in commercial, recreation, or subsistence fisheries. However, many indirect effects such as those on growth, mortality, and reproduction, would not be expected to be observable for some time (Patten 1977). The following summary represents only the preliminary results of the NRDA. Further information on sublethal population-level impacts and the rates of natural recovery will be needed in order to finalize restoration plans and adapt these plans to future conditions.

Salmon

Spawning Areas

Up to 75% of the pink and chum salmon in PWS spawn in intertidal areas which are highly susceptible to oil contamination (Meacham 1990); the remainder move upstream. Oil contamination was observed and documented in the intertidal zone at the mouths of 43 streams (Sharr et al. 1990b). Adult spawning salmon in these areas may be expected to have been exposed to oil. Although no gross shift in the utilization of spawning habitat was detected, ongoing studies are comparing pre- and post-oil spill spawning distribution between oiled and unoiled streams and within intertidal and upstream portions of individual streams.

In the Kodiak/Chignik areas, few salmon spawn in the intertidal zones; most move up streams for spawning. As a result of fisheries closures in response to the oil spill, escapement (salmon returns to the river) levels were very high, which resulted in massive numbers of spawning salmon (up to 7 standard deviations above long-term annual means) moving into small streams. Such excessive escapement and the resulting large number of spawners are associated with poor survival and recruitment due to density-dependent induced mortality of eggs and fry (Larkin 1978).

Eggs/Fry

Preliminary analysis indicated a 5% increase in mortality of pink salmon eggs laid in the fall of 1989 in oiled streams compared to non-oiled controls (Sharr et al. 1990a). Eggs have lower rates of hydrocarbon uptake than alevins or fry and therefore, the damage to egg embryos from long-term exposure may not be evident until after hatching. Pre-emergent fry digs are currently underway to assess impacts. It was noted that pink salmon alevins are more adversely affected by oil in sea water than in freshwater.

Juveniles

Results of studies to date suggest reduced growth rates, more scattered migration patterns, and slower swimming speeds for juveniles released in oiled versus oil-free areas. Juvenile pink and chum salmon were more abundant in the non-oiled areas (Wertheimer 1990). Comparisons of fry grouped by collection area, as well as by tag lot, indicated that the presence of oil was correlated with reduced growth rates (Raymond et al. 1990). Other studies (Thomas et al. 1989) suggest that hydrocarbon uptake may be significantly greater in juvenile compared to adult salmon. "Apparent" depressed growth rates based on length-weight analysis in the vicinity of the AFK hatchery were observed, despite good food abundance and temperature conditions.

Sockeye Over-escapement

Sockeye salmon use lake nurseries for 1 or 2 years. The over-escapement due to the 1989 closure of the fishery resulted in extremely large numbers of sockeye entering the spawning system. This may result in the production of more juvenile salmon than can be supported by current lake productivity (Larkin 1978). This over abundance may, in turn, result in reduced freshwater or marine survival and consequent reduction in future adult returns. Since returning sockeyes can also constitute a major source of nutrients in their spawning systems, future declines in adult returns could also affect the existing nutrient balance, thereby reducing lake carrying capacities.

Dolly Varden Char and Cutthroat Trout

Char and trout use nearshore and estuary areas for feeding; some of the most important stocks inhabit areas that have been severely impacted by direct exposure to oil. Damage assessment studies have indicated that dolly varden have the highest levels of bile hydrocarbon concentration of any fish sampled. High concentrations impair reproduction, growth, and survival rates of both char and trout. Bioassays have suggested that even low concentrations of crude oil can affect the survival of prey species that provide forage for these fish (Meacham 1990).

Herring

Herring are a major resource in PWS from both a commercial and an ecological perspective. Herring use intertidal and subtidal areas for forage and spawning. Although results of aerial surveys did not indicate major direct mortalities to adult herring, results of damage assessment studies indicate that egg mortality was greater in oiled areas (Meacham 1990). Larvae that survived in oiled areas had high rates of embryonic, cytologic, and cytogenetic abnormalities. High bile hydrocarbon concentrations also were observed (Biggs et al. 1990). Although observed population growth rates were higher at control sites than at oiled sites, this may have been due to higher temperatures at control sites (McGurk et al. 1990).

Rockfish

Approximately 30 species of rockfish are found in PWS; this group is composed of both demersal species (benthic feeders) and semi-pelagic species that feed in the water column. Rockfish are the only species for which mortality has been definitively linked to oil exposure. Five rockfish brought to collection centers were autopsied, and crude oil was found to be the cause of death (Hepler et al. 1990). Eleven of 36 rockfish bile samples analyzed from oiled areas of PWS showed hydrocarbon accumulation (Meacham 1990). The results of studies suggest that contamination persisted in the environment well after the initial oiling and that oil contamination has extended to benthic habitats. Since rockfish are relatively sedentary and long-lived, this evidence raises concern over the long term sublethal effects of oil contamination, particularly for the benthic feeding species. Impacts on benthic food resources may last more than 10 years (Dauvin and Gentil 1990).

Other Finfish

A representative collection of species taken from trawl surveys were submitted for hydrocarbon analysis. Preliminary results from bile sampling indicate that a number of species, including flathead sole, halibut, herring, Pacific cod, and pollock, have been exposed to oil (Haynes and Urban 1990). These species are subject to important commercial, recreational, or subsistence fisheries and also play an important role in the PWS ecosystem by providing food for a variety of marine mammals and birds.

Spot Shrimp

Spot shrimp are known to be sensitive to oil contamination in both larval and adult stages. Spot shrimp hold their eggs externally, which permits direct contact with oil; the spill occurred during the documented egg release period. Preliminary results indicated that approximately 20% more shrimp from oiled areas than from non-oiled areas had one or more dead eggs (Donaldson and Ackley 1990). Egg samples are currently being analyzed. Tagging studies indicated that spot shrimp inhabit nearshore, deep, rocky areas and have limited movement both within and between years. Pots placed in unoiled areas had a significantly greater catch-per-unit-effort.

Clams

Adult bivalve mollusks are sedentary filter and deposit feeders. They are susceptible to oil contamination due to continued exposure, as tidal action oils and re-oils intertidal mud flats and as oil settles out of the water column into subtidal regions. Clams are particularly vulnerable because they do not have an efficient method of metabolizing hydrocarbons; therefore, high concentrations potentially can develop (Shaw et al. 1976). Although no direct mortality of clams was detected immediately after the spill, clams utilized for subsistence fishing were sampled and tested for hydocarbons. These specimens yielded the highest level of hydrocarbon content for any fish/shellfish species (Meacham 1990). In addition to the potential health hazard to subsistence fishers, this may also impact the health of mammalian predators such as sea otter and bear. Beach washing and fertilization may also have affected clam settlement.

BIRDS

The northern Gulf of Alaska, including PWS and Cook Inlet, hosts some of the largest populations of marine birds in North America. Millions of pelagic seabirds, including fulmars, storm-petrels, cormorants, kittiwakes, murres and puffins breed at major colonies on or near the Kenai and Alaska peninsulas and Kodiak Island (Piatt et al. 1990). Hundreds of thousands of coastal marine birds, including loons, grebes, seaducks (e.g., scoters, eiders, oldsquaw), and murrelets winter in PWS and sheltered bays throughout the area.

Surveys and Non-species Specific Studies

Approximately 30,000 dead birds comprising 90 species were recovered between 25 March and 1 August 1989 from PWS and the Gulf of Alaska. Of the 92% identified, 74% were murres. Eighty-eight percent of the dead birds were retrieved outside of PWS. Based on actual dead counts and population surveys, an estimated 100,000-300,000 birds were killed by the Exxon Valdez oil spill (Wohl and Denlinger 1990). Short-term responses to the oil, as measured by aerial surveys, indicated that there was a general movement of birds away from oiled transects into unoiled transects between March (pre-spill) and April (post-spill) 1989, especially for sea ducks, diving ducks, and alcids (Klosiewski and Hotchkiss 1990). However, comparisons to data from surveys conducted in 1971 indicate that the estimated number of gulls, shorebirds, and small alcids was greater than expected in oiled versus unoiled areas. Boat-based surveys showed that pigeon guillemots, black oystercatchers, red-neck phalaropes, and black-legged kittiwakes declined in abundance between 1984 and 1989 in the oiled transects of 1989 relative to unoiled ones.

Population surveys of seabird nesting colonies were conducted with special emphasis on the cliff-nesting black-legged kittiwake and the common murre. No significant changes were found in the number of kittiwake adults, regardless of proximity to the oil spill; breeding success was found to be highly variable or low (at oiled and unoiled sites) except in the vicinity of glacial waters (Nysewander 1990). The number of murres, however, appeared to decrease on the Barren Islands (60-70%), Alaska Peninsula (50-60%), and the Triplet Islands (35%) with respect to historical data spanning the last 17 years, while no significant changes in numbers were observed at the control area, the Semidi Islands (Nysewander 1990). Breeding success of murres was good at the Semidi Islands, while very low or poor at all other sites.

Species Specific Studies

Marbled Murrelets

Marbled murrelets are the most abundant alcid in PWS and are widely distributed throughout the area exposed to the oil spill. Within PWS, murrelet densities were generally highest at unoiled sites and lowest at heavily oiled sites, but boat traffic was also heaviest at the latter (Kuletz 1990). Historical data (1978-80) from Naked Island indicates that densities of marbled murrelets were significantly lower during the early period of the breeding season (7 June-12 July) in 1989 than in previous years, while later in the season (13 July-5 August), no significant differences between 1989 and historic records were detected. However, since historical surveys of PWS indicate a decline in murrelet numbers prior to the spill, it is uncertain what mortality can be directly attributed to the oil spill.

Pigeon Guillemots

The Naked Island area supports about 20% of the PWS guillemot population, estimated to be approximately 5,000 birds in 1984-85. Population surveys conducted at Naked Island (an area ranging from lightly to heavily oiled) indicated a 25-36% decrease between the early 1980s and 1989 (Oakley 1990). As the PWS guillemot population declined 50% between 1972 and 1985, the extent to which the observed decline at Naked Island can be explained by the oil spill as opposed to an overall population decline is unknown; however, the largest declines in Naked Island guillemots occurred in those areas most heavily oiled. Due to the cryptic nature of nests, too few were monitored to estimate rates of successful hatching, fledging and nesting in 1989; however, observations indicate that, compared to other good weather years, chicks were fed at similar rates on similar foods and fledged at similar weights.

Black-legged Kittiwakes

Black-legged kittiwakes are the most abundant colonial nesting seabird in PWS, with 30 colonies comprising roughly 40,000 nests. Reproductive success was measured at 24 of these colonies for six years prior to the spill; the spill oiled 10 of these colonies. In 1989, reproductive success at oiled colonies was about one half of what was expected from previous years (Irons 1990).

Black Oystercatchers

Hatching success of black oystercatcher eggs was higher on an oiled site (Green Island) than on an unoiled site (Montague Island), with predators destroying a larger number of nests on the unoiled site (Sharp 1990). Chick survival appeared to be inversely correlated with the degree of site oiling. Feeding rates were approximately 2 1/2 times lower at the oiled site than at the unoiled location.

Glaucous-winged Gulls

Most of the glaucous-winged gulls in PWS come from Egg Island (outside PWS, near Cordova) and Perry Island. Egg Island is the largest glaucous-winged gull colony in the world, with 10,000 breeding pairs historically. No significant changes in the population or productivity of gulls on Egg Island were detected in 1989 compared to historical data (Patten 1990a). Glaucous-winged gulls may have escaped immediate impact because Egg Island was not in the immediate vicinity of the oil spill, and most gulls on the island may have been defending territories on site, not foraging far from the island.

Sea Ducks

Gross necropsies indicate that harlequin ducks and Barrow's goldeneyes were the sea ducks most affected by the oil spill (Patten 1990b). Being diving ducks, harlequins and goldeneyes feed over a range of water-covered intertidal areas. Birds collected within oiled portions of PWS and the Kodiak Archipelago were in poor physical condition compared to those found in unoiled areas of Cordova and Juneau. No sublethal effects were documented for scoters, which forage in deeper water than harlequins. Results from the histopathology study were not available at time of workshop.

Bald Eagles

No significant difference in total numbers of bald eagles was found between surveys conducted in 1982 and April 1989; however, 144 dead bald eagles were retrieved during spill response activities (Schempf 1990). Autopsies performed on a few eagles indicate that death was caused by ingestion of oil. The 1989 survey found 3230 eagles between Cape Spenser and Homer. Nest occupancy rates were not significantly different between nests along oiled and unoiled beaches; however, nest failure rates were significantly higher along heavily and moderately oiled beaches (80%) than along lightly or unoiled beaches (50%).

Peale's Peregrine Falcon

An estimated 40-60 pairs of Peale's falcons inhabit PWS and coastal Kenai Peninsula. Observers on aerial surveys after the spill recorded 19 adult Peale's falcons at 13 nesting territories compared to a total of 30 adults and 25 sites in 1985 (Hughes 1990). Seventy-four percent of the historical nesting sites apparently were unoccupied by falcons during the late spring and summer of 1989. Although annual variability in number of occupied nesting sites is normal, the low rate of occupancy and the lower number of observed adults after the spill exceeds expected variation. Other reproductive parameters (success rate, productivity, and number of young per nest) were also lower in the spill area than those documented elsewhere in the limited breeding range of Peale's falcon.

Fork-tailed storm-petrel

No significant difference was observed in reproductive success between 1989 and three previous years of data on East Amatuli Island, adjacent to the Barren Islands (Nishimoto 1990). Historically, this island has had breeding adults by the 10,000s (Isleib and Kessel 1973). After the *Exxon Valdez* oil spill, dead bird receiving stations documented 444 dead storm-petrels, constituting 1.22% of all birds found.

MARINE AND TERRESTRIAL MAMMALS

Marine Mammals

Beaches from Kayak Island to King Salmon (Bristol Bay) were surveyed for the carcasses of stranded cetaceans from March through October 1989. Thirty seven carcasses were located, comprised of: 26 grey whales, 5 harbor porpoises, 3 unidentified cetaceans, 2 minke whales, and 1 fin whale. Necropsies to determine the cause of death were inconclusive for all animals. Tissue from seven of the stranded animals was collected for hydrocarbon and histopathological analyses. Results from tissue analyses were not available at the time of the workshop. The number of grey whales stranded in 1989 was significantly greater than the 6 reported in previous years between Kayak Island and Unimak Pass (Loughlin 1990). Researchers suggest that this increase may be attributed to the coincidence of the increased survey effort due to the oil spill with the annual northern migration of grey whales.

Humpback Whales

There were no reports of stranded humpback whales in Alaskan waters in 1989. Using the capture-recapture method of population estimation applied to visual sitings, there was no decline observed in the number of humpback whales in PWS in 1989 (54; 95% C.I. 46-62) from 1988 (34; 95% C.I. 27-41) and 1984 (62; 95% C.I. 45-79) observations. However, the number of whales observed using the Lower Knight Island Passage area ($n = 94$) declined significantly (31% , Chi square $p < 0.01$) from 1988 observations ($n = 136$) (Dalheim and Loughlin, 1990a). Researchers attribute this change in distribution to the effect of increased vessel and aircraft traffic due to clean-up efforts. The "finite reproductive rate" calculated for PWS humpback whales in 1989 was 6.3%. Reproductive rates of PWS humpback whales have varied considerably between 1980 and 1988, with a "combined annual rate" of

9.8%. However, the 1989 rate is the lowest obtained, with the exception of the 3.6% rate observed in 1986 (Dahlheim and Loughlin, 1990a). During the 1989 NRDA study, humpbacks were never observed swimming through oil; however, there is one anecdotal report of a humpback swimming inside a secondary contaminant boom at Crafton Island. To assess whether substantial population redistribution occurred as a result of the spill, the southeast Gulf of Alaska was surveyed for the presence of PWS humpbacks; none were identified.

Killer Whales

Thirty one killer whales from three resident pods were missing in 1989. Seven of the missing whales were from AB pod, the most frequently encountered resident pod in PWS. If these animals are not sighted in 1990, the 1988-1989 projected mortality would be 19.4%, ten times higher than the expected natural mortality rate based on 24 years of research (Dalheim and Loughlin 1990b). The two whales missing from AE pod represent an average loss over the past three years; this loss is well within the limits of the natural mortality rate in PWS. The remaining 22 missing whales were part of a subgroup. Because subgroups occasionally travel away from the main pod, researchers could not conclude whether the absence of these animals represents a significant loss at this time. In late August and early September each year, multi-pod aggregations are reported in Lower Knight Island Passage and Montague Strait. During these months AB and AI pods are present virtually the entire time in aggregations with various other pods. In 1989, typical multi-pod aggregations did not occur. Observations of AB and AI pods were of a short-term nature and, in contrast with other years, the whales did not use Lower Knight Island Passage but remained in Montague Strait (Dalheim and Loughlin 1990b). The researchers surmised that redistribution of resident pods probably occurred, but changes in habitat use cannot be demonstrated adequately due to the lack of quantitative data from past studies. Killer whales frequently were observed swimming through oil, making no apparent attempt to avoid oil contaminated areas. There was no apparent redistribution of the Prince PWS killer whale population to the southeast Gulf of Alaska.

Sea Lions

Oil contamination of Steller sea lion rookeries and haul-outs was described to be minimal and short-term. Ten sea lions were found dead in oiled areas. Five of the 10 dead animals were necropsied; however, researchers made no statements regarding the causes of death of these animals. Tissue samples for hydrocarbon and histopathological analyses were obtained from six of the 10 dead animals and from 17 collected animals. Results of tissue analysis are not available at this time. Sea lions were observed swimming through oil in PWS regularly, making no attempt to avoid oiled areas. The expected increase in the rate of premature pupping resulting from exposure to oil was not observed in 1989 (Calkins et al. 1990b). In light of the historic decline of the sea lion population in PWS, researchers emphasized the need to continue to study the incidence of premature pupping for the next one to two years to detect any delayed effects of oil exposure on sea lion reproduction.

Harbor Seals

Harbor seal habitat in the Gulf of Alaska was impacted by oil as far to the southwest as Tugidak Island. Some of the largest haul-out sites in PWS, and waters adjacent to these haul-outs, were impacted by substantial amounts of oil. Nineteen harbor seals were found dead or died in captivity during clean-up and were necropsied. Researchers can not draw conclusions regarding the causes of death until tissue samples for hydrocarbon and histopathological analyses obtained from these animals and 20 additional collected harbor seals have been analyzed. Histopathological data available from one heavily oiled pregnant female showed degenerative lesions in myelin sheaths of the central nervous system, cellular necrosis of the liver, and ulcerations of the mucosa of the trachea (Frost 1990). Researchers made no statements regarding the significance of these observations. Counts of oiled seals older than pups, in oil impacted areas, showed that 70% of all seals encountered were oiled in May, 40% to 100% were oiled in mid-July, and less than 20% were oiled in early September, after molting. Researchers considered four possible explanations for the progressive decrease in the number of oiled seals observed: 1) immigration of clean seals into the area, 2) emigration of oiled seals away from the area, 3) mortality of oiled seals, or 4) natural cleaning of oiled seals. Because seals are known to exhibit considerable site fidelity and no oiled seals were observed in unoiled areas and because much of the heaviest oil was removed from major haul-outs in May, it was concluded that seals probably became cleaner over time. Seal pups born in oiled areas became oiled within one to two days after birth. In Bay of Isles and Herring Bay, 89-100% of all seal pups seen were oiled. Many pups remained oiled through September because they do not molt in their first year. There was no significant difference in the ratio of pups to non-pups for oiled versus unoiled areas in 1989. The historic decline in harbor seal population was similar at oiled and unoiled areas between 1988 and 1984 (37% vs 36%); however, from 1988 to 1989, the decline at oiled sites was significantly greater than at unoiled sites (45% vs 17%), as indicated by orthogonal contrasts from a repeated measures ANOVA (Frost 1990).

Sea Otters

Boat surveys of shoreline otter habitat in PWS suggested a net population decrease of approximately 700 otters relative to baseline studies conducted in 1984-1985. Of 878 carcasses recovered from the entire oil impacted area, 710 suggested oil related deaths. Spill-related otter mortality was particularly high in PWS, where 415 of the 490 carcasses recovered indicated oil related deaths. Females predominated among the carcasses recovered from PWS and the Kenai Peninsula, suggesting that injury to the population is likely to be long-lasting due to reduced reproductive potential. Analysis of blood parameters from otters in oiled and unoiled areas showed values consistent with liver and kidney damage in otters from oiled areas. Intensive helicopter surveys conducted as a result of the oil spill revealed a substantial off-shore population of sea otters, which researchers believe is separate from and independent of the shoreline population. Researchers emphasized that this previously undocumented population may have important implications for estimating total sea otter mortality and interpreting population redistribution studies (DeGange and Burn 1990).

Otter rehabilitation centers were located at Valdez and Seward. Most of the otters treated at the Valdez center were taken from PWS. Fifty eight percent of otters treated at the Valdez center died in captivity, compared to 15% mortality at the Seward treatment center. At Valdez, mortality was significantly related to the degree of oiling, with heavily oiled animals having only a 27% chance of survival (DeGange 1990). The researchers interpret this evidence to suggest that oil effects were more acute in PWS than on the Kenai Peninsula, Kodiak Archipelago, and Alaska Peninsula. One hundred seventeen (36%) of the total 329 cleaned otters died in captivity. Confounding variables such as the timing of exposure and degree of oiling limited researchers' ability to distinguish factors affecting survival of rehabilitated otters. Insufficient data are available to test the various hypotheses related to survival and reproduction of rehabilitated otters.

Terrestrial Mammals

Sitka Black-tailed Deer

Soon after the spill, deer were observed eating oiled intertidal vegetation on Kodiak Island. Some of these deer had oil contamination on their legs and feet. Observations conducted in mid-April 1989 indicated that few deer were using the beaches and that many had moved to higher elevations. Researchers suggest that this somewhat premature movement to higher elevations was related to increased human activity on the beaches resulting from the oil spill. No statements were made regarding the degree of prematurity of movement to higher elevations or whether a similar early movement occurred outside the oil impacted area in 1989. During response and clean-up, 64 deer carcasses were found. None of these animals were externally oiled. Tissue samples suitable for hydrocarbon analysis were obtained from eight of the dead animals; results were not available at time of the workshop. None of the 64 carcasses provided tissue suitable for histopathological analysis. An additional 38 deer carcasses were found between 25 May and 15 June, during a pilot study to determine whether an extensive, systematic, rigorous search for oil-killed deer was warranted. None of these animals were externally oiled. These carcasses provided no tissue suitable for histopathological or hydrocarbon analysis. Most of these 38 deer appeared to have died of complications from malnutrition; these mortalities could not be directly linked to the effects of exposure to oil. Tissue samples for hydrocarbon and histopathological analysis were obtained from 32 live deer collected on or near oil contaminated beaches. Two of these animals were eating oiled vegetation and had oiled legs and feet when collected. Histopathological analysis of tissues from these two animals indicated that one had tubular nephrosis, which may be an early lesion associated with ingestion of oil (Calkins et al. 1990a). No other tissue analysis results were available at the time of the workshop.

River Otter and Mink

Eleven river otter and three mink carcasses were found on oiled beaches. Tissue samples suitable for histopathological and hydrocarbon analysis were obtained from seven of these carcasses. Hydrocarbon analysis of one of these samples indicated a high polyaromatic hydrocarbon level in the lung tissue, suggesting oil related mortality. Other results of tissue analysis are not available at this time. Three necropsy reports documented evidence of exposure to oil. Researchers studying otter scat deposition rates as a measure of population density found no significant difference in scat deposition rates between oiled and unoiled sites (Faro et al. 1990).

Brown Bear

Brown bears utilize areas impacted by oil. It is suspected that brown bear population density along the Katmai coast is higher than that reported for any other brown bear population (Calkins et al. 1990c). Oil spill related injury to brown bear populations was expected because they are omnivorous, opportunistic feeders that may have ingested oil by eating congealed floating oil or tar balls washed ashore, by eating oiled plants and clams, by scavenging oiled carcasses of animals killed offshore and deposited on beaches, or by consuming animals that had been physiologically affected by sublethal doses of oil. No mortality or significant redistribution has been observed among 30 radio-collared brown bears in an oiled area along the Katmai coast.

CULTURAL

Background

Although formal damage assessment studies were not funded for cultural resources in response to the *Exxon Valdez* oil spill, some limited information was presented at the restoration planning workshop.

Approximately 900 archaeological sites had been identified in the entire impacted area prior to the *Exxon Valdez* oil spill. The Kodiak archipelago was thought to be the general location of the largest prehistoric human populations, had the highest site density, and contained large, complex, deep archaeological sites, some of which had undergone only partial erosion to the beach. Site density and characteristics were similar on the Katmai coast and in Kenai Fjords. Little was known about the archaeology of PWS prior to the spill. The area had never been investigated in depth, and the only available landmark surveys were out of date. The session consensus was that the hurried, "combat archaeology" technique used to survey PWS beaches prior to the initiation of clean-up activities probably did not meet minimum reconnaissance standards, potentially overlooking a considerable number of sites.

Types of Damage to Cultural Resources

Effects of Oil

Oil contamination is suspected to have masked beach deposits, making them difficult or impossible to identify by ordinary methods of site reconnaissance. Where stratified deposits exist in the intertidal and subtidal zones, oil penetration may mask the stratigraphy, thus reducing the information available from those deposits. In addition, oil contamination of materials used to determine the age of archaeological sites will interfere with current radiocarbon dating techniques. Potential effects of fertilizers used in bioremediation and chemical dispersants on artifacts are unknown.

Erosion

The presence and activities of the massive beach clean-up force resulted in considerable accidental and deliberate disruption of beach deposits; consequently, cultural information that could have been obtained from the patterns of human and animal bones and other artifacts present in the deposits has been minimized or lost. In addition, the destruction of the matrix in which artifacts are embedded results in the loss of important information, such as paleoecological data (e.g., contemporary pollen types) and other clues to the age of the deposit. Cleaning techniques, particularly washing beaches with high pressure hot water, contributed to disruption of deposits and destruction of matrix, as well as to general beach erosion. The potential loss of supratidal beach vegetation due to the toxic effects of oil splattered by storms may further destabilize beaches, resulting in additional erosion of lag deposits and potential degradation of some relatively undisturbed upland deposits.

Vandalism

The influx of people on PWS and Gulf of Alaska beaches due to the oil spill has made the location of artifacts general knowledge. In fact, participants suggested that artifact hunters currently may have more information about the location of sites than resource managers. The session discussed anecdotal evidence that amateur and professional artifact hunters are removing items of archaeological and cultural significance from PWS and Gulf of Alaska beaches in quantity. In support of such evidence, session participants described a shift in collector attention from high arctic artifacts to native artifacts from the PWS and Gulf of

Alaska area, that was occurring even prior to the Exxon Valdez oil spill and has resulted in increased market value for such items. In addition, the session reported that a government agency employee involved in clean-up has been prosecuted for looting artifacts. This would seem to suggest that spill related attention may further increase the demand for artifacts from the PWS area. Improper removal of artifacts from beaches contributes to destruction of matrix and to erosion by leaving holes in the beach.

Loss of Heritage

The session emphasized that Native Alaskan communities, with their rich traditions, represent an invaluable cultural resource. The participants expressed concern that Native Alaskans whose ancestral sites have been degraded by the effects of the oil spill and clean-up may perceive a sense of injury and insult to their heritage. In addition, the session participants suggested that these groups may have lost faith in the health of the resources upon which their subsistence lifestyle, and ultimately their entire culture, is based. Systematic analysis of the seafood resources harvested by subsistence fishermen indicates that fish are generally clean but that shellfish in some areas are contaminated with polyaromatic hydrocarbons. There is concern that if subsistence resources are perceived to be tainted, Native Alaskans will be forced to rely on other sources of support, losing their sense of self sufficiency and potentially forgetting traditional fishing methods and associated customs. The session pointed out that a Minerals Management Service social indicator study has shown an increase in alcoholism and suicide rates among Native Alaskans in 1989. Participants suggested that spill related alterations in the traditional routine may contribute to the erosion of the culture.

Estimating the Cost of Damages to Cultural Resources

The session participants pointed out that section 106 of the NHPA (36 CFR 800) stipulates that planned destruction of historic properties must be mitigated and provides guidelines for estimating the cost of damages to historic resources from a planned disturbance of a site, such as development. In addition, the ARPA provides guidelines for recovering the value of archaeological resources. The costs considered eligible for recovery under these two acts are:

- Pre-impact site survey costs

- Market value of artifacts lost to looting resulting from site identification
- Data collection costs
- Landscape mitigation costs.

Although these guidelines for cost recovery are typically employed prior to the execution of a planned disturbance of an historic property, the session participants suggested that these guidelines could be applied to the effects of the oil spill accident by analogy, to provide a framework for determining the monetary value of damages to historical and archaeological resources in Prince William Sound.

RECREATIONAL

Although formal damage assessment studies were not funded for recreational resources in response to the Exxon Valdez oil spill, some limited information was presented at the restoration planning workshop. Various state and federal land and water resources used for recreation experienced oiling from the spill; however, the degree to which these areas have been affected was unknown at the time of the Technical Workshop. Some of these areas include: Kenai Fjords National Park, Katmai National Park and Preserve, Aniakchak National Monument and Preserve, Lake Clark National Park and Preserve, Becharof National Wildlife Refuge, Alaska Peninsula National Wildlife Refuge, Kachemak Bay State Park, and Alaska Maritime National Wildlife Refuge.

Although no formal damage assessments had been conducted at the time of the Technical Workshop, some specific information was provided for the Kenai Fjords National Park. Approximately 30% of the 400 miles of coastline within Kenai Fjords National Park received some degree of oiling. On a qualitative basis, 59 miles experienced very light impact, 50 miles light impact, 5 miles moderate impact, and 0.31 miles heavy impact. Visitation of the park has increased approximately 10-13% per year since establishment in 1980. Although visitation also increased between 1988 and 1989, with 59,000 and 77,000 visitors, respectively, "package" visitors to Alaska must plan and make a non-refundable payment on their trips well in advance (ferry schedules and cruise tour packages require early bookings). Therefore, it was hypothesized that a decrease in this type of visitation would be unlikely immediately after the oil spill. However, other user groups, such as kayakers and anglers, did exhibit a decline in total number of visits to the park in 1989. The decrease in these types of recreational activities in turn affected businesses providing support (e.g., supplies, guides). Potential effects of the oil spill on the 1990 park season are unknown at this time, although inquiries about the effects of the oil spill on the park have remained steady throughout the winter and early spring. Publicity generated by the spill could have both positive and negative effects in terms of attracting recreational users.

The type of "use" information provided for Kenai Fjords National Park is the first step in documenting damages to recreational resources. Simple measures alone, however, are inadequate in that they do not capture important information on changes in quality and type of use. Determination and quantification of recreational resource injury is complex and changes in both actual use and perceptions must be evaluated. Increased use numbers are not necessarily desirable. Impacts may be higher for some groups (e.g., kayakers) than for other groups (e.g., cruise ship passengers). Hence, damage assessment must take into account the "platform of use."

The Alaska Department of Natural Resources (ADNR) and the National Park Service (NPS) constructed a framework from which to design a formal proposal for damage assessment of oil spill impacts on recreation and tourism. As was previously mentioned, no damage assessment studies were funded, but the ADNR and NPS framework identifies types of activities potentially impacted and the nature of those impacts. Session participants identified general recreational activities within the PWS-Gulf of Alaska area which were at risk due to the oil spill. The lists generated by the two groups are similar; a composite list is presented in Table II-3. Any impact to these activities will have economic consequences on the sale of outdoor equipment and supplies, the sale and rental of boats, lodging and meals, ridership on trains, air charters and regular scheduled air service. The spectrum of potential injuries to recreation and tourism, as identified by ADNR and NPS, is listed in Table II-4.

Table II-3. Recreation and tourist activities for southcentral Alaska

1. **FISHING**

Freshwater-Guided/Unguided	Marine-Guided/Charter/Unguided
Salmon	Salmon
Trout/Char	Trout/Char
	Halibut
	Rockfish
	Shrimp & Crab

2. **HUNTING & TRAPPING**
   - Deer
   - Waterfowl
   - Bear (brown and black)
   - Goat
   - Elk
   - Small Furbearers

3. **BOATING**

Power	Sail	Other
Cruise Ships	Individual	Canoe
Yachts	Regattas	Kayak
Tour Boats		
Inflatables		
Skiffs		

4. **OTHER**

Natural History/Aesthetic Appreciation	Athletic
Wildlife Observation	Camping, tents
Beach Combing	Cabin Use
Berry Picking	Mining, Recreational
Photography & Painting	Scuba Diving
Gift Shopping	Wind Surfing
Visiting Cultural Sites	Outdoor Skills
Nature Study/Outdoor Education	Hiking
Anchoring	Climbing
Picnicking	Clam Digging/Crabbing/Shrimping
Flightseeing	Jet Skiing
"Armchair" (indirect, away from site appreciation of wilderness and aesthetics)	Water Skiing

Table II-4. Potential injuries to recreational and tourism uses in southcentral Alaska as a result of the <u>Exxon</u> <u>Valdez</u> oil spill

1. Direct displacement of recreational and tourism use -- redirect use.

2. Deteriorated scenic values.

3. Loss of wilderness characteristics.
   A. Physical
   B. Perceptual - Solitude, Mystique, Pristine

4. Damage to state's attractiveness as a visitor destination (visitor image).

5. Health and safety threats (on site).

6. Competition with cleanup efforts for equipment - disruption of infrastructure and economies in support of recreation and tourism.

7. Loss of wildlife and other resources which support recreation and tourism.

8. Loss of wholesalers of recreation and tourism.

9. Loss of visitation - state-wide and regionally (impacted area).

10. Damage to recreation places/settings.

11. Disruption of recreation activities (see Table III-6).

12. Loss (reduction) of visitor satisfaction levels.

13. Changes in use patterns (location, duration, participation rates, demographics, origin, etc.)

14. Increased management costs due to changes in use patterns and oil spill activities (e.g., additional staff, information/education needs, facility repair/replacement, etc.).

15. Loss of intrinsic values.
    A. Existence values
    B. Option values
    C. Request values

16. Ecological integrity.

17. Loss of air quality (smell).

18. Loss of recreation and tourism investments in:
    A. Promotion
    B. Resource Management
    C. Equipment

19. Loss of commercial recreation/small business.

20. Loss of recreation & tourism baseline area.

21. Loss of quality of life/lifestyle.

22. Loss of taxes (sales, real estate).

23. Water quality.

24. Loss of agency user fees.

III. STATE-OF-THE-ART OF ECOLOGICAL RESTORATION FOR NORTHERN LATITUDES

This section describes the state-of-the-art for ecological resource restoration in northern latitudes. The state-of-the-art review was not exhaustive but does indicate the range of restoration activities that might be applied to restore habitats or other ecological resources in PWS and the Gulf of Alaska. Many unsuccessful restoration efforts are not documented, and this makes it difficult to assess restoration performance from the literature.

A. FISH/SHELLFISH AND COASTAL HABITATS

The state of the art for fish/shellfish and coastal habitat restoration includes restoration of damaged habitats, replacement of fisheries, and the acquisition of alternate habitat resources. The techniques or methods applied to restoration are largely identical to those used for mitigation; the primary difference is the reason for application. Restoration is applied to correct past problems or "inadvertent" damage, whereas mitigation is applied for a planned action that has been characterized as having the potential for significant adverse effects on the environment (Clark 1987).

Although this review focused on applications suitable for northern latitudes, the general approaches used in temperate coastal systems potentially are applicable for the subartic conditions of PWS and the Gulf of Alaska. In reviewing past restoration applications, species differences were noted, but technology transfer to related species seemed possible. The primary "northern latitude" constraints are likely to be logistical impediments imposed by the remoteness of the area and meterological and oceanographic conditions. Another factor that may limit the applicability of some of the reviewed methods would be the difficulty associated with increasing the scale of the effort to meet larger areal requirements.

Some restoration methods reviewed focused on other, non-aquatic habitats, such as riparian or coastal shorelines. Restoration or preservation of these habitats would have direct or collateral benefits for fisheries. Protecting these habitats from further development through the acquisition of logging or mining rights or property purchase would benefit commercial, recreational, and subsistence fisheries, as well as birds and mammals, by reducing the potential for erosion and other processes which facilitate the release of toxic materials.

In addition, since some of the potentially impacted fish are exploited resources, restoration measures could include changes in how these resources are managed. Since restoration actions directed at reducing overall risks to harvested resources are appropriate under the scope of protecting these resources from further harm, both out-of-kind habitat acquisition and modifications to management strategies were judged to be appropriate "restoration" measures under the framework described in the introduction of this report.

Habitat Restoration

Efforts to restore habitat can include rehabilitating existing habitat or creating new habitat, using either natural or artificial materials. Rehabilitating habitat includes such actions as restoring fish passage for anadromous species, cleaning gravel in spawning beds (Mih 1978), or on-site replanting of marsh areas (Seneca 1982). The creation of new habitat includes the use of extensive long-line kelp culture methods for off-site habitat enhancement, artificial reefs or substrates, beach terracing for clam culture, and building new spawning channels. Creating alternative habitat is appropriate where or when direct on-site rehabilitation is not possible or cost-effective due to persistent contamination or other conditions that reduce the potential for success.

The use of stream channel modifications has been reviewed recently (Welch 1985), and a range of measures such as fishways, egg boxes, and stream gravel cleaning methods (Mih 1978) are potentially useful for salmonid restoration. The use of artificial reefs for mitigation has also been reviewed (Sheehy and Vik 1985). Investigations in California using a quarry rock reef in conjunction with kelp transplantation (Jesse et al. 1985) indicate use of the artificial reefs by rockfish and other demersal species. Large-scale prefabricated reefs have also been applied for estuarine mitigation projects, based on the transfer of this technology from East Asia (Sheehy and Vik 1989, 1990). Marsh and submerged aquatic vegetation (SAV) transplantation is also a potential for PWS. A series of demonstration projects have been conducted and are being evaluated as part of a National Marine Fisheries Service -- Corps of Engineers cooperative agreement (Thayer et al. 1989). Although SAV methods may require adaptation to Fucus or other native species in PWS, the general approach shows merit and the concept appears to have potential. Additional feasibility studies and developmental testing are required prior to operational implementation.

Aquaculture-Based Supplemental Production

For some fin and shellfish species, existing aquaculture methods may be applicable to PWS and the Gulf of Alaska to provide direct replacement of impacted stocks or to provide alternative stocks for use until native stocks recover. Salmonid hatchery operations in Alaska are quite advanced, and herring and other mariculture techniques have been developed in Japan and other areas (Sheehy and Vik 1981).

In addition to replacing target species, extensive culture methods also can be used to create habitat for spawning and nursery areas or as a means of replacing forage bases for some species. Macroalgae provide food and habitat for fish and shellfish. Kelp and _Fucus_ provide food directly to invertebrate herbivores such as the sea urchin and serve indirectly to concentrate planktonic and encrusting food resources for a number of species. Herring deposit eggs on nearshore macroalgae, and in California, the distribution and density of eelgrass are a critical part of annual Pacific herring spawning biomass estimates (Spratt 1989). Some salmon also spawn in intertidal areas and use nearshore waters as rearing areas.

Culture and transplantation methods for kelp, such as _Laminaria japonica_ and _Macrocystis_, exist and could be adapted to local species. Methods for _Fucus_ might be developed, if required. Some of these habitat enhancement applications could serve as interim measures to compensate for critical habitat loss until natural recovery occurs. One possible approach to _Fucus_ transplantation is discussed in one of the feasibility projects included in Chapter V.

A variety of culture methods for shellfish exist and might be adapted to provide supplemental production either of impacted species, equivalent species, or species that provide forage for effected species. Hanging culture methods such as those used for mussels, oysters, or scallops might be applied to maintain fishery harvests by deploying culture long-lines or baskets off or outside of contaminated bottom areas. Long-line or hanging culture methods take advantage of the third dimension of the water column and, with adequate circulation, can provide substantial crops in a relatively small area, compared to bottom culture methods. Hanging culture can be used to provide a continuous supply of seed to recolonize areas once natural recovery has reduced contamination to levels that permit normal bottom colonization. These methods also could be used to provide alternate resources for local aquaculture operations or forage for other animals. Stable, wave resistant long-line culture techniques have few surface floats to interfere with navigation, thus reducing conflicts with other water uses.

The application of integrated stocking and habitat enhancement methods is also a potential means of supplementing production of selected species, including mollusks, crustaceans, and a variety of finfish. The integration of hatchery production with nursery area enhancement has increased survival of stocked organisms significantly or permitted stocking of smaller organisms for a given level of survival. This approach generally is cost effective since it permits a more optimum approach to combining fixed cost habitat enhancement with the recurring operational costs of hatcheries. For example, in other areas, stocking abalone at a smaller size in artificially enhanced habitat permits more efficient use (more than one crop) of hatchery capacity (Sheehy and Vik 1981).

Management Changes

The commercial, recreational, and subsistence fisheries of Alaska are economically and socially important public resources. To ensure the preservation and enhancement of important fish stocks, resource managers gather information needed to regulate fishing effort effectively. Gathering this information has both costs and benefits, and these should be weighed to decide the nature or extent of information gathering efforts and the risks posed by inadequate information.

Alterations in current management practices to regulate fisheries based on the additional risk to these resources associated with the potential effects stemming from the oil spill can also function to promote restoration. Controlling fishing mortality (limiting harvest) as well as hatchery output (creating alternate target stocks) are both methods of reducing risk to potentially threatened stocks. With effective monitoring, areal and temporal fishery closures can be implemented to provide additional protection of specific stocks or habitats identified as being adversely affected by the oil spill. However, the potential long-term biological consequences of closures must also be considered in planning management changes. For example, the closures in the sockeye salmon fishery may result in overescapement and the need to consider fertilization of some lakes to accommodate the increase in rearing juveniles.

B. BIRDS AND MAMMALS

Attempts at direct restoration of populations of marine and terrestrial mammals and birds have concentrated on the reintroduction of species by translocation and captive breeding. These techniques involve the intentional release of captive-reared or wild-caught animals to establish, reestablish, or augment a population. The varied goals of reintroduction programs include bolstering genetic heterogeneity of small populations, establishing satellite populations to reduce the risk of species loss due to catastrophes, and speeding the rate of recovery of species after their habitats have been restored or have recovered from the negative effects of environmental toxicants or other limiting factors (Griffith et al. 1989).

Due to an increasing perception among the scientific and conservationist communities of the value of biological diversity, attention has been focused on reintroductions of rare and endangered native species. Such programs are expensive and have had limited success (Booth 1988, Griffith et al. 1989, Clark and Westrum 1989, Clark et al. 1989). Examples of restoration techniques and reintroduction programs applied to mammal and bird species present in Prince William Sound and their results will be discussed later in this section. Some general considerations regarding the use of translocation to restore bird and mammal populations will be discussed below.

Based on a survey of translocations of native birds and mammals conducted in Australia, Canada, the United States, and New Zealand between 1973 and 1986, Griffith et al. (1989) found that 90% of translocations involved game species, primarily ungulates. Typical translocations in the survey released between 30 and 75 animals in six releases over a period of three years. Defining a successful translocation as one resulting in a self-sustaining population, Griffith et al. (1989) identified the following factors associated with success:

- Classification of the species translocated (e.g., game, threatened, endangered)
- Quality of the habitat
- Location of the release site relative to the species' historic range
- Feeding habits of the species
- Number of animals released
- Absence of potential competitors of a similar life form
- Early breeding and large clutch size
- Use of exclusively wild-caught animals
- High density in the source population
- Translocation from an increasing source population rather than one that is stable or declining.

In general, translocation of herbivorous native game species to high quality habitat at the core of the species' historic range was found to have the greatest probability of success. Successful translocations released more animals than unsuccessful translocations; however, there was an asymptotic relationship between translocation success and numbers released, so that beyond a certain level, no additional benefit was accrued by releasing a larger number of animals. The asymptote for translocated bird species was reached at 80 to 120 animals released; for large native game mammals the asymptote was reached at releases of 20 to 40 animals (Griffith et al. 1989).

Griffith et al. (1989) emphasized that without high quality habitat and active management to maintain that quality, translocations have low chances of success, regardless of how many animals are released. The authors suggest that because translocation of small numbers of endangered or threatened species have relatively little likelihood of success, translocation should be considered long before population density has become low and populations are declining.

Restoration Techniques Applicable to PWS Bird Species

The restoration of habitat, such as wetlands, has had indirect restorative effects on a number of different types of species, including birds. For example, following the restoration of two wetlands in California, Wilcox (1986) and Novick (1983) observed an increase in bird species diversity and use of the area by shorebirds and waterfowl.

Of applicability to bird species at risk from the Exxon Valdez oil spill is work connected with the captive breeding and rearing of sea ducks (Makins 1987), and the restoration efforts with puffins in Maine (Lancaster and Johnson 1974), Bermuda petrels, and raptors.

Initial restoration efforts for the seriously depleted population of Bermuda petrel on the offshore islets of Bermuda centered on eradicating rats, which prey on the eggs and young of this burrow-nesting species (Wingate 1977). Subsequently, it was realized that nest site competition with another bird species was a critical limiting factor. Over a 15-year period the production of young tripled as result of the implementation of two conservation techniques to improve or increase nest site availability. One technique involved fashioning a baffler at the entrance of an occupied petrel burrow to preclude a larger bird species from entering, killing petrel young, and the burrow. Although successful, bafflers required frequent checking (every 2-4 days) to ensure continued successful operation. The second technique involved the construction of additional nest sites. Designs for these burrows were based on the differences in nest-prospecting behavior between the petrel and its competitor to ensure sole usage by petrels.

Probably the most well documented and prolific bird restoration work applicable to PWS and the Gulf of Alaska is the development and improvement, predominantly over the last 15 years, of reintroduction techniques for birds of prey. Extensive work has been conducted with peregrine falcons and bald eagles as a result of worldwide population declines due predominately to organochlorine insecticides, particularly DDE, a persistent metabolite of DDT. Since the mid-1970s, over 3,000 peregrine falcons have been reintroduced in the United States (Moser 1990). Releases have occurred along the mid-Atlantic coast (Barclay 1988), the Rocky Mountain states (Burnham et al. 1988), the Pacific states (Walton and Thelander 1988), the Upper Mississippi Valley, and the western Great Lakes region (Redig and Tordoff 1988). Outside the United States, Canada, Sweden and West Germany also have reintroduced peregrine falcons into areas that previously supported populations (Fyfe 1988; Lindberg 1988; Saar 1988). Over 300 bald eagles have been reintroduced in 11 states within the U.S. between 1976-1985 (Green 1985). The reintroduction work performed with these two species includes: captive breeding, hacking, fostering, and recycling. The goals of these reestablishment programs were to maximize the production of persisting wild pairs by fostering, to enhance remnant populations through hacking, and to reestablish breeding pairs by hacking in areas where the species were once prevalent. Each of these techniques will be discussed below.

Captive Breeding

Within the United States there are two major captive breeding programs for bald eagles and peregrine falcons. In 1976, captive propagation of bald eagles began at the USFWS Patuxent Wildlife Research Center in Laurel, Maryland. The counterpart for peregrine falcons began in the early 1970s at Cornell University (The Peregrine Fund) and in Colorado. In 1974, in a cooperative effort between The Peregrine Fund and Colorado Division of Wildlife, a propagation facility was created at Ft. Collins, Colorado. This breeding facility was relocated to Boise, Idaho in 1984, becoming the World Center for Birds of Prey.

Artificial insemination is often used and, at least with peregrine falcons, semen is supplied predominantly by behaviorally imprinted donors (Moser 1990, Burnham et al. 1988). Eggs are incubated, and chicks are maintained in brooders and hand fed only a short period of time before being placed with captive foster parents. Subsequently, these captively bred and reared young will be released either to wild foster parents or hack sites (detailed falcon propagation techniques are described by Weaver and Cade 1983). Without captive foster parents, bald eagle rearing efforts in Oklahoma have used a life-like eagle hand puppet to deliver food to young to prevent imprinting on humans prior to hacking back (Pollard 1985). Another source of eggs for reintroduction programs are thin-shelled wild eggs which are not likely to hatch in the wild. These eggs are collected from eyries, hatched, reared and released to foster parents or hack sites.

Fostering

"Fostering" involves placing young birds, typically a few weeks before fledging, in the nests of breeding pairs whose eggs have failed to hatch. Most of the young are the result of captive propagation, although wild young from destroyed nests also are placed with foster parents. Eight-five percent of fostered bald eagles have fledged successfully (Green 1985). Besides intraspecific fostering, successful interspecific fostering (cross-fostering) of peregrine falcons has been accomplished with red tailed hawks, prairie falcons, goshawks and kestrels (Gerriets and Saar 1988). Although there are concerns about peregrine young imprinting on the wrong species, cross-fostering work in California and Washington indicates no adverse behavioral effects (Walton and Thelander 1988, Burnham et al. 1988). Within the Rocky Mountain program, 75% of fostered and 34% of cross-fostered peregrine falcons have survived to flying (Burnham et al. 1988).

Conservation programs of the Spanish imperial eagle have removed the smallest and weakest chicks, which suffer aggression from their fellow nestlings and are not likely to survive, from their nests (WWF 1985). These chicks are held in captivity long enough to recuperate and strengthen. They then are returned either to their original nests, now equal in size to their siblings, or to other nests with less aggressive chicks of the same size. This reintroduction technique has had excellent success.

Hacking

"Hacking" is a falconry term which refers to the release of a captively held raptor into the wild to sharpen its hunting skills, with subsequent recapture by the falconer (Hammer et al. 1983). In reintroduction programs, hacking involves the release of fledglings without adults to predominantly artificial nest (hack) sites. The hack sites are attended continuously, and food is provided surreptitiously until flying and hunting skills have been perfected. Hack sites are fitted with a cage designed to protect vulnerable young birds from predators while allowing them to exercise their wings. Cages are opened when young are ready to fly. Early releases of peregrine falcons utilized natural cliff sites, but young were extremely vulnerable to predation by golden eagles and great horned owls. Much higher rates of survival of fledglings and a higher rate has been observed with hacking from structures or towers of return of subadults and adults (Barclay 1988). The success observed in hacking raptors from man-made structures likely is due to the ability to place structures and release birds optimally, where prey is concentrated, where appropriate habitat for perching and roosting is located, and away from predators' preferred habitat. Hacking has been extremely successful for both eagles (Green 1985; Hammer et al. 1983) and peregrine falcons (Burnham et al. 1988; Barclay 1988).

Advantages and Disadvantages of Fostering and Hacking

Fostering and hacking are similar reintroduction techniques in that they both require the physical transport and manipulation of young. There are also certain advantages and disadvantages inherent in their application. To implement fostering techniques as a reintroduction tool, there must be wild breeding adults. If this requirement is met, fostering allows the fledging of young to historical territories even though thin-shelled eggs have been laid. Although the recipient nest must be monitored closely to determine when eggs are laid so that thin-shelled eggs can be removed and replaced with young, fostering does not require weeks of extensive feeding prior to and subsequent to fledging, as does hacking. In the absence of wild breeding birds, hacking can be used to reestablish populations. Operations at hack sites, while largely successful, are labor-intensive, relatively costly, and especially for peregrine falcons, subject to predation considerations. A combination of techniques may be most appropriate for restoration programs. As new pairs become established through hacking, a shift to fostering young into their nests to increase productivity and nesting density can be implemented until an optimal carrying capacity is reached. This approach may be preferable to continuing long-term hacking efforts (Walton and Thelander 1988).

Recycling

The removal of eggs from a wild nest soon after laying can cause the parent to recycle, i.e., lay another clutch. Although it has been reported that removal of bald eagle eggs often results in the abandonment of the donor nests (Green 1985), the removal of eagle eggs in Florida for reintroduction efforts in Oklahoma, resulted in all donor pairs producing a second clutch of eggs (Pollard 1985).

Habitat Requirements

Of significant relevance to reintroduction efforts are the specific habitat requirements of species under consideration. Although site specific management plans are necessary to insure habitat preservation for restoration efforts, generic guidelines based on concentric buffer zones around a nest site have been developed for protecting bald eagle nesting areas (Grier et al. 1983).

Prior to implementing reintroduction techniques, the process of selecting candidate sites for a prospective program must minimize, or at least not exacerbate, the natural limiting factors imposed by habitat. These limiting factors include food and nest site availability as well as the proximity of the two requirements to each other. With increasing anthropogenic pressures imposed on raptor habitat, general degradation is possible to the extent that prey availability per unit area is reduced. In turn, this may result either in: 1) the hunting range becoming too large to be feasible; or 2) the two natural pressure points in the life cycle, rearing young and winter mortality, preventing the population from being self-sustaining (Fox 1987). The potential for a decrease in the size of habitat areas also exists, and with that, the likelihood that a population will become fragmented and vulnerable. If prey abundance is cyclic the raptor population may not survive the lowest point in the cycle (Fox 1987). During the reintroduction decision making process, these factors must be considered to facilitate the evaluation of the applicability and feasibility of site- and species-specific efforts.

Restoration Techniques Applicable to PWS Mammal Species

Captive Breeding

Captive breeding programs in zoos have been proposed as a potential source of rare and threatened mammals for reintroduction to the wild since the early 1960s. In a review of 15 years of census data for rare, threatened, and endangered mammal species maintained for captive breeding programs in zoos around the world, Pinder and Barkham (1978) found that only 61 species had reproduced frequently enough to warrant consideration. Of those species investigated, only four species of ungulates, related or similar to domesticated species, were determined to have achieved entirely self-sustaining populations in zoos. Only one of these species, the European bison, owes its restoration to reintroduction to suitable habitat following a successful captive breeding program. Since the source animals for captive breeding programs must be wild-caught, Pinder and Barkham (1978) concluded that, on balance, captive breeding programs are still net consumers of rare, threatened, and endangered mammalian species rather than producers.

Pinder and Barkham (1978) further identified characteristics of captive breeding programs that warrant consideration in evaluating this restoration technique. It was noted that mammalian species with migratory or learned behavior patterns, such as hunting, in their ethology would be difficult to reestablish successfully from captive-bred populations. Inbreeding due to the limited genetic pool is a common problem in captive breeding programs which results in reduced fertility of individuals. Furthermore, the authors noted that there are selection pressures exerted by life in captivity. Although there has been little research on the subject, it is assumed that the genetic changes resulting from such selection pressures could reduce the viability of a species and adversely affect its chances of survival after return to the wild.

If all mammal species (not just rare, threatened, and endangered) being bred in captivity are considered, only 26 species can be classified as having achieved self-sustaining populations (Pinder and Barkham 1978). No species present in PWS and subject to injury from the oil spill are included among these; therefore, reintroduction by captive breeding is probably not an appropriate restoration technique for PWS mammal populations.

Translocation

Aside from the historical and well established translocation of the Sitka deer, the best known translocations of a mammal species present in PWS are those of the sea otter on the coast of California. Sea otter translocations have had limited success. For example, fewer than one quarter of the 63 otters translocated from the coast of Big Sur to San Nicolas Island, southwest of Los Angeles, during 1988 remain (Booth 1988). Many of the stronger adults returned over 200 miles to their original breeding territories; at least ten translocated otters were confirmed dead from stress, drowning, or deliberate destruction. Additional problems associated with translocating otters in California include the extreme difficulty of capture and the intense political opposition from California fishermen to the expansion of the otter's range (Booth 1988).

River otters have been the subject of at least two translocation efforts (Erickson 1983; Hoover et al. 1985). In translocations of a total of 20 American river otters from Louisiana to Oklahoma in 1984 and 1985, 60% of the otters released in the first year survived for at least one year, and 70% of otters released in the second year survived at least ninety days, despite extensive handling and surgical implantation of intra-abdominal radiotelemetry devices prior to release (Hoover et al. 1985). Researchers in this study documented improvements in holding pens, diet, and medical and surgical treatments associated with improved health and increased chances for initial survival after translocation.

The preceding examples of translocations involving species present in PWS are not necessarily exhaustive. They reflect the most readily available information about application of state of the art direct restoration technology for mammals to PWS species with documented injury related to the Exxon Valdez oil spill. It is important to note that these reintroductions were attempted to restore populations primarily impacted by hunting rather than by habitat degradation or destruction.

IV. WORKSHOP RESULTS-DEVELOPMENT OF RESTORATION ALTERNATIVES

This section describes the candidate restoration alternatives identified by each of the six work sessions (fish/shellfish, coastal habitats, birds, mammals, cultural and recreational). A broad perspective was applied to identifying restoration alternatives in order to generate an inclusive list of options for restoration planners. As a result, some of the actions identified may not be appropriate under either the narrower, legal definition of "restoration" or the final findings of the NRDA. The reader is referred to Chapter III and the references identified in this section as well as the literature search results included in Appendix F and G for further information on the subject of restoration.

The participants in the technical sessions included biologists and resource managers from state and federal resource agencies as well as academic and private sector scientists. Lists of participants in each session and their affiliations, are included in Appendix B.

Each session approached its designated natural resource area in a slightly different manner. This chapter captures the individual character of these sessions and attempts to summarize the findings regarding restoration alternatives and additional data requirements. Most work sessions ranked identified restoration alternatives according to level of priority. The methodologies employed by each session were unique, and no attempt was made to equilibrate results or make comparisons between sessions. Only minor organizational changes have been made. Editorial comments are included where they support or expand upon session results, and minority points of view are included, when appropriate.

A. COASTAL HABITATS

Because the damage assessment information available at the time of the restoration workshop was not adequate to identify specific coastal zone habitat types, communities, and species which were significantly affected and damaged, the coastal habitats session could not identify restoration alternatives for specific environmental resources known to have been damaged by the oil spill. Instead, session participants considered restoration alternatives for all coastal resources that may have been negatively impacted by exposure to oil and/or clean-up actions. Session participants identified ecological communities most probably affected by the oil spill in the eight coastal habitats described in Chapter II. Individual species with commercial, recreational, or ecological importance suspected of being impacted by the spill were also identified. Session participants then suggested and evaluated various restoration actions that potentially could hasten the recovery of those communities and species to pre-spill conditions, or at least to some acceptable condition. Restoration alternatives were not ranked because session participants felt that restoration priorities could be determined only after more complete damage assessment information becomes available.

Little information is available to estimate the natural recovery rates of PWS habitats and species likely to have been damaged by the spill. Although there are some similarities with coastal species from the better studied Northern Californian and Columbian Provinces of the west coast, general understanding of the ecological systems of the PWS area is inadequate to make these estimations confidently. Similar problems were identified by Cowell and Monk (1977) during previous oil effects studies of Port Valdez, Alaska. Recommendations made by session participants were constrained further by the lack of baseline population data on the dominant and important species present in the PWS ecosystem.

Generic Alternatives

Despite these limitations, session participants identified generic restoration alternatives applicable to all of the eight habitat types previously defined. These were:

- Acquisition of equivalent resources
- Protection of remote critical habitats
- Revision of management practices
- "Do nothing" or no action.

Acquisition of Equivalent Resources

The coastal habitats session emphasized that the primary goal of any restoration effort should be the recovery of the entire ecosystem rather than recovery of a particular species or portion of beach. For this reason, coastal habitats session participants concluded that a viable restoration option for all habitat types would be to acquire equivalent, unimpacted habitats in and around PWS. This approach has a number of advantages. First, resource acquisition protects at least some portion of the habitat from some future disturbances. For example, certain supratidal regions may be buffered from the effects of logging, and beaches can be protected from disturbance by tourists, hunters, and fishermen. Second, protected areas may provide a source of young, larvae, and gametes to recolonize areas of the Sound and the Gulf. This rationale is appropriate for mobile species and most sedentary species having planktonic larvae, but does not apply to species with more limited dispersal abilities.

Acquisition is primarily a risk reduction approach and has very limited capacity to directly restore or replace damaged resources. Changes in the overall condition of biological resources in the PWS-Gulf of Alaska ecosystem will be difficult to detect. Any changes detected will be difficult to attribute to specific habitat protection efforts, due in part to the lack of background data on natural variability in this environment. In general, distinguishing long-term trends resulting from the oil spill from natural background variability requires a long-term monitoring program (NAS 1990; Strayer et al. 1986). Furthermore, although the health of area in general may improve as a result of acquisition and protection efforts, specific heavily impacted areas may not benefit.

Protection of Remote Critical Habitats

The coastal habitats session noted that Alaskan coastal habitats are frequented by many migratory species that are likely to be most stressed in the southern portion of their migratory ranges, where disturbance due to contaminant loadings and habitat loss is greater than experienced in the less chronically disturbed habitats of Alaska. The greatest benefit to these species and the greatest enhancement of recovery rates in PWS and the Gulf of Alaska may be gained by protection of these remote southern habitats, rather than by initiating restoration efforts in PWS and the Gulf of Alaska itself. This idea is based upon the assumption that the overall success of certain species is more limited by habitat degradation and loss in other geographic regions than in Alaska. The ecology of few species is known in sufficient detail to draw this conclusion confidently. Session participants concluded that since most species for which this option is appropriate would be considered by the other sessions, the option would not be explored further in the coastal habitats session.

Management Action

Session participants suggested that implementation or alteration of certain management practices potentially could enhance the restoration of damaged resources in the Sound and the Gulf.

For example, state agencies could restrict access to certain areas of the coast to minimize further damage to naturally recovering resources. Management practices relating to commercial or recreational hunting and fishing were mentioned briefly, but were determined to be the purview of other topic sessions. The Alaskan Departments of Natural Resources, Fish and Game, and Environmental Conservation, and the U.S. Departments of Commerce, Interior, and Agriculture were mentioned as agencies having specific regulatory capabilities that could be employed to promote restoration in the Sound.

The "Do Nothing" Alternative

The option to do nothing in terms of direct restoration was strongly supported for each of the communities and species considered by coastal habitats session participants. Thus, the session generally was supportive of the self-healing approach proposed by John Teal during the public restoration symposium (26-27 March 1990). Similar recommendations have been made by other researchers studying oil effects and ecological recovery in nearcoastal habitats (Ganning et al. 1984; Foster et al. in press). The general absence of long-term baseline data concerning the ecological resources of the area and the paucity of information concerning the success of restoration efforts in high latitude coastal environments generated skepticism regarding whether any restoration efforts would be effective. For example, the rate of recovery from environmental perturbations is thought to be slow for high latitude environments (Cretney et al. 1978; NAS 1985). Session participants expressed concern that direct restoration efforts may do little to enhance natural rates of recovery. There also was concern that further intensive human activity in the area could exacerbate current conditions and cause additional damage. For example, damage assessment researchers indicated that, in some cases, simply walking on beaches could mix oil deeper into sediments, delaying biodegradation and leading to more long-term effects. The "do nothing" option, as well as other alternatives, will require environmental monitoring to assess the success of natural recovery.

Specific Restoration Alternatives for Particular Habitats

Specific alternatives were identified for only two of the coastal habitat types considered by the session: supratidal-low energy and intertidal-low energy. These were the habitat types with the greatest documented or suspected damage and for which state-of-the-art restoration techniques have been developed.

Supratidal - Low Energy Habitats

Session participants thought that supratidal vegetative stands probably had a good chance of recovery where oil had been removed quickly, had not mixed deeply into the sediments and where no hard asphaltic layer had formed from the remnants of degraded oil. However, in those areas exposed to oil for a long time, where oil had mixed into the sediment, and especially where hard asphaltic layers had formed, natural recovery was likely to proceed very slowly.

Restoration options proposed for low energy supratidal habitats focused upon reestablishment of vegetative communities and reduction of erosion. The principal restoration alternative recommended to enhance natural rates of reestablishment for vegetative communities was fertilization. The application of fertilizers not only enhances the productivity of the vascular plants within the supratidal, but also has been used by clean-up crews as a means of biologically removing oil by promoting bacterial biodegradation (Turner 1990). However, workshop participants were uncertain of the effectiveness of fertilization in enhancing natural rates of recovery.

Participants noted that in those areas where an asphaltic mat has formed, the mat must be broken-up and removed before the vascular plant community can be expected to recover; the group was uncertain about the best method of asphalt mat removal. The suggestion that sections of sediment and asphalt could be excavated was rejected. This action would remove essential nutrients and trace elements necessary for the reestablishment of vascular plant communities and might actually retard recovery. The session advised that the best approach would be one which removes as much of the asphalt layer as possible, while minimizing the amount of soil removed and the amount of asphalt transported to deeper layers.

The session suggested placing clean rip-rap in the supratidal regions of heavily eroding beaches to reduce erosion. The likelihood of effectiveness of this option was not thoroughly evaluated; however, it was noted that rip-rap might be washed away in a severe storm. Emplacement of rip-rap has the added disadvantage of not being natural.

Intertidal - Low Energy

The coastal habitats session considered restoration options for three distinct ecological communities within the low energy intertidal habitat. These communities were:

- Intertidal marsh communities
- Intertidal shellfish communities
- Rocky intertidal communities.

It must be emphasized that because damage assessment information was not yet available, session participants had to assume what potential damages, if any, had been sustained by these communities and the species within these communities.

Restoration options identified for the intertidal marsh communities focused upon the reestablishment of marshes, grasses, and sedges. Session participants believed that if the dominant plant communities can be restored, associated fauna will recover quickly. The areal extent of these vegetative stands within PWS is believed to be relatively small. Considering that marshes are reported to be important nursery grounds for many coastal species (Daiber and Roman 1988; Odum 1988; Lippson et al. 1979), the ecological value of marshes judged solely by areal extent may be underestimated. Moreover, marshes and wetlands are perceived by the general public to be important ecological resources and thus, warrant consideration (The Conservation Foundation 1988).

Session participants believed that restoration efforts could not proceed until tarry layers, which form a physical barrier to plants, were broken-up and removed. As in supratidal habitats, the ideal solution is to remove as much of this asphaltic layer as possible while minimizing the removal of sediments containing essential nutrients and trace elements.

There were three alternatives specifically considered by the coastal habitats session to reestablish vascular plants in low energy intertidal areas. These were:

- Fertilization
- Aeration
- Transplantation.

Fertilization stimulates the growth and productivity of existing plants. This alternative has the advantages of causing minimal additional disturbance to existing resources and not being very labor intensive. The disadvantage of this alternative is that recovery will take a long time if the size of affected patches is large, since recolonizing growth occurs from the edges inward. Further, the enhancement of natural recolonization rates due to fertilization is not well quantified. Finally, fertilizer would have to be reapplied often since the tides will wash away previous applications. Increased nutrient loadings to bays and inlets with restricted circulation (as might be expected in low-energy environments) could cause localized problems associated with nutrient enrichment and eutrophication.

Aeration involves forcing air into marsh sediments to stimulate and promote biological activity. This activity enhances the breakdown of deposited oil and increases the remineralization of organic matter, thus increasing the supply of nutrients for use by vascular plants. Increased nutrient supplies would have the same affects, advantages, and disadvantages of the fertilization restoration option.

Transplantation would involve moving healthy plants from an unaffected area into areas where vegetative coverage was reduced by exposure to oil. Marsh transplantation has been attempted in other areas of the world with various degrees of success. However, to date there have been no large-scale marsh transplantation projects in high latitude environments. Transplantation presents the added problem that in order to restore the affected region, an unaffected area must be disturbed. The overall impact of such disturbances is generally unknown.

Intertidal shellfish communities were considered by both coastal habitats session participants and the fish and shellfish session. No direct mortality of clams was detected immediately after the spill (Meacham 1990). The coastal habitats session, therefore, did not concentrate on identifying restoration alternatives to provide alternate shellfish resources for local subsistence purposes. Clam samples from some of these areas, however, showed the highest hydrocarbon concentrations of any fish or shellfish tested (Meacham 1990). Coastal habitats session participants identified four restoration alternatives to replace contaminated shellfish within the PWS area: transplantation, aquaculture, reseeding, and bed closure.

In general, session participants were not strongly supportive of any of these alternatives. Because of the overlap of similar subjects with the fish and shellfish session, the restoration alternatives identified by the coastal habitats session were not discussed further.

Session participants discussed what restoration efforts might be employed to enhance the natural recovery rates of rocky intertidal communities. It was decided that if the dominant part of the structure of this community could be restored, recovery of other parts of the community will follow quickly. Because of its dominance, session participants felt that restoration of intertidal habitats depends upon the reestablishment of _Fucus_.

A fair amount of information has been collected about _Fucus_ recolonization following oil spills (Southward and Southward 1978; Steele 1978; Floc'h and Diouris 1980). _Fucus_ recolonization occurs via three mechanisms: regeneration from damaged holdfasts, distribution of propagules from parent plants, and the random distribution of floating plants broken off from established patches. Except for this last mechanism, _Fucus_ recolonization will generally occur on localized scales and will depend upon the distribution of remaining plants. Where holdfasts have been washed away by extensive and harsh cleaning techniques, _Fucus_ generally will recolonize from the edges of bare patches inward. Thus, small patches will be reestablished more quickly than large patches.

The coastal habitats session considered two restoration options that may enhance the natural recovery rates of _Fucus_: transplantation and reseeding. Transplantation would involve moving _Fucus_ plants from healthy patches into damaged areas. Once established, the transplanted plants would distribute propagules which would attach and fill-in the spaces between the transplanted patches. Session participants had reservations about transplantation success. There are no large-scale examples of _Fucus_ transplantation to review for guidance concerning specific techniques for transplantation, optimal patch size for transplanted individuals, and overall success rate. _Fucus_ transplantation would be labor intensive, and the necessary manipulations could disturb other communities and species within coastal habitats. Session participants questioned whether initial transplants could be washed away by severe storms. The group also suggested that this approach, if successful, would only enhance natural recovery rates by a few years and, therefore, might not be worth the effort.

Although similar concerns were raised over reseeding as a restoration option for _Fucus_, session participants were of the opinion that the advantages of reseeding probably outweighed the disadvantages. Reseeding could be conducted by releasing or spraying cultured propagules of _Fucus_ into the intertidal zone. Reseeding has the advantages of not being labor intensive and not requiring a large deployment of field crews that could disturb already stressed communities. Reseeding can also cover fairly large areas since propagules potentially could be released from aircraft. The coastal habitats session was very supportive of further investigation of reseeding as a means of restoring _Fucus_ communities in the rocky intertidal zone. Session participants suggested that a pilot-scale reseeding study could be initiated during the summer of 1990 to determine the success rate of this method and to develop specific techniques. This option is developed further in the section outlining potential feasibility projects (Chapter V).

Session participants were uncertain about the availability of techniques for direct restoration of invertebrate populations in low energy rocky intertidal communities. The possibility of transplanting invertebrate egg masses from relatively clean areas to impacted areas was considered; however, no information is available to evaluate the likelihood of success or the potential for reduction of recovery time for this labor intensive technique.

Session participants also briefly discussed potential impacts to small, non-commercial fish species which frequent rocky intertidal regions, since habitat appears to be the principle determinant of intertidal fish density (Gibbons et al. 1990). Damage to these populations is unknown. Participants deferred discussion of specific restoration options for these species to the fish and shellfish session.

Summary of Restoration Alternatives

The restoration alternatives considered by the coastal habitats session are summarized in Table IV-1. The alternatives most emphasized by session participants were long-term research (i.e., get complete damage assessment information) and the alternative to "do nothing".

B. FISH AND SHELLFISH

Organization of Session

The fish/shellfish session began with a review of the current status and results from the NRDA studies, expanding the summary given in the plenary session. Preliminary restoration alternatives, as well as information gaps, then were identified for each group of similar species. Finally, a list of restoration measures and additional data requirements were recommended for consideration.

It became clear immediately that only.limited damage assessment information is currently available, due to the ongoing nature of the multi-year damage assessment studies and the fact that some samples have been collected, but not yet analyzed. In addition, there is a lack of baseline inventory information and basic knowledge on the biology and ecology of many fishery resources of PWS and the Gulf of Alaska. Lack of information

Table IV-1. Summary of restoration alternatives considered for coastal habitats having different energy regimes

	Supratidal Low Energy	Supratidal High Energy	Intertidal Low Energy	Intertidal High Energy	Subtidal Low Energy	Subtidal High Energy
"Do nothing"	X	X	X	X	X	X
Protection/management of upland resources	X	X	X	X	X	X
Acquisition of equivalent habitats	X	X				
Protection of equivalent habitats	X	X	X	X	X	X
Changes in management practices	X	X	X	X	X	X
Emplacement of rip-rap	X					
Transplantation of vascular plants	X		X			
Fertilization of vascular plants	X		X			
Reseeding of vascular plants	X		X			
Transplantation of shellfish			X			
Substrate aeration	X					
Aquaculture			X			
Research	X	X	X	X	X	X

represents a critical limit to more complete damage assessment and future decisions on the requirements for restoration. As a result, the recommendations developed during this session were not limited to the strict definition of restoration (as described in the introduction and Appendix C), but included further information gathering activities judged to be essential for fully assessing fisheries damage and making final decisions on fish and shellfish restoration requirements.

The session participants identified specific restoration alternatives for species or groups of species known to be or suspected of being impacted. The session consensus was that additional information requirements were imposed by the uncertainty introduced into the PWS ecosystem as a result of the oil spill. Many of the potential restoration actions were described as contingency measures that should be applied if the results of ongoing or expanded damage assessment studies indicate significant impacts.

The potential restoration measures were considered for six groups of species:

- Salmon
- Herring
- Dolly varden char/cutthroat trout
- Groundfish
- Clams
- Other shellfish.

<u>Restoration Alternatives</u>

<u>Salmon</u>

The following types of measures were identified under the direct restoration category for salmon:

- Management changes
- Habitat restoration
- Stock-specific enhancement
- Predator-prey considerations.

A number of changes to the current management of fishing effort were proposed to protect salmon stocks from further risk, thereby accommodating the uncertainty introduced by the spill. Most of these approaches are standard methods of controlling harvests (Gulland 1978). Implementing these actions would require more precise and/or real-time information to permit directed efforts to reduce further risk to the potentially impacted year classes. Recommended actions included the application of mass-marking techniques to differentiate hatchery stocks from wild stocks. This would improve information on hatchery-wild stock interactions and aid in the estimation of wild stock escapement. It would also permit managers to relate the timing of harvest with escapement. Managers would use this information to search for time-area controls on the harvest rates of hatchery salmon. In the absence of this information managers would be forced to move the fisheries closer to terminal areas. This would require a more tightly regulated fishery, with associated burdens on the fishing industry, and an appreciable drop in product quality.

Habitat restoration measures identified by the session included stream rehabilitation, fish passage projects, and lake fertilization. These measures are focused on rehabilitating those areas affected by oil directly or indirectly. Stream rehabilitation would include actions such as replacing gravel substrate or using mechanical or hydraulic disturbance to clean spawning gravel in stream beds (Mih 1978). Fish passage projects, such as the construction of fishways, could aid in opening salmon migration routes.

Lake fertilization was suggested as a means of compensating for impacts on lake productivity caused by over-escapement resulting from fishery closures. Lake fertilization has had some success (Parsons et al. 1972; Schindler 1974) in improving productivity and may be used to increase zooplankton biomass, resulting in greater smolt size and survival. Evidence has been presented that smolt size changes in fertilized lakes will lead to increases in the harvestable surplus of sockeye adults by promoting both increases in marine survival and earlier return-at-age to the fishery (Hyatt and Stockner 1984). Experimental validation of smolt population responses to changes in the fry/forage base ratio has been provided recently (Koenings and Burkett 1987).

Stock-specific enhancement actions included targeted stocking of hatchery reared fish at specific impacted sites. Predator-prey interactions might also be considered if it is necessary to rehabilitate runs from a low level. Predator control programs have met with mixed success but have potential if stocks are significantly reduced in relatively small coastal lakes (Gulland 1978).

Additional hatchery capacity, "off-site" restoration measures similar to those mentioned above, and either the relocation of subsistence fisheries or the provision of alternate subsistence projects were identified as possible ways to replace impacted salmon resources. Similar efforts to identify and develop currently under-utilized species and unaffected stocks for recreational fishing also were mentioned.

Projects related to the acquisition of alternate resources included efforts to reduce other risks to impacted stocks via the acquisition of riparian habitats to protect critical areas from further adverse impacts and the purchase of oil leases (particularly in Bristol Bay). These options also have collateral benefits to birds and terrestrial mammals. In addition, the acquisition of new access areas for recreational fishing to reduce pressure on affected areas was also suggested.

Dolly Varden Char and Cutthroat Trout

Both these species can be restored through supplemental production and habitat rehabilitation. Most of the specific suggested actions for these species were identical to those for salmon. A specific effort to manage a shift in fishing effort away from impacted areas through a public education program was also included for Dolly Varden char and cutthroat trout.

Herring

Options identified for restoring herring stocks included: 1) cleaning spawning areas; 2) cataloging and protecting alternate spawning areas; 3) providing additional spawning substrate; 4) herring "hatchery" development; and 5) improving management information. The last item would include stock identification via scale pattern recognition techniques and the use of hydroacoustic surveys to estimate the size of adult resident stocks. The restoration of spawning habitat by replacing algae or using other materials for ovideposition substrate was considered. It was noted that herring routinely spawn on pound cages, when available.

One of the problems discussed with respect to regulating exploitation of the herring fishery was the lack of current information on exploited stocks. This problem was given a high priority since, without further information, routine fishing activities could further endanger stocks impacted by oil effects.

Replacement options included the identification and development of under-utilized species or the replacement of the loss of the herring fishery by compensating with other culture-based species, such as salmon.

Acquisition alternatives included the purchase of upland habitat or timber rights to protect nearshore spawning areas. Either acquisition alternative would help preserve conditions at unoiled spawning sites by reducing erosion or by preventing future development impacts. This risk reduction approach would also have collateral benefits for other species and possibly for cultural resources.

Groundfish

Groundfish include halibut, sablefish, Pacific cod, flathead sole, pollock, arrowtooth flounder, rockfish, and other species. Restoration alternatives included the acquisition of data on basic biology as well as cataloging and inventorying stocks to support management decisions. In addition, stress checks to assess sublethal effects were suggested.

Replacement approaches were confined to identifying alternate species or stocks for potential development. Acquisition approaches included the acquisition of uplands to help protect against future habitat degradation. Habitat enhancement alternatives mentioned included artificial reefs and mid-water fish habitat devices.

Clams

Methods suggested for the restoration of clam resources included transplantation to cleaned beaches, beach terracing to expand available habitat, the use of artificial substrates, and the compilation of additional information for management purposes.

Replacement options include identifying unoiled beaches with available resources to support subsistence fishing and providing access to these areas until contaminated areas have recovered. Mariculture was also suggested. Acquisition options were limited to upland areas.

Other Shellfish

Other shellfish include king crab, tanner crab, oysters, sea urchins, scallops and other non-clam resources. Restoration options discussed included identification and protection of critical habitat, habitat replacement and improvement including the use of artificial substrate, and monitoring contamination to support management decisions.

Replacement options included transplantation and the culture of selected species. Acquisition was restricted to adjacent upland areas to protect against future risks to important habitats.

Recommendations

After reviewing the damage assessment information and the list of potential restoration alternatives, the session identified those specific restoration alternatives which, in the their opinion, had the highest priority. Participants were asked to select the three top restoration measures identified based on their knowledge of the fisheries and management information requirements. Table IV-2 lists the potential "restoration" alternatives recommended by the session participants. The alternatives are grouped by resource category. The ranks associated with each alternative reflect the makeup and perspective of individuals selected to participate in the session. Participants ranked alternatives in terms of their priority with respect to limited 1990 funds and not solely on their long-term priority.

Several guidelines were considered by the participants in selecting among alternative restoration measures. These guidelines or criteria included:

- Ecological importance
- Socio-economic value
- Relationship to NRDA
- Resource benefit
- Habitat benefit
- Cost effectiveness
- Probability of success
- Time critical nature.

Table IV-2. Recommended 1990 fish/shellfish restoration alternatives

Group/Restoration Alternative	Overall Rank*	Type of Action
SALMON		
Escapement (continue-NRDA)	1	Resource Assessment
Adult tagging	2	Stock Identification
Otolith Analysis	4	Resource Assessment
Lake fertilization	6	Habitat Restoration
Fishways	7	Habitat Restoration
Egg boxes	7	Habitat Improvement
HERRING		
Catalog spawning areas	5	Management Information
Scale pattern analysis	6	Stock Identification
Resident hydroacoustics	0	Management Information
SPORT FISH		
Port sampling (continue - NRDA)	3	Management Information
GROUNDFISH		
Trawling surveys (continue - NRDA)	6	Management Information
Population enhancement	0	Supplemental Production
Port sampling (continue - NRDA)	0	Management Information
ROCKFISH		
Artificial reef	6	Habitat Restoration
Tagging on natural reefs	0	Resource Assessment
SHELLFISH		
Reciprocal clam transplants	7	Assessment/Restoration
Catalog alternate areas	0	Resource Assessment
Mariculture	0	Supplemental Production
Transplantation for deparation	0	Alternate Resource
Beach terracing	0	Habitat Improvement

* Ranks reflect the sum of scores assigned by session participants in a straw poll (low number reflects higher priority).

These criteria were not applied in any formal decision analysis approach but were identified by the session as important considerations.

The results reflected a strong emphasis on the need for additional information, particularly for the currently exploited resources: salmon and herring. This information was considered particularly time critical and cost-effective and was recommended for immediate action.

Salmon

Recommended restoration actions for salmon included stock identification and characterization efforts and more precise management, as well as more standard restoration activities. As a heavily exploited resource, this group received the greatest emphasis for restoration. Session participants agreed that, in the absence of additional information, a conservative fishery regulatory program that could result in economic loss would have to be implemented to protect these resources from further potential harm. Direct habitat restoration efforts should focus on maintaining or expanding critical fresh water habitats to ensure future recruitment and to compensate for over-escapement and potential stream degradation. A systematic approach to restoration planning is required. As stated in Chapter III, closures for sockeye salmon may result in collateral effects, such as over-escapement, that must also be considered.

Assessing salmon escapement was judged to be the most important action proposed. Salmon fisheries management is escapement driven; therefore, escapement enumeration information from both ground and air sources was considered to be essential for making management decisions. The importance and potential benefits of regulating escapement for sockeye salmon have been reviewed recently (Welch and Noakes 1990). Escapement information is needed on a short time horizon to facilitate adaptive management of stocks. For example, the best use is made of the sockeye resource by delaying capture (Ricker 1962) during the full growing season. This approach, which delays capture until the fish are close to the river outlet (terminal fishery), permits the resource to be managed to make the best use of individual stocks as they pass through the fishing grounds (Shepard and Withler 1958).

Adult salmon tagging in the vicinity of key locations in PWS also was rated highly due to the importance of stock identification information for regulating the terminal fishery. This information is needed to properly allocate fishing effort among areas.

Otolith (a calcareous structure within the ear of a vertebrate) analysis was also strongly recommended to aid in identifying salmon stocks. Mass marking techniques are being used in some hatcheries, and recovery and analysis of otoliths would help distinguish hatchery and wild stocks. The potential for detecting stress effects from otolith analysis was also mentioned as an additional potential benefit.

Potential sockeye over-escapement resulted from fishery closures due to the presence of oil in fishing areas. Lake fertilization has been proposed as an interim measure to increase the carrying capacity of lakes that may have received an abnormally high number of rearing juveniles as a result of this over-escapement. State policies require detailed studies and analyses of the lake's nutrient cycle and biota constituency prior to implementing fertilization; restoration could be initiated following the completion of these analyses.

Fishway rehabilitation and/or construction were proposed to restore or open passage to upstream areas currently blocked from migratory passage. Egg boxes designed to improve hatching success were suggested for compensating for direct oil impacts on spawning areas.

Herring

Stocks of Pacific herring in Alaska have fluctuated considerably in size due to both exploitation and variation in recruitment (Reid 1971, Fried and Wespestad 1985). Environmental factors are presumed to be the ultimate cause of variation in recruitment. Pacific herring are affected by changes in the inshore habitat since they spawn in the intertidal zone, and juveniles feed and grow in estuaries and/or embayments (McGurk 1989). A number of spawning areas in PWS were exposed to and potentially impacted by oil.

Recommendations for herring restoration included stock identification using a proven scale pattern analysis method and development of further information to catalog spawning areas. These efforts were directed at providing additional information needed to manage this commercially and ecologically important exploited resource effectively.

Although herring from different spawning grounds tend to mingle in nearby nursery areas (Houston 1959), later exchanges of individuals among larger areas are reduced so that an array of local populations with recognizable characteristics develops (Rounsefell 1935). The identification of local stocks in PWS is not clear. Therefore, the fishery is currently managed on a biomass basis, without information on individual stocks. While this management approach may have been adequate prior to the spill, the potential effect of oil on herring spawning areas makes this stock information critical for protecting potentially impacted stocks from additional risk due to overfishing.

Similarly, information on the extent of spawning habitat is necessary to assess the proportion of habitat potentially impacted by the spill. Since the spill coincided with the migration of herring to the spawning area and some effects are demonstrably evident, prudent management will require projection of the extent of potential impact. Once information on both spawning areas and separate stocks is available, restoration measures such as transplanting eggs on substrates could be applied effectively, as needed.

Other fish

Session participants clearly felt that additional port sampling of sport fish catches and trawling surveys for groundfish (including rockfish) are needed to provide information on potential long-term effects of oil on these species. Some of these species are long-lived and/or dependent on benthic food resources. Indirect impacts on these species may not be apparent immediately. Without continuing evaluation, this information will not be available to fishery resource managers in time to affect needed regulation. Although the original NRDA tasks to conduct this sampling did not show direct evidence of impact from oil, the session felt very strongly that this information was critical to protect and manage these stocks adequately. This information would also be important if reductions in some fisheries suggested the further expansion of these fisheries as an alternative to traditional targets during the recovery period.

The port sampling for sportfish was assigned a high priority, especially for rockfish, since there has been indication of both direct and indirect oil effects. Obtaining an age-size data base to identify recruitment rates was considered important. The data obtained from the trawling effort was also considered important. Session participants were critical of this effort being dropped from the NRDA for 1990. The consensus was that the information from continued trawling might be even more important this year than last. Effects on demersal species dependent on bottom food sources that can suffer long term damage from oil will not be detected without additional sampling.

The construction of artificial reefs for rockfish was identified as a potential means of compensating for degraded habitat if further studies indicate continuing impacts or the need to replace fishing opportunities lost due to confirmed contamination. The use of reefs as a means of in-situ bio- monitoring for long-term effects and for obtaining information on rockfish behavior-ecology was also mentioned.

Shellfish

The use of reciprocal transplanting was recommended to provide information needed to assess long-term impacts and the potential for future restoration actions such as beach terracing, depuration, and larger-scale transplanting. This approach would also provide a means of monitoring for sublethal and chronic effects.

Information Requirements

Session participants reached a clear consensus that more precise and real-time information was needed to permit appropriate fisheries management under the uncertain environmental conditions introduced as a result of the *Exxon Valdez* oil spill. The session participants felt strongly that these information needs were required for the maintenance of the economic benefits associated with all forms of fishing as well as for rational and flexible restoration planning. Furthermore, it was stated that these efforts should be considered under the scope of actions eligible for funds made available for environmental restoration.

Unlike most other natural resources or habitats, the exploited fisheries resources generate significant, direct, recurring economic benefits from harvests. The self-healing approach described at the Public Symposium (held in Anchorage on March 26-27, 1990) was not judged appropriate for managed fisheries. The perturbation introduced by the spill necessitates more precise management which, in turn, generates the need for better resource assessment and accurate real-time information. Since this requirement is a direct impact of the spill, it was felt by participants that these costs should be recoverable under the scope of damage claims. The best way to protect stocks from further damage or reduce overall risk and to select appropriate restoration measures, including regulatory actions, is to acquire the information needed for better management. The rationale for this requirement is explained in Appendix F. This appendix is an editorial expansion of concepts expressed during the fish/shellfish session and may also apply to other managed natural resources.

C. BIRDS

Organization of Session

The bird session of the restoration planning workshop was composed predominantly of some of the principal investigators directly responsible for the NRDA studies connected with the Exxon Valdez oil spill (see Appendix B). These participants generally agreed that for most species, the number of adult birds immediately killed by the spill may not significantly impact populations at the species level; however, the long-term effects on growth and reproduction may pose a more serious threat to many of the waterbirds in the oil spill region. With these impacts in mind, discussions during the two day workshop centered on the appropriateness of direct restoration alternatives, the relevance of indirect restoration options, and the generation of guidelines with which to evaluate alternatives. Finally, a matrix was created which ranked restoration alternatives with respect to targeted species, based on the priority level given by the work session.

Direct Restoration Alternatives

Direct restoration or replacement alternatives such as captive breeding, translocation, or fostering are most appropriate when intensive human intervention is required to establish, reestablish, or augment a population which is severely threatened or which has disappeared from the area of interest. The work group decided, based on historical knowledge of bird populations in the oil spill area and data generated from damage assessment studies, that these measures were neither necessary nor practical at this time. However, due to the large geographic range of the spill and the number of species and colonies potentially affected, insufficient information was available to assess the extent of damage to all species in all areas of PWS and the Gulf of Alaska.

One such case was the unknown status of bird populations on the Smith Islands. These islands, which were heavily oiled by the Exxon Valdez, are among the few islands in PWS where the parakeet auklet breeds. Unsubstantiated observations indicated that bird populations on the Smith Islands were severely impacted by the spill. If this were found to be specifically true for the parakeet auklet, a translocation restoration project could be used to reestablish colonies of this uncommon, local breeding species.

Aside from the degree of appropriateness of widespread application to PWS, certain limitations are associated with direct restoration options. Limitations associated with captive breeding include behavioral problems (lack of food-finding and predator-avoidance capabilities) required for assimilation into the wild, tendency for disease and low survival, and high cost. While behavioral problems are not common with translocation of birds, there is the possibility of transmitting disease with introduction and, depending on the species and the distance between source and recipient populations, birds with maladaptive migratory tendencies. Fostering (the placement of young within established, active nests to be raised by recipient parents) has been used widely and found to be effective with several species, including bald eagles and peregrine falcons. Although there are no behavioral limitations associated with fostering, small broods are preferred, with no evidence of food stress within the recipient population. Synchrony of the source and recipient populations is also required. The characteristics of the source population are important factors in all three of the direct restoration alternatives above described. There must be sufficient information for each candidate species and documentation that the source population is viable and strong enough to withstand removal of individuals.

Besides discussing these direct restoration options, the use and effectiveness of nest boxes or structures was reviewed. Within the PWS-Gulf of Alaska area, nest boxes have been employed with fork-tailed storm-petrels on the Barren Islands. Two other species, pigeon guillemot and black oystercatcher, may respond positively to structure construction. Since guillemots nest repeatedly in the same crevice, it might be possible to make the nest more predator exclusive. As oystercatcher young are sensitive to predation by otters and crows, chick survival may be increased by providing cave refuges (e.g., driftwood) from predators. However, it was the general consensus that nest sites were not severely limited in the PWS area and that the scale to which nest or refuge habitat would have to provided to be of significant benefit would not make this a cost effective alternative, based on the degree of injury likely sustained by these species.

Restoration Guidelines and Indirect Restoration Alternatives

While no direct restoration options seemed appropriate to compensate for the effects of the *Exxon Valdez* oil spill, other, less direct, alternatives were identified by the session. These options were conceived as a means to reduce the sub-lethal impacts identified by damage assessment by decreasing anthropogenic stresses (other than the spill). Relief of some of these stresses may enable species to recover at a faster rate than without indirect restoration efforts. Once these alternatives had been identified, a list of species or bird groups which had sustained damage from the spill and would benefit from each alternative was created. Subsequently, restoration guidelines were developed to assess the priority of the alternatives with respect to each of the species or groups. These guidelines were not rigorously or quantitatively applied but provided a framework within which to evaluate alternatives in terms of low, medium, and high priority of restoration for specific species or groups.

The guidelines created by the work session are not necessarily parallel in structure; some encompass relative priorities while others indicate performance evaluations. A few stipulate issues of fundamental importance to the participants rather than reflecting concrete criteria or guidelines. The guidelines for evaluating indirect restoration alternatives are as follows (order does not indicate relative importance):

- Creating the appropriate clean habitat is fundamentally important
- Degree of effectiveness of technique -- numbers of individuals must increase
- Favor those alternatives that affect a broader geographic range than one of lesser coverage
- Restoring the "natural" distribution of a species is important
- Favor those alternatives that benefit a multiple array of species rather than ones targeted to just one species (collateral benefits)
- Cost effectiveness
- Must examine the relative recovery time of natural versus manipulative approaches
- Favor natural (e.g., acquisition of habitat) versus artificial (e.g., nest boxes) techniques
- Favor options that permanently restore the habitat or population versus temporary, repetitive measures
- Must consider the length of time required for the active phase of the restoration; favor short versus long-term
- Favor the reduction of introduced rather than natural predators to restore a population

- Relationship to damages

- Priority should be given to those species and geographic areas that have been directly affected by the spill, although a broad geographic range should be considered

- Priority to endangered, threatened, or sensitive species

- Favor species and alternatives for which performance evaluation of restoration effectiveness is possible.

Under federal law, environmental restoration includes the restoration, replacement, or acquisition of the equivalent of injured natural resources. Since the restoration alternatives recommended by the work session as being most applicable to the Exxon Valdez oil spill are indirect in nature, the succinct matching of restoration options and restoration categories (restore, replace, or acquire) is not always possible. All of the alternatives proposed stipulate reduction or restriction of particular activities, and many of the options also include some form of acquisition as a means to reduce stress and protect habitat from future disturbances.

Once indirect restoration alternatives, targeted species or groups, and guidelines had been identified, the work session ranked species/group -- alternative combinations by strength of recommendation. Ten restoration alternatives were identified for a total of 20 species/groups. Table IV-3 presents a matrix of this ranking. The sections that follow describe the restoration alternatives, provide some background and justification for work group ranking, and identify major information needs necessary to place spill damage effects in perspective.

Logging

A decrease in logging pressure in the PWS area was identified as a restoration effort which potentially could benefit a number of different species by maintaining and protecting quality habitat. Increased habitat protection of the islands within PWS and the Gulf of Alaska would not only benefit a variety of marine birds but some marine mammals as well. Water- borne logging activities, especially log storage sites, eliminate important intertidal and shoreline areas for birds.

The actual acquisition of land would not necessarily be required, but the purchase of logging and development rights could have substantial positive effects. Even a change in

Table IV-3. Priority matrix of restoration alternatives with respect to various species or species groups, created by the bird session of the restoration planning workshop

	Logging	Disturbance	Commercial Fishing High Seas	Commercial Fishing Near Shore	Predation	Chronic Oil Pollution	Mariculture	Erosion	Mining	Disease	Hunting and Egging
Bald Eagle	1	2	2	2	3	3			2		
Peregrine Falcon	3	1				2		3			
Murrelet	1	1		2			3				
Great Blue Heron	1	2									
Guillemot	2	2					3				
Owl	1										
Shearwater			1								
Albatross			1								
Kittiwake				2							1
Cormorant				2							
Merganser	1			2					1		
Gulls				3	1			1			1
Sea ducks	1				2	1	1	2	1	3	1
Colonial sea birds		1	1	2	1						2
Non-colonial sea birds	1	2									
Shore birds (oyster catcher)		1				2		3			
Shore bird (migrants)		1		2							
Diving alcids			1	2							
Ground nesters					1			1			
Passerines	1				1						

1 = high priority
2 = moderate priority
3 = low priority
"priority" = potential to be of significant benefit

logging practices from clear-cutting to one that is more selective could have advantageous ecological results. Although this would be difficult to implement on private lands, it may be feasible on federally owned land. At a minimum, creating logging-free buffers (provided they were of the appropriate critical size) along streams and the coastal perimeter would ensure nesting habitat for a variety of species such as bald eagles, falcons, great blue herons, owls, sea ducks (harlequin and Barrow's goldeneye) and mergansers. In addition to these species, pigeon guillemots are known to nest among exposed tree roots. South of Alaska, marbled murrelets utilize trees as nest sites, but equivalent information is lacking for PWS-Gulf of Alaska populations. As the marbled murrelet is a species for which historical data indicates a population decline, determination of breeding habitat requirements and subsequent protection of those habitats is critical. The reduction of logging pressure was given the highest degree of priority for eight out of the ten species/groups which were identified as potentially benefiting from this restoration alternative (Table IV-3). Montague, Kodiak, Naked, Perry and Afognak islands, and the Kenai Peninsula were specifically identified as areas where restrictions on logging may be the most beneficial.

Besides the need to improve the knowledge of the breeding requirements of the marbled murrelet, the working group proposed that a long range land development analysis be initiated to help focus restoration efforts. This analysis could be based on a GIS capable of displaying land acquisition and protective options with data layers documenting the areal extent of: land threatened by ownership or use, bird colonies, timbered habitat (coastal, stream-side, upland), streams, critical sites, offsite out-of-spill potential. It appears some data are already available (USFWS, USFS, ADNR) from shoreline surveys, but these are not terrestrially oriented. A forest component layer is needed to address wildlife and bird habitat issues. The concept of designating land (islands especially) as marine parks, state parks, or national marine sanctuaries was discussed. There were, however, some reservations on the part of the work session participants. Without more environmentally protective restrictions by the owning government agencies, the acquisition of land under these programs for restoration purposes may not be successful, due to intense water and air disturbance.

Disturbance

Some kinds of disturbance, especially during the breeding season, have a significant negative impact on bird colonies. Disturbance may be caused by tourism and recreation, commercial fishing, air traffic, logging and logging traffic, egging (human collection of eggs for consumption), and oil spill clean-up efforts. Enforcement is critical for the reduction of some disturbances; others require more guidelines for people to follow to achieve the desired bird-protective behavior. While the increase in tour boat activity is a means by which to educate the public about important and unique island and coastal habitats and fauna, boat operators should be cautioned (and periodically checked) against the use of whistles and about maintaining a protective distance from shore, especially during the sensitive time of egg laying. The designation of islands as refuges may be a means to structure and regulate the use of those areas for educational and viewing purposes. Gull Island (near Homer) has high potential for public education and its acquisition as a refuge has been attempted at least once by USFWS. As additional clean-up activities continue this year, the trade-offs in terms of disturbance to birds should be evaluated. Perhaps the clean-up of kelp or other near shore activities should be limited and landing access by crew members restricted.

The bird work session identified nine species/groups which are sensitive to human disturbance (Table IV-3) including raptors, colonial and non-colonial sea birds, resident shore birds (e.g. oyster-catchers) and migrant shore birds, as well as great blue herons. The reduction of disturbance to seabird populations received the highest priority for five out of the nine species/groups identified as benefiting from lower levels of disturbance.

Commercial Fishing

Commercial fishing is a potential source of stress to seabird populations due to disturbance, competition and direct mortality. The deployment of nets in the vicinity of bird nesting colonies can be detrimental to a variety of populations, due to frequent disturbance. The work group specifically made reference to the trawl fishery near Round Island and Cape Pearce.

The herring fishery was also mentioned in terms of both disturbance and potential competition impacts. Many birds such as murres, cormorants, gulls, kittiwakes, guillemots and eagles rely on forage fish, such as herring, as a mainstay in their diet. There is evidence that competition with the fishing industry can have a negative impact on seabirds. The pollack fishery has been correlated with the decline in the red-legged kittiwake in the Bering Sea (Technical Workshop 1990). Historical data indicate that herring repeatedly spawn in the same places, and birds concentrate in those areas to feed. If competition was shown to be a factor depressing marine bird populations, a restriction on herring fishing near Naked, Green and northern Montague islands, documented as fairly consistent spawning grounds, could alleviate some of the competition pressure as well as disturbance effects. While there is presently no commercial fishery for other forage fish such as sand lance or capelin in Alaska, work session participants felt a prohibition of any future fishery should be considered.

A major concern within the work group was the apparent historical population decline in many of the seabirds (e.g., marbled murrelets, pigeon guillemots) and the difficulty of placing the effects of the oil spill in perspective to this existing trend. The causes of these declines are unknown, but the need for understanding basic forage fish distribution and abundance seems critical for unraveling causes of population declines. In addition, since many forage fish species are dependant on shallow subtidal areas, the potential for significant oil spill impacts exists. A decrease in forage fish populations may have delayed effects on bird productivity. If negative impacts to forage fish are documented, intensive, temporary mariculture would be an option to augment stocks. For example, *Macrocystis* or *Laminaria* could be provided as spawning substrate for collected herring. This might be especially pertinent for some of the islands in PWS (e.g., Green Island) which were heavily oiled and where herring have historically spawned on the kelp beds. This kind of restoration effort has collateral benefits to fish, birds and mammals.

The third source of stress to seabirds associated with commercial fishing is the mortality resulting from net entanglement. The working group was unanimous that the use of high-seas squid gill nets should be banned, as shearwaters, albatross, and diving alcids such as puffins are extremely susceptible to entanglement in these nets. The magnitude of bird mortality from ghost nets from foreign fishery operations and the link with the populations of the Aleutian Islands is unknown at the present but could be especially detrimental to migratory birds.

For purposes of the restoration alternatives matrix, restrictions on commercial fishing were split into a "high-seas" and "near shore" category (Table IV-3). The high-seas category encompasses benefits to species resulting from reducing the potential for entanglement. The near-shore category includes benefits realized by reducing disturbance, competition and entanglement. A reduction in pressures associated with high-seas commercial fishing received the highest priority recommendation for all species identified as being susceptible to entanglement. For the shearwater and albatross, this restoration alternative is the only one identified as providing any benefit. Actions designed to reduce the negative impacts caused by near-shore commercial fishing were given a moderate level of recommendation for nine of the ten species/groups identified as susceptible.

Predation

The effects of introduced predators on island seabirds was viewed by the working group as a major factor in seabird survival rates. The removal of introduced species, such as foxes (first introduced to Alaskan islands by the fur industry in the 1700's) and rats, has produced dramatic increases in bird populations. Work on islands in the western Aleutians has documented at least a 400% increase in breeding birds in less than 10 years with fox removal (Baily 1990). The USFWS has a prioritized list of islands where predator removal would be advantageous (Wohl, 1990, pers. comm.); cost estimates range from $10,000-13,000 per island. Ground nesting species would benefit the most from this restoration alternative (Table IV-3). These would include various marine birds, waterfowl, passerines, and, in some cases, bald eagles.

Chronic Oil Pollution

Although examining the effects of chronic oil pollution on seabirds was not within the scope of Exxon Valdez damage assessment studies, previous work mentioned by the bird work session has indicated significant impacts. Reductions in chronic oil pollution by improved stormwater management and bilge cleaning practices could be a means to alleviate incremental stresses on sea birds. Elevated hydrocarbon levels are associated with oil terminals as a result of cleaning (bilge) activities and run-off problems. Some data exist for storm petrels, comparing levels 10 years ago with present ones. Due to their prolonged stay in harbors, overwintering populations of sea ducks are species most likely at risk (Table IV-3). The intertidal and subtidal forage habits of these species in conjunction with the well documented ability of bivalves to concentrate pollutants, makes the potential for long-term chronic effects great. USFWS collected harlequin and merganser ducks in the ports of Valdez and Wells in 1987 although analyses of tissue hydrocarbon levels have not yet been completed.

The concentration of contaminants through the food chain may also affect bird predators such bald eagles; however, assessing the potential magnitude of that impact requires fundamental information presently lacking on eagle food habits within PWS. Boat harbors, such as in Cordova are also experiencing chronic oil problems as evidenced by the presence of contaminated sea otters (Technical Workshop 1990).

Mariculture

The interest in commercial mariculture continues to grow in the PWS area and with it a potential increase in the attractiveness of these areas as forage sites for both birds and mammals. This will require protective devices to keep predators out with the possibility of mortality resulting from entrapment. In addition, some mariculture operators may desire to shoot birds to protect their stock. Increased mariculture activities also increase the likelihood of disturbance. Three species/groups were identified by the working group as potentially benefiting from a reduction in future mariculture activities (Table IV-3) with only one high priority recommendation given.

The subject of providing cultured organisms as a food source for seabirds was also discussed by the work group. If invertebrate intertidal/subtidal food resources have been significantly impacted by the spill, supplying interim cultured alternatives is a possible restoration option. The consensus among group participants was that providing site-specific relief would only concentrate hunting pressure on birds as well as instill bad habits of birds frequenting mariculture operations. In addition, providing food resources to hundreds of thousands of birds over 600 miles of affected coastline would be difficult to achieve effectively. As a potentially more effective restoration measure, the group recommended the release and distribution of bivalve and gastropod larvae to help restore large areas of habitat, which in turn promotes food resources for birds.

Erosion

Erosion can have significant negative impacts on sea birds, especially ground nesting species. Clear-cut logging practices and grazing by domestic cattle are particularly destructive in coastal and island habitats by removing or severely cropping erosion preventive vegetation. Five species/groups were identified as potentially benefiting from improved erosion control practices (Table IV-3) and this restoration alternative received a high priority rating for sea gulls and other ground nesters. Planting rye grasses could help expedite stabilization and regrowth in damaged areas. The work session referred to Semidi Island in particular as a location where soil erosion control measures could provide relief to breeding colonies now that introduced cattle have been removed.

Mining

Placer mining of gold and copper can have dramatic effects on water quality. These mining practices create large plumes of suspended sediment impacting intertidal habitats and the birds utilizing those areas. Tugidak Island, southwest of Kodiak Island, has great potential for mining with a substantial number of claims staked. This island is also important as a bird colony, especially as no foxes are present. Tugidak is owned by the state of Alaska and claims could be bought back to protect the island from future mining impacts. Alaska F&G has created a file on this site and a motion to establish it as a state critical habitat has been proposed but not yet passed. Three species/groups were identified as potentially sustaining impact from poor water quality associated with placer mining (Table IV-3). As a restoration alternative, a reduction of these practices received a high priority for mergansers and sea ducks.

Disease

The magnitude of the effects of disease on seabirds in PWS and the Gulf of Alaska is not well known. As expected, different species succumb to different ailments. The potential for avian cholera does exist and conditions could become acute for sea ducks which concentrate on wintering grounds. Cliff nesters have the tendency to contract avian influenza. Means of reducing stress caused by disease were not discussed and sea ducks were the only species identified as possibly benefiting from a reduction in the likelihood of disease (Table IV-3). As a restoration alternative, disease reduction received a low priority level. Clearly, research to identify appropriate disease preventative methodologies is necessary prior to considering the topic of disease reduction as a viable restoration alternative.

Hunting and Egging

Local hunting pressure on harlequin and sea ducks exists within PWS, but workshop participants did not have information on harvest levels. Unfortunately, there is also little information on population levels, therefore, placing hunting impacts in perspective to the population is impossible. Closure of hunting may help reduce stress on particular species but without more documentation it is unknown whether this is justifiable. Before reduction of hunting could be recommended as a restoration alternative, the population status of harlequin ducks needs to be investigated, including winter distributions, site fidelity and breeding habitat requirements. Kachemak Bay is a popular area for sea duck hunting, but information on the magnitude of harvests and the identification of other prime hunting sites should also be assimilated. Collection of gull eggs, especially black-legged kittiwakes, was identified by the group as another source of stress to sea bird populations. A reduction in egging pressure was given high priority recommendation as a restoration option for those species, while a reduction in hunting pressure was given a high and moderate level of priority for sea ducks and colonial sea birds, respectively (Table IV-3).

Summary of Matrix, Additional Alternatives, and General Limitations

Once each of the restoration alternatives had been discussed, species likely to benefit had been identified, and priority of recommendations assigned, the bird work session reviewed the resultant matrix (Table IV-3) and evaluated which alternatives would potentially provide the most relief to stressed sea bird populations of PWS and the Gulf of Alaska. A reduction in logging, disturbance, and predation were the three restoration options which, in the judgement of the group, would benefit the greatest number of species impacted by the *Exxon Valdez* oil spill.

Besides the ten possible restoration options described above, the work session participants stressed the importance of four other subjects relating to sea birds in southcentral Alaska. Due to the nature of the subjects and the design of the matrix, the workgroup realized they were not appropriate for inclusion in the matrix. Although these topics -- acquisition, public education, research, and monitoring -- are not directly applicable under the Federal definition of restoration (see Appendix C), with the exception of acquisition, each is capable of complementing more direct restoration efforts by improving or widening the range of effectiveness or clarifying the focus.

Although some form of acquisition was a component in many of the indirect restoration options, acquisition of land (not just rights), be it coastal or island, provides the means for entire habitat protection (with the accompanying collateral benefits to non-bird species) and the opportunity to implement multiple restoration efforts in an area (e.g., reduction in logging, disturbance, and predation), possibly improving total restoration effectiveness. During the workshop, various islands, such as Afognak, Montague, Gull, Semidi and Tugidak and sections of Kodiak Island and the Kenai Peninsula, were identified as locations where restoration efforts may be most applicable. In addition to these locations, Middleton Island was mentioned as an important wintering ground for the Canada goose and generally utilized by murres, kittiwakes and sea lions. Acquisition of easements on Middleton would constitute an equivalent resource restoration possibility. Little is known about the population movements of the common murre, a resident of PWS region and even less about offshore wintering densities. The fact that murres constituted almost 75% of the dead birds retrieved after the spill behooves further investigation into their abundance and distribution. The bird work session also identified the duck flats management area within Valdez Arm (a state critical habitat area) as an important habitat which provides an excellent opportunity for viewing sea ducks, and indicated that it may be appropriate to dedicate funds to maintain it.

Increasing public education about what constitutes quality wildlife habitat and the need to reduce anthropogenic stresses to help restore and maintain seabird populations will be a critical factor in determining the degree of acceptance and hence, the long-term effectiveness of restoration programs. Without concerted efforts to improve public education and acceptance, some of the proposed restoration measures may meet with stiff local opposition.

A common limitation of most of the proposed restoration alternatives was the paucity of some basic biological, life history information. Data on abundance, distribution, breeding and feeding habits, and habitats and reproductive productivity are critical to evaluate and focus successful restoration efforts. Session participants felt that continuing research and monitoring programs are required to provide much needed information to assess the long term effects of and recovery from the Exxon Valdez oil spill.

D. MAMMALS

Approach and Rationale

In an initial discussion of the legal definition of restoration provided as a guide for this workshop (see Appendix C), the participants in the mammal session of the Technical Workshop concluded that no direct attempts to return injured mammal populations to their baseline conditions or functions were feasible or advisable in PWS. This conclusion was based on the session consensus that, according to the information currently available regarding the magnitude of damage to marine and terrestrial mammal populations, these populations should be capable of recovering to their pre-spill levels naturally, if other perturbations which could inhibit natural recovery are reduced or eliminated. However, session participants could not estimate the time frame necessary for natural recovery. Translocation to augment depleted populations of appropriate species (e.g. sea otter, river otter, mink) was determined to be unnecessary and inadvisable at this time because of the high degree of uncertainty of success due to the continued presence of oil in the habitat, cost, and likely public resistance associated with this approach.

An indirect restoration alternative to enhance prey populations (e.g. plant mussel beds to provide food for otters) was considered to be infeasible because of the large scale on which such projects would need to be conducted to produce a measurable effect.

The participants in the mammal session agreed that because the toxicity of oil to particular species and the long-term sublethal effects of ingested oil on reproduction and other physiological functions are unknown or not completely understood, mammal populations throughout the oiled area should be monitored to assess whether natural recovery occurs and the rate at which recovery progresses. The session consensus was that, although not specified in the legal definition of restoration, monitoring to evaluate recovery is a vital part of any restoration alternative. Because there is the potential for delayed, long-term sublethal injury to mammal populations, natural reproduction may not be sufficient to accomplish recovery to pre-spill population levels. Therefore, the alternative not to take direct restorative action should be evaluated with respect to subsequent information on the delayed effects of oil on mammal populations in order to adaptively manage restoration, if necessary.

No replacement alternatives relevant to mammal populations were identified by the session participants.

Because there is documented oil spill-related injury to specific marine and terrestrial mammal populations in PWS and surrounding areas and because further damage is predicted, the participants of the mammal session agreed that restoration by acquisition and protection of equivalent resources is justified. This conclusion is based on the assumption that any restoration alternative that will reduce or eliminate other perturbations which could inhibit the recuperation of injured resources is valid within the acquisition and protection option for restoration. The session listed the following stressors influencing mammal populations and their habitats in PWS that could be eliminated or reduced to facilitate natural recovery:

- Logging
- Mining
- Recreational and commercial disturbance
- Oil development, transport, and storage

- Commercial development (e.g., other business, resorts)
- Excessive commercial fishery harvests.

The session recommended several generic alternatives to reduce stress on injured mammal populations in PWS and to provide the information necessary to evaluate natural recovery of these populations. Priorities were assigned to these alternatives (relative to each other) for each of the species that was the focus of a damage assessment study and specific alternatives were identified for particular species, where possible. These alternatives and their priority rankings will be discussed further in the following sections.

Guidelines for Selecting Restoration Alternatives

After developing general alternatives and specific suggestions for marine mammal restoration efforts, the mammal session participants defined guidelines that should be considered in developing and evaluating restoration alternatives. The session consensus was that ecological/biological "need" was the most important guideline for assessing the appropriateness of restoration alternatives. Other factors that the participants agreed should be considered are:

- Technical and biological feasibility
- Technical and biological effectiveness
- Cost effectiveness
- Public "need" and acceptance.

The consensus of the session was that, beyond identifying ecological/biological need as the most important guideline, it was inappropriate to rank the importance of the other factors generally, because the relative importance of these factors will be determined by the specific characteristics of the damaged resource. No formal application of these guidelines was accomplished; however, the guidelines were considered generally to develop alternatives for terrestrial mammals and to reevaluate the alternatives developed for marine mammals.

Generic Restoration Alternatives

Tables IV-4 and IV-5 were developed by session participants to summarize the acquisition and protection alternatives identified for marine and terrestrial mammals, respectively. Footnotes indicate specific alternatives for particular species within the appropriate generic alternative. A brief explanation of the session participants' justification for the generic alternatives follows.

Trust Fund

It was the session consensus that an appropriate use of restoration funds would be the establishment of a trust fund to support: (1) research to provide the additional information (eg. sublethal effects of oil on mammals, habitat use and food habits of injured or potentially injured populations, stock identification) necessary to evaluate the need for future direct restoration efforts; (2) monitoring to assess natural recovery of injured populations; (3) non-consumptive use programs such as the establishment of additional recreational viewing areas for marine and terrestrial mammals as an equivalent resource.

Protection of Habitats

The session strongly recommended the purchase of logging rights and oil leases in important habitats, such as rookeries and foraging areas, to provide undisturbed refuge for reduced or injured populations (see footnotes to Tables IV-4 and IV-5 for specific suggestions).

Education and Enforcement to Prevent Disturbance

The session recommended committing funds to the development of a public education program highlighting the detrimental effects of deliberate disturbance of marine mammals and to improving enforcement of existing regulations that protect marine mammals from excessive recreational disturbance.

Reduction of Stranding, Entanglement, and Fishery Interaction

The session emphasized the need to reduce negative interaction between marine mammals and commercial and recreational fisheries (see footnotes to Table IV-4 for specific suggestions). In addition, the session suggested expanding the stranding and debris entanglement response networks to facilitate more rapid response to troubled animals in PWS and elsewhere.

Table IV-4. Matrix of restoration alternatives with priorities by species for marine mammal populations injured as a result of the Exxon Valdez oil spill. Footnotes indicate specific alternatives identified for particular species. (NA = not appropriate)

	Priority by Species[a]				
Generic Alternatives	Humpback Whale	Killer Whale	Sea Lions	Harbor Seals	Sea Otters
Trust fund for research	1[b]	1[c]	2	1	1
Habitat protection	2	4[d]	1[d,e]	2[d,f]	2
Education/Enforcement to prevent disturbance	3	3	3	3	3
Reduction of stranding, entanglement, fishery interaction	4	2[g]	4[h]	4	7
Environmental education	5	5	5	5	4
Mobile veterinary pathology unit	6	6	6	6	6
Translocation	NA	NA	NA	NA	8[i]
Harvest management	NA	NA	NA	NA	5[j]

[a] Priorities for each alternative are relative to the other alternatives within each species. No general ranking with regard to high or low is implied; rather the numbers are intended to convey that for each species, an alternative ranked as "1" is more important than an alternative ranked as "2," and so forth.
[b] Expand catalog of fluke ID's to facilitate investigation of population dynamics.
[c] Expand catalog of dorsal fin photographs to facilitate investigation of population dynamics.
[d] Purchase oil leases in Bristol Bay for the protection of marine mamal habitat.
[e] Purchase logging rights for Marmot Island and establish the island as a refuge.
[f] Establish refuges at Channel Island (Prince William Sound), Seal Island, Applegate Rocks and Tugidak Island.
[g] Reduce interaction with black cod fishery in Prince William Sound.
[h] Regulate commercial harvest of groundfish so that marine mammal prey populations are not depleted.
[i] Translocation into Channel Islands (CA), and Queen Charlotte Islands (BC).
[j] Quantify and consider need to restrict harvest in Prince William Sound and surrounding oil impacted area.

Table IV-5. Matrix of restoration alternatives with priorities by species for terrestrial mammal populations injured as a result of the Exxon Valdez oil spill. Footnotes indicate specific alternatives identified for particular species. (NA = not appropriate)

	Priority by Species[a]				
Generic Alternatives	**Sitka Deer**	**Black Bear**	**Brown Bear**	**River Otter**	**Mink**
Habitat protection	1	1	1	1[b]	1[b]
Trust fund	2[c]	2[c]	2[d,e,f]	2[g]	2[g]
Harvest management	3	3	3	3	3
Translocation	NA	NA	NA	4	4

[a] Priorities for each alternative are relative to the other alternatives within each species. No general ranking with regard to high or low is implied; rather the numbers of are intended to convey that for each species, an alternative ranked as "1" is more important than an alternative ranked as "2," and so forth.
[b] Restrict mineral extraction in tidal areas
[c] Determine the importance of beach and marsh vegetation use to evaluate the need for restoration of those resources
[d] Create additional sanctuary, viewing areas (like McNeil River)
[e] Educate deer hunters to avoid bear
[f] Develop cost effective population and habitat use survey techniques
[g] Continue population estimate, food habit, and habitat use studies

Environmental Education

The session emphasized the need for environmental education to increase public understanding of the scientific and technical basis for management of damaged ecological resources in order to reduce conflict created by poor communication between the public and resource managers. In addition, improving the public understanding of ecological principles may result in the reduction of negative interactions between natural resource users and marine and terrestrial populations and their habitats.

Mobile Veterinary Pathology Unit

The session suggested the development of a mobile veterinary pathology unit to facilitate more rapid and efficient response and collection of data in case of future oil spills. In the absence of feasible direct restoration alternatives, the session participants concurred that planning for future perturbations constitutes protection of resources.

Translocation

This direct restoration alternative was included for consideration in the event that natural recovery fails, leading to severe decline in or complete extirpation of particular populations. As indicated in Tables IV-4 and IV-5, this alternative is considered inappropriate for many marine and terrestrial mammal species and is assigned low priority for appropriate species, at this time.

Harvest Management

Some members of the session suggested reducing harvest of marine and terrestrial mammals until populations have recovered to their pre-spill status.

Specific Alternatives and Related Information Needs

Humpback and Killer Whales

The session emphasized the need for more complete identification catalogs for humpback and killer whales using PWS. This information would facilitate the identification of transient versus resident pods of killer whales, more accurate tracking of reproduction and other changes in the composition of humpback and killer whale populations using PWS, the identification of trends and changes in trends in habitat use, and the collection of other information necessary for evaluation of recovery of whale populations from the effects of the oil spill. In addition, prey availability surveys are needed to assess the resources available to support the whale populations in PWS.

In the context of protection of similar resources, the session participants recommended purchasing oil leases in Bristol Bay to protect Beluga whale and other marine mammal populations using this area.

As a means of protecting the killer whale population, the session recommended attempting to reduce the interaction between killer whales and the black cod fishery in PWS. Killer whales routinely prey upon black cod on long line gear. The session suggested reimbursing black cod fishermen for their losses to dissuade these fishermen from attempting to protect their catches by injuring or destroying killer whales.

Sea Lions and Harbor Seals

The session recommended purchasing logging rights on Marmot Island and establishing the island as a refuge for sea lions. Marmot Island is Alaska's second largest Steller sea lion rookery. Part of the island is privately owned, and the owner is reported to be planning to clear a road in order to harvest timber and then, to open the island for tourism. In the opinion of the session participants, such activity may disturb the rookery, potentially resulting in increased pup mortality and other deleterious effects on the sea lion population. The sea lion population in PWS and the Gulf of Alaska has declined over the past 30 years to approximately one third of its previous size. This decline prompted the National Marine Fisheries Service to classify Steller sea lions in Alaska as threatened under the Endangered Species Act, in an emergency ruling issued on 5 April 1990. The specific causes of the decline are unknown. Additional research is required to determine the effect of the oil spill on the rate of decline of the Steller sea lion population in PWS and the Gulf of Alaska. The session participants concurred that protection of the sea lion population under the auspices of restoration for the Exxon Valdez oil spill is justified at least until the population recovers to the pre-spill level.

The session recommended further regulating commercial harvest of pollock, suggesting that current harvest levels of this species is depleting prey available to the Steller sea lion, and other marine mammals and bird populations.

The session suggested that several of the larger harbor seal haulouts, as well as sea lion haulouts and rookeries, could be established as refuges. Candidates for refuges are Channel Island, Seal Island, Applegate Rocks, Tugidak Island, and The Needle (sea lions only).

Sea Otters

The session discussed the possibility of attempting to hasten sea otter recolonization of vacant historical habitat outside the Gulf of Alaska (eg. Channel Islands, California and Queen Charlotte Islands, British Columbia) by translocation of the appropriate stock of animals, as a means of protecting the resource. This suggestion arose from the observation by a session participant that the PWS sea otter population was the only naturally occurring population in the eastern Gulf of Alaska contributing to the natural expansion of the species and that the impetus for otter range expansion is food stress on the population. It was noted that prior to the oil spill, the sea otter population in Prince William Sound had grown large enough to warrant some consideration of management of numbers. Depletion of that population as a result of the spill may have reduced the likelihood of natural expansion of the species' range. This specific translocation suggestion was assigned a low priority relative to the other general alternatives for restoration of the sea otter population by consensus of the session participants (Table IV-4). However, the session participants emphasized that, if a long-term ecological goal is to restore the historical distribution of the sea otter in Alaska, it is particularly important to monitor the natural recovery of the population to determine whether it is capable of achieving the numbers required to drive natural expansion. Management planning will be needed to determine long-term goals for sea otters based on the ultimate conclusion regarding the effect of the oil spill on the population. Session participants emphasized the need for population modeling to derive an accurate estimate of the proportion of the PWS otter population lost as a result of the oil spill and to predict the effect that this loss will have on the reproductive rate of the population.

It was suggested by some session participants that harvest of sea otters could be restricted to reduce or eliminate a stress that might impede natural recovery of the population.

River Otter and Mink

It was noted that the state has jurisdiction over a three-mile wide band of coastline in the tidal zone. The session suggested that mineral extraction activities in this zone should be restricted to protect river otter and mink by reducing the likelihood of further perturbations of important habitat for these species.

The session emphasized the need for additional information on population estimates, reproductive potential, food habits, and habitat use to assess the long-term, delayed effects of oil on these species and to evaluate natural recovery. The session supported the continuation of the laboratory study of the effects of oil ingestion on mink reproduction to contribute to an estimate of the magnitude of delayed damage to the population.

It should be noted that the session participants recommended considering translocation to augment the populations of these species only in the case of complete extirpation of the populations as a result of potential delayed effects of the spill.

Sitka Black-tailed Deer, Black Bear, and Brown Bear

It was noted that deer and black bear will forage on beach grasses and salt marsh vegetation. Bear exploit these resources in spring, while deer use them primarily in winter, when other food is scarce, and at other times, to a lesser extent. Although methods of grass and marsh vegetation restoration are well documented, the session concurred that because these resource types comprise a relatively small portion of PWS resources, additional information on the frequency and intensity of use of grasses and marsh vegetation by deer and bear is required to evaluate the ecological/biological need for restoration of these resources to protect deer and black bear populations.

The session participants recommended the establishment of additional sanctuary/viewing areas similar to the McNeil River site for the protection of the brown bear and its habitat; however, the group did not identify appropriate locations for such refuges. In addition, the group emphasized the need for a public education program teaching deer hunters to avoid bears in order to reduce unnecessary destruction of animals.

The session recommended the development of cost effective population and habitat use survey techniques for monitoring bear populations.

E. CULTURAL

The session discussed the eligibility of PWS-Gulf of Alaska archaeological and historic resources for protection under the National Historic Preservation Act (NHPA), which concerns sites approximately 50 years old and older, and the Archaeological Resources Protection Act (ARPA), which concerns sites equal to or greater than 100 years old. This discussion was based on the agreement that all sites of human activity, regardless of age, are eligible for inclusion in the National Registry of Historic Places (NRHP), provided that they satisfy the criteria for inclusion. An important criteria for eligibility for the NRHP is the physical integrity of the site. Satisfaction of this criteria may be questionable for PWS-Gulf of Alaska sites which have been reduced to beach lag deposits by erosion and the effect of the 1964 earthquake. However, the ultimate test of site integrity is the ability of the site to yield critical historical or prehistorical information, and the session consensus was that considerable information may still be recoverable from such beach sites. In addition, due to the practically instantaneous changes in land elevation that resulted from the 1964 earthquake, some stratified deposits may remain intact where they sank into the intertidal and subtidal zones. The physical integrity of such stratified deposits would not be in question.

Restoration Needs

The session participants emphasized the need to obligate a budget for a Natural Resource Damage Assessment study of the effects of the oil spill on cultural resources in the PWS-Gulf of Alaska area. Session participants suggested that it would be premature to define the nature and magnitude of the restoration efforts required without a more precise understanding of the extent and degree of damage that has occurred and whether there is continuing damage. Several session participants expressed the opinion that cultural resources should be given priority for restoration funding because, unlike biological and ecological resources, archaeological and historical material has no regenerative capacity. The session identified the following preliminary restoration needs:

- Complete inventory of sites to assess the extent of damage from oiling
- Reduction of accelerated erosion of PWS-Gulf of Alaska beaches impacted by the spill and mitigation of the effects of clean-up

- Reduction or elimination of vandalism and looting of artifacts

- Development of a technique to remove oil from artifacts and materials typically used for radiocarbon dating

- Restoration and preservation of native cultural integrity and trust in the quality of subsistence resources.

A discussion of specific restoration alternatives suggested to address each of these needs follows.

Restoration Alternatives

Site Inventory

Because there is minimal pre-spill information about site locations and characteristics and because participants believe that the Exxon surveys may have been inadequate, the session recommended an intensive beach survey to identify sites. Because there is concern that many sites may be difficult to identify due to oil contamination, the session recommended testing for sites in upland areas adjacent to beaches. This recommendation is based on the assumption that eroded lag deposits containing artifacts may be present on the beaches below any identified upland sites. The session pointed out the value of employing Native Alaskan knowledge of ancestral sites to locate deposits and remarked that this resource is already being tapped to some extent. The session suggested developing a site occurrence model to derive a statistical estimate of the total number of sites and the most likely locations of sites. The model could use GIS data to identify physiographic regimes and other factors, such as floral and faunal assemblages, slope, and aspect, that correlate with site occurrence.

Reduction of Erosion

Because of concern about continuing beach erosion due to loss of supratidal vegetation killed by oiling, the session participants recommended conducting a survey and analysis to determine whether vegetation loss has occurred and the extent of loss. A suggested method for the survey was to produce an annotated videotape of the PWS-Gulf of Alaska coastline, filmed during a helicopter fly-over. A session participant experienced in this technique estimated the cost of such an effort to be approximately $20,000. Once the extent of vegetation loss has been determined, it would be possible to evaluate what long term stabilization technologies (such as construction of riprap barriers) are available and appropriate for PWS-Gulf of Alaska beaches (see Appendix G). A session participant suggested that an appropriate short term beach stabilization technique would be to plant annual rye grass, a species that will not reproduce and proliferate. The session emphasized the importance of considering erosion of archaeological deposits in planning any further clean-up activities for PWS and expressed concern that some plans for beach restoration may present additional threats to cultural resources.

Reduction of Vandalism

Session participants recommended undertaking a public education campaign to prevent looting of artifacts. The campaign would be comprised of radio and television public service announcements, brochures to be distributed with fishing licenses, and posters in appropriate locations stating that it is a felony to disturb, destroy, or remove artifacts on public lands. Session participants considered the possibility that such a campaign would draw additional attention to the presence of artifacts, resulting in intensification of the problem. The session's general conclusion was that correcting public ignorance of the law regarding artifact hunting and improving enforcement of that law was preferable to taking no action to reduce vandalism. Session participants recommended improving enforcement of laws protecting cultural resources by increasing surveillance of beaches and posting warning signs in areas where looting is occurring, so that looters can be prosecuted. The session suggested the development of a study of the sociological aspects of artifact looting behavior because there is little data currently available about the psychology of commercial and amateur looting. It was felt that such information may assist in the identification of looters and in the ability to predict the most likely sites for looting activity. The session emphasized the need to impress upon the agencies involved in clean-up and damage assessment their obligation to comply with the historical and archaeological preservation acts. In conjunction with these efforts, the session recommended committing funds to the development of a "site steward" program that would compensate Native Alaskans for watching over sites of cultural significance and reporting observations of looting activity. The session felt that such a program would have the additional benefit of contributing to the restoration of a sense of cultural integrity for populations whose ancestral heritage and subsistence economy have been adversely affected by the oil spill.

Removal of Oil from Artifacts and Associated Material

The scientists recommended committing funds to the development of techniques for removing oil from artifacts and associated material that is typically used for radio carbon dating of archaeological deposits. This effort is particularly important because the age of sites is a key piece of archaeological data.

Restoration of Native Cultural Integrity and Trust

A session participant emphasized that ecological restoration of subsistence use areas is essential for the restoration and preservation of the native subsistence economy and culture. The session recommended a survey to develop a thorough understanding of the native perception of the effects of the oil spill. In addition, the session offered numerous suggestions for restoring native trust and counteracting cultural erosion, including:

- Hosting a potlatch, a traditional Native Alaskan gathering, for the affected communities to convey the message of appreciation of and regret for their losses

- Developing an oral history project to record historic native use of the PWS-Gulf of Alaska area

- Conducting studies of Prince William Sound place names and their cultural significance

- Conducting an inventory of artifacts of Chugach origin currently in museum collections and producing a photo brochure for distribution to native villages

- Investigating opportunities to recover native artifacts in private collections to public holdings

- Assisting native communities to establish interpretive museums

- Establishing a per-unit-of-volume curation agreement with the University of Alaska, Fairbanks for long term archival and maintenance of native artifacts, for repatriation when native curation capability is achieved

- Providing native communities the opportunity to video tape traditional activities that may disappear as a result of the oil spill (estimated cost is approximately $10,000 for 20 minutes of tape).

It was noted that a traveling art exhibit entitled "Crossroads of the Continents", which contains pertinent native material is scheduled to reach Anchorage in 1992. The session recommended attempting to make this exhibit available to native communities, particularly to school-aged children.

The session noted that Exxon is planning to produce an information pamphlet on cultural heritage in PWS. The session suggested that, in the interest of addressing Native Alaskan cultural issues expediently, it might be useful to present some of the suggestions listed above to Exxon for voluntary implementation.

Additional Suggestions

Several generic restoration related activities were recommended as well. These include:

- Developing cooperative agreements or joint cultural resource management plans between the state and Native Alaskan communities
- Completing the regional portion of the State Historic Preservation Plan for south central Alaska
- Establishing an information clearing house to track the progress of cultural restoration in PWS-Gulf of Alaska.

Priorities for Summer 1990

When asked to identify their priorities for restoration activity during the summer of 1990 the session participants focused on the following alternatives:

- An intensive survey to identify beach and upland historic, and archaeological sites
- An annotated video tape survey and analysis of the status of PWS beach vegetation
- A feasibility study of methods of beach stabilization
- A public education campaign to reduce vandalism and looting
- Improved enforcement of historic preservation laws
- A "site steward" program

- o Completion of the regional State Historic Preservation Plan.

The participants weighted the importance of these alternatives relatively equally, emphasizing their primary concerns for site identification, reduction of erosion, and protection of vulnerable cultural resources. With respect to the law enforcement alternative, session participants noted a burial cave site that has been exposed as a result of oil spill activity. The session expressed specific concern for the protection of this valuable site.

F. RECREATIONAL

For the concept of restoration to be complete, the recovery of physical and biological properties of resources, as well as the recovery of the lost users of those resources should be addressed. The existence of natural resources provides the means for different types of human uses, one of which is recreation. The objective of the recreational resource work session was to explore possibilities of restoring recreational value impacted by the *Exxon Valdez* oil spill.

The quality of ecological resources is critical to the quality and potential of recreational uses; therefore, biological and physical restoration is fundamental. However, the work session recognized that biological and physical restoration would not fully restore the recreational services provided by natural resources in the oil spill area. In particular, biophysical restoration will not address certain wilderness values and existence/option values. Full restoration of the recreational uses provided by ecological resources will require restoration dependant on the quality and type of recreational experience.

Without damage assessment information, the work group did not attempt to specifically recommend restoration alternatives as much as identify general restoration options which may be appropriate depending on determination of actual damages. More applied, even site-specific, restoration options may become apparent once impacts have been documented. The group assigned each alternative a high, medium, or low priority. This ranking was qualitative, although guidelines with which to evaluate restoration options were generated. These guidelines could be rigorously implemented once damage assessment information is collected. Lastly, the workshop participants identified information which would improve the evaluation of restoration options. In effect, many of these information needs constitute areas recommended as damage assessment. The remaining portion of this section presents the restoration alternatives, guidelines, and information requirements discussed by the recreation work session.

Restoration alternatives were organized into those that restore or replace injured resources and those that acquire the equivalent natural resources, both inside and outside the spill area.

Restoration or Replacement Alternatives

High Priority

- Conduct additional clean-up efforts at prime recreational sites if long-term impact of further cleaning is less than the long-term impact of leaving remaining oil.

- Restoration of public perception. Provide interpretation of event and status of environment and resources

- Encourage hands-on public participation in restoration activities. Provide opportunities for observance, commemoration, or celebration where hands-on participation is not possible.

Medium Priority

- Provide alternative recreational destinations (e.g., cabins, campsites, water moorings) if existing ones are irreparable

- Revise public land management plans. (Revisions may be in the form of interim plans for the duration of the impact.) Review allocation of land-use designations (wild and scenic, state parks). Consider modifying or precluding development (e.g., logging, mining) on public lands. The restoration plan should be integrated with (or at least stimulate revisions to) land management plans.

Acquisition of Equivalent Resources (within oil spill area)

High Priority

- Review options and plan for acquisition of inholdings on public lands. (Acquisition itself will range from low to high priority on a site-by-site basis.) Create public "inholdings" on private lands (to create public access for strategic sites and resources). While session participants questions the relevance of using existing lists not developed specifically in response to this spill, it was noted that many agencies already have priority lists for acquisition which were developed for other purposes. For example, ADNR has already identified and prioritized approximately 20 prime recreation sites of high biological value.

- Review options and plans for temporary or permanent purchase of development rights on private lands, easements, logging rights, commercial development rights, access rights, and mineral rights. Again, actual purchase of development rights will range from low to high priority on site-by-site basis.

Medium Priority

- Assess alternative economic base for native/rural villages

- Establish perpetual trust (endowment, revolving, or matching) fund for future acquisitions

Low Priority

- Improve response to future oil spills including preplacement of response equipment. Minimize impacts to key scenic recreational, and cultural (in addition to key fauna) sites. (Participants noted that this is a low priority for restoration planning, but clearly a high priority for contingency planning)

Acquisition of Equivalent Resources (outside oil spill area)

Medium Priority

- Secure public access to key fishing and recreational sites. (First priority is within spill area.) Emphasize small public access sites rather than purchase of large tracts of wilderness.

- Establish perpetual trust fund (endowment, revolving, or matching) for future acquisitions.

Low Priority

- Acquire threatened wilderness or recreational areas outside Alaska.

When choosing restoration options, session participants cautioned against a shift from low-volume, high-value recreation and tourism to one of high-volume, lower value. An increase in recreational activities is not necessarily conducive to maintaining quality recreation (i.e., restoration efforts should not necessarily increase recreational use). If a loss in the consumer surplus value enjoyment of the wilderness experience can be documented and if monetary compensation is available, these funds should not be applied to recreational development as this will only exacerbate the impact. Instead, acquisition of like habitat (wilderness) should be attempted. Finally, consideration must be given to the statutory obligation to provide wilderness habitat.

Restoration Guidelines

The work session generated a list of guidelines which can be used to evaluate the appropriateness of restoration alternatives. These guidelines were not analogous in structure; as shown below, some constitute criteria, while others incorporate performance evaluation and priority determinations.

General Guidelines

- Biological and physical restoration is fundamental to recreational restoration.

- Restoration strategies should address people's perceptions. (Perception is at least as important as reality.)

- Restoration strategies should address existence values ("armchair" recreation).

- Given the large acreage of public lands in Alaska, providing small public access sites will restore more value than acquisition or designation of additional wilderness acreage.

Selection Criteria

- Direct linkage of restoration activity to user groups that were impacted by spill. Activities should restore value to the user groups that were impacted directly by the spill.

- Effectiveness in fulfilling intended purpose.

- Rate of natural recovery versus rate of recovery under direct intervention/restoration.

- Cost effectiveness.

- Effects of activity on other resources or other uses.

Priority Determination

- Favor restoration of areas where both recreational resource values and oil spill impacts were greatest.

- Favor acquisition and other restoration alternatives within the spill area so that values are restored to the same populations as lost the value.

- Favor restoration of recreational opportunities which are less easily replaceable or more unique. For example, activities with a higher degree of dependence on the resource (such as camping and other shoreline and beach dependent activities) should be deemed more important than less resource-dependent activities (such as cruise ship travel).

- Favor protection or acquisition of sites which are most vulnerable to other (non-spill-related) threats. Protect or acquire most threatened sites first.

Information Needs

Without damage assessment information, a variety of questions arose as to the nature and magnitude of recreation loss. The answers to these questions are critical for focusing restoration efforts. A basic need is for detailed site-specific data regarding the extent of oiling and resource injury at recreational sites. In addition, public attitude surveys of both direct and indirect users could provide needed information on values and perceptions. Questions potentially answered by a survey include:

- o What is the nature and extent of displacement of recreation use resulting from the spill?

- o Did or will displacement of recreation use from the spill area affect the quality or quantity of use in other areas in Southcentral Alaska?

- o Did the spill adversely affect the quality or quantity of wilderness values of PWS-Gulf of Alaska for local residents? What about the perception of wilderness for potential visitors to the area? For actual visitors?

- o Will the spill result in more recreation use through the spill's "advertising" or name recognition value? Will visitors pay less than they would have if the area had not been oiled? Will there be a trade-off of high-value/low-volume tourism for lower value/high-volume tourism?

- o Will the spill attract disaster junkies, as was the case with Three Mile Island or Mount St. Helens?

- o Will a new tourism industry develop out of people wanting to visit the spill area or learn about or study natural or human supported restoration?

- o What is the effect of the spill on the recreation opportunity spectrum in PWS-Gulf of Alaska?

An assessment of direct recreation and tourism uses in PWS-Gulf of Alaska should also be accomplished, namely:

- o What are the patterns of use?

- o What is the number of users?

- o What is the value of recreational opportunity translated into consumer surplus?

- o How much worse-off are the PWS-Gulf of Alaska users?

The above surveys are damage assessment activities necessary to support informed determination of restoration alternatives. Additional information is necessary to evaluate restoration options and develop a restoration plan. In particular, information is needed to characterize land status and acquisition opportunities with respect to guidelines and criteria developed by the ecological, recreational, and cultural resource sessions. This information should then be integrated with priorities of public land management agencies as reflected in land use plans. Combining this information with spill extent and recreational site location and values will be fundamental to analysis of any restoration activity for recreational resources.

G. COMMON THEMES

Although the work sessions reflected the unique characteristics of their subject resources as well as the technical disciplines and experience of their participants, several common themes developed during the course of the Technical Workshop. These common issues include: 1) the need for more complete damage assessment information to formulate appropriate restoration plans; 2) the recommended application of broadly inclusive stress- or risk-reduction approach to restoration; and 3) the requirement for more basic biological information to adaptively manage the restoration process. The participants in Technical Workshop reached a clear consensus that the current level of information and knowledge was inadequate for final planning.

Clearly, PWS and Gulf of Alaska ecological, cultural and recreation resources were injured or at risk of damage as a result of the Exxon Valdez spill. However, the nature and extent of that injury has not yet been diagnosed fully and, in many cases, sublethal or long-term population or ecosystem impacts may not be symptomatic for some time. To address this problem, additional information on the nature and extent of injury and the baseline pre-spill conditions of the resources are needed to plan adequate restoration. In order to protect those resources potentially at risk, a broad risk or stress reduction effort, permitting restoration actions that may not be linked directly to the damage or even the impact area, may be necessary. This approach would allow protection of a wide-range of resources when direct restoration is not practical due to lack of existing methods or cost. Finally, an adaptive strategy for managing restoration is appropriate due to the uncertainties associated with the extent of long-term impacts, effectiveness of restoration methods, and the potential rate of recovery. To facilitate an adaptive management approach, more detailed, real-time information on these resources will be needed. Obtaining this information will require basic studies of the resources, and monitoring to permit resource managers to protect those resources from further harm. This theme was particularly emphasized for exploited or otherwise regulated resources (i.e., fish/shellfish, some birds and mammals) or protected. Acquiring additional information on exploited resources would enable resource managers to modify their management strategies to protect the resource, while permitting an acceptable level of utilization.

There were many relationships noted between restoration options for the various categories of natural resources. In some cases, restoration action, focused on one resource may have collateral benefits or negative impacts on other resource categories. For example, some options for enhancing bird populations could reduce or complicate fish restoration measures, and some suggestions for protecting prey resources for mammals could impact commercial and recreational fisheries. Similarly, conservative fisheries management could temporarily reduce recreational fishing. Several recommendations for the removal of asphalt mats to enhance coastal habitat recovery were contradictory to recommendations for the protection of archaeological resources. In many cases, however, collateral benefits were clear. This was particularly evident for generic risk-reduction approaches associated with the acquisition of logging or mineral rights to protect habitat or reduce the potential for future development. There clearly will be trade-offs involved in the final decisions on restoration actions. Hopefully, additional information from the ongoing NRDA and special studies will help resolve some of these complex issues.

The restoration planning project will be a precedent-setting effort and will influence the future of PWS and the Gulf of Alaska resources and the people and economies of the region. This Technical Workshop has outlined a range of restoration alternatives and information requirements that will help focus the restoration process.

V. POTENTIAL FEASIBILITY STUDIES

At the request of the interagency Restoration Planning Work Group, workshop participants discussed and formulated potential restoration feasibility studies or demonstration projects. These projects were recommended for potential application during the summer of 1990 in order to provide needed information to support the restoration program. In some cases, these are pilot projects designed to assess the feasibility of potential restoration projects. In other cases, they were developed to provide additional information on resources potentially at risk due to the spill. These projects are submitted for further consideration and, if accepted, could be developed into formal proposals.

COASTAL HABITATS

Remote Sensing Assessment of Habitat Damage, Clean-Up, and Restoration

Oil damage to coastal habitats containing significant amounts of vegetation (e.g. marshes, intertidal zones, and super-tidal areas) should be detectable by high resolution (10-30m) satellite multispectral images. The impact of clean-up and restoration efforts, including disturbance of associated near-coastal habitats, should also be evident. It seems possible that the current generation of satellite sensors (Landsat 5, SPOT 1), coupled with recently developed image processing methods, would be able to overcome the problems associated with detecting these impacts.

This project can demonstrate the feasibility of using satellite remote sensing data to assess quantitatively the extent of damage to coastal habitats within Prince William Sound and to monitor recovery and the effects of clean-up and/or restoration. Formal statistical tests of observed spectral differences between undamaged control areas, damaged areas, and areas undergoing clean-up and/or restoration can be applied. If significant differences are established, this can be considered a successful demonstration of the technique for quantitative oil spill damage assessment and clean-up/ restoration/recovery management.

Restoration of Oil-Impacted Marshes

Recovery of oil impacted marshes in Prince William Sound and the Gulf of Alaska may be slow, as these marshes are small and uncommon, especially compared to those of major river deltas such as the Copper River. Because of their limited areal coverage and their patchy distribution, opportunities for natural recolonization through seeding or propagule dispersal are extremely limited. These marshes are important resources for the area, serving as an alternate food source for browsing mammals (especially in harsh winters), as refuge for small birds and migratory water fowl, etc.

Natural removal from marshes is a slow process because they are sedimentary, anaerobic habitats with minimal flushing. It is unlikely that current clean-up techniques will be effective (or even attempted) in marshes, without long term adverse impact on the plants comprising the habitat and the associated flora and fauna. This project will utilize several approaches to remove oil from impacted marshes, while attempting to minimize the impact of the removal process. Without reduction of oil to soil concentrations less than some critical value, regrowth in the oiled area will not occur. Restoration will utilize natural regrowth and transplant techniques to introduce healthy plants back into the impacted marshes. Performance criteria for evaluation of success will be assessments of oil removal efficiency over the course of the summer for several different treatment techniques. Additional measures of success will include quantifying the manner by which the removal techniques maintain minimal impact on soil compaction and minimum residual traces of trenching, raking, or foot paths. Once oil has been removed, proven transplant techniques will be evaluated by percent viable plantings and growth (biomass) of the transplants.

Restoration of *Fucus* Communities

Fucus is one of the most abundant intertidal algal species inhabiting the coasts of PWS and the Gulf of Alaska. It is an important perennial plant that is a critical structural component of the intertidal habitat in PWS and the Gulf of Alaska and serves as an important spawning habitat for herring. Qualitative evidence indicates that *Fucus* was damaged by both the oil itself and by subsequent clean up efforts. There may be substantial delay in the natural recovery of areas where populations were reduced over large (100 to 1000 meters of shore line) areas because dispersal of embryos is probably limited (< 1 meter in most circumstances). Drift plants may increase this distance, but the importance of this mode is unknown. This project will explore the feasibility of reestablishing *Fucus* in damaged areas of PWS-Gulf of Alaska by developing large scale seeding techniques and determining the efficacy of seeding vs. transplanting.

Reestablishment of Critical Intertidal Species

Intertidal communities were probably the most heavily affected of coastal environments. Elimination of entire communities, either through oiling or cleanup activities, has been documented. Further, initial results suggest that certain key species that are likely to structure these intertidal communities were moderately to heavily affected. Natural restoration processes in these communities will be limited by recolonization rates of these key species, which in some cases are known to be quite low. Reestablishment of *Fucus* alone, therefore, may not be sufficient to ensure reestablishment of pre-spill conditions on ecologically meaningful time scales.

This project will compare rates of recovery of intertidal areas with and without key species and combinations of species. Grazer, predator, and grazer/predator exclusion and enhancement plots will be established to demonstrate the feasibility of reestablishing key faunal elements needed to recover fully functional rocky intertidal communities in PWS and other affected locations.

Artificial Reef Evaluation

The Exxon Valdez oil spill potentially has damaged fishery habitat types that are of known importance, including rockfish reefs, herring spawning areas, and salmon spawning/nursery areas. Artificial reefs or SAV beds are possible interim restoration measures that may provide additional habitat to replace at least some of the functions of the reef or rocky subtidal habitat lost or damaged as a result of the oil spill.

This project will evaluate the feasibility of providing artificial reef and/or SAV habitat to replace habitat damaged or degraded as a result of the Exxon Valdez oil spill. The proposed pilot project will include the construction and evaluation of an artificial reef placed in Prince William Sound. The specific objective of artificial reef placement is to test the hypothesis that rockfish or other fish and shellfish species will use reefs as shelter and/or feed on the forage base that is 1) concentrated by or attracted to the reef, 2) develops on the reef surface, or 3) uses this fouling community as microhabitat. This demonstration project will determine the effectiveness of this habitat replacement approach for future restoration in Prince William Sound.

Stock Identification for Management Restoration Efforts

The extent of damage resulting from the oil spill and attendant operations is not well documented for several important species of commercial fishes. It is likely that the greatest impact of the damage will be seen in the year-classes, produced during the year of the spill and the next several years. Management efforts directed particularly at species (e.g., salmon and herring) of high economic and ecological value that have been identified as being at risk from the oil spill are needed. Management of salmon and herring stocks requires additional information on stock identification to permit a reduction of fishing effort. This information must be available in a timely manner to allow protective actions to be implemented.

There is still some mixing of stocks at this time, but the extent is not known. A demonstration project for the 1990 harvest would entail identifying wild and hatchery reared salmon stocks in the terminal fishery by the rapid recovery and identification of hatchery marked fish, from which data on the proportion of non-hatchery fish could be calculated. If the catch of wild fish was considered inappropriately high, fisheries efforts could be curtailed or redirected. For the 1991 season, adult fish in various fishing areas would be tagged and released so that tags recovered at hatcheries and in oil-impacted, spawning/rearing waters would provide detailed stock distribution data.

A similar problem exists with the herring fishery of Prince William Sound and adjacent waters. It is possible to shift the herring fishery from the Sound to outside waters, but there are indications that some herring in outside waters may be juveniles of the Sound herring stocks. If that is the case, then shifting the fishery to outside would still impact the Sound stock. If, by scale analysis, it can be shown that the outside stocks are indeed separate, then such fishery shifts for the next several years would protect the potentially impacted Sound herring stocks.

Marbled Murrelet Breeding Habitat Identification

The numbers of marbled murrelets have been decreasing in the Sound since the early 1970s, with only 40% of the numbers in 1972 found in 1989. These birds depend upon the fisheries resource in the Sound which may have been damaged by the 1989 oil spill, further contributing to the stress on the population and potentially accelerating the rate of decline. Preservation of breeding habitat would contribute to support of the population and maintenance of a viable population. However, in Alaska, marbled murrelet nesting habitat requirements are unknown.

This project will determine breeding habitat requirements for marbled murrelets in the Prince William Sound area. Specifically the goal is to determine if they nest in trees and, if so, whether they are dependent upon old-growth forest habitat or can utilize second growth timber.

Forage Fish Availability

Many of the colonial and noncolonial nesting seabirds, as well as bald eagles, are dependent upon near-shore fisheries for a food source. It is suspected that a decrease in these resources over the last 10 years may be contributing significantly to the gradual decline of the seabird populations. If the oil spill of 1989 also affected the numbers and/or distribution of these forage species, then continued and accelerated declines in the bird populations can be expected, and restoration attempts such as replacement of breeding habitat would be severely impaired. Acoustic tracking of schools of herring, sandlance, and other fish in PWS could be done to determine numbers and distribution of forage fish for seabirds. Distribution and numbers of fish species would be plotted using a GIS currently under development for the Sound. Known locations of oil already have been entered into this system. Additional overlays could include locations of nesting colonies of seabirds and known locations of bald eagle nests.

Predator Control at Breeding Bird Colonies

Many of the small islands along the Kodiak Peninsula and in the Aleutian chain have had predator species of mammals introduced during the last 100 years. For example, foxes and rats have become abundant on several of the islands. Eggs and chicks of ground-nesting colonial seabirds are a preferred prey item for these mammalian predators. Removal of introduced predators by the USFWS in the past has resulted in more than a 400% increase within 10 years of the numbers of eiders and cormorants on an island. This project will reduce the number of introduced predators on selected islands to enhance success of reproduction of ground-nesting colonial seabirds by utilizing trapping and/or poison baits. USFWS has standard protocols already established for predator control.

Prioritization for Acquisition of Sensitive Habitats

Long-term restoration plans identified during the Technical Workshop for avifauna in the spill areas include reduction in timber harvest, acquisition of islands intensively used by colonial nesters, eradication of introduced predators from islands with ground-nesting colonial birds, and reduction of human disturbance in sensitive areas. The USFWS has begun a process of prioritizing locations of these sensitive areas in relation to long-term plans for acquisition or providing protective status. However, given the added stress of the oil spill and imminent increase in logging activity, the time-frame for this planning process should be shortened.

This project will provide a list of areas of high, medium, and low priority for protection and/or preservation to maintain a viable, diverse avifauna in Prince William Sound and other oil-impacted areas. This list will be generated by gathering and collating information from several agencies (USFWS, ADFG, USFS, ADEC) on areas of particular sensitivity to avifauna in the spill area.

MAMMALS

Sea Lion/Harbor Seal Habitat Protection

Both sea lion and harbor seal populations have been declining in Alaska. Consequently, any additional risk from the oil spill will accentuate this decline. The object of this study is to identify habitat use, and document the disturbance to the populations using this habitat in order to develop measures to preserve habitat critical to successful reproduction of the species. Once this information is obtained, it will justify the preservation and protection of these critical habitats through possible acquisition or protection by minimizing disturbance through restrictions on use or access.

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APPENDIX A

WORKSHOP AGENDAS

AGENDA

ECOLOGICAL RESOURCES

Tuesday, April 3

8:30	Restoration Planning Process Expectations of Workshops
9:00	Fate and Status of Oil
9:30	Summary of Natural Resource Damage Assessment Results
12:00	Break for Lunch
1:00	Work Group Assignments
1:30	Work Groups convene concurrently (Coastal Habitat, Fish/Shellfish, Mammals, Birds) Tasks: Review state-of-the-art in restoration technology and the feasibility of applying these technologies to Prince William Sound and the Gulf of Alaska. Develop broad scientific guidelines for evaluating restoration alternatives. Discuss initial damage assessment results with respect to potential restoration alternatives.
5:00	Break for Dinner
7:00	Session chairs meet to review progress and develop overall scientific guidelines which can be applied across all work groups.

Wednesday, April 4

8:00 Plenary Session: Summary of Day 1

8:30 Reconvene Work Groups

Task:

Develop broadly-inclusive matrix of restoration alternatives (including restoration, replacement, and acquisition of equivalent resources) that warrant further evaluation.

12:00 Break for Lunch

1:00 Reconvene Work Groups

Task:

Based on broad scientific guidelines, identify information needs and/or feasibility studies necessary to evaluate candidate restoration alternatives.

4:00 Plenary Session: Summary Reports

5:00 Break for Dinner

7:00 Session chairs meet to discuss work products

Thursday, April 5

8:30 If necessary, key individuals may meet to continue discussion of work products.

AGENDA

CULTURAL AND RECREATIONAL RESOURCES

Thursday, April 5

8:30	Restoration Planning Process Expectations of Workshop
9:00	Fate and Status of Oil
9:30	Summary of Site Damages
10:30	Work Group Assignments
11:00	Work Groups convene concurrently (Cultural, Recreational) Tasks: Review state-of-the-art in restoration technology and the feasibility of applying these technologies to Prince William Sound and the western Gulf of Alaska. Develop broad guidelines for evaluating restoration alternatives
12:00	Break for Lunch
1:00	Work Groups convene concurrently Tasks: Develop broadly-inclusive matrix of restoration alternatives (including restoration, replacement, and acquisition of equivalent resources) that warrant further evaluation. Based on guidelines, identify information needs and/or feasibility studies necessary to evaluate candidate restoration alternatives.
4:00	Plenary Session: Summary Reports
5:00	Session chairs meet to discuss work products

APPENDIX B

LIST OF PARTICIPANTS BY WORK SESSION

COASTAL HABITATS

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Gibbons, Dave	USFS, Wildlife and Fisheries P.O. Box 21628 Juneau, AK 99802-1628	586-7918 (907)
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APPENDIX C

INFORMATION SHEETS

Fact Sheet:
Exxon-Valdez Oil Spill Damage Assessment

State and federal agencies are conducting a comprehensive assessment of the effects of the spill on natural resources in Prince William Sound and the Gulf of Alaska. Approximately 60 studies are being conducted with a first-year budget of $35 million.

> 26 studies focus on the effects of the spill on fish and shellfish (e.g., salmon, herring, shrimp, rockfish, clams, and crab).

> 14 studies focus on the effects of the spill on birds (e.g., bald eagles, peregrine falcons, sea ducks, kittiwakes, and shorebirds).

> 6 studies focus on the effects of the spill on terrestrial mammals (e.g., bear, deer, river otter, and mink).

> 7 studies focus on the effects of the spill on marine mammals (e.g., sea otters, whales, seals, and sea lions).

> 6 studies address the effects of the spill on air, water, sediments, and coastal habitats.

Several of these studies are expected to continue in 1990 and some new ones, including studies of effects on cultural resources, are proposed. These studies are being funded by the state and federal governments and Exxon. They are being conducted under the authority of two federal laws: the Comprehensive Environmental Response, Compensation, and Liability Act and the Clean Water Act. Study results will be used to:

1. assess the extent and magnitude of damage caused by the spill;
2. guide the development of an action plan to promote the long-term recovery of injured natural resources; and
3. determine the level of monetary compensation to be paid by Exxon.

Any compensation received from Exxon as a result of this process must be used to "restore, replace, or acquire the equivalent" of the injured natural resources.

Three federal officials (the Secretaries of the Departments of Interior, Agriculture, and Commerce) and one state official (the Commissioner of the Department of Fish and Game) have been appointed as natural resource "trustees" to oversee the studies and restoration work. In addition, the Alaska departments of Environmental Conservation, Natural Resources, and Law, the U.S. Justice Department, and the U.S. Environmental Protection Agency are playing important roles in the overall process.

Introduction: Restoration of the Environment Following the Exxon-Valdez Oil Spill

A broad variety of environmental restoration projects and activities may be appropriate following the Exxon-Valdez oil spill. Under Federal law, funds available for environmental restoration are to be used **to restore, replace, or acquire the equivalent of injured natural resources.** The Alaska departments of Fish and Game, Natural Resources, and Environmental Conservation, the Federal departments of Agriculture, Commerce, and Interior, and the U.S. Environmental Protection Agency are carrying out a restoration planning project to identify and report on restoration alternatives.

"Restoration" includes direct attempts to return an injured resource to its baseline condition or function. An example would be to rehabilitate an oiled marsh ecosystem by augmenting natural plant and animal populations (after removal of the oil).

"Replacement" includes substitution of a new resource for an injured resource. An example is to use hatchery/aquaculture techniques to establish an entirely new fishery stock in lieu of one that had been severely damaged.

"Acquisition of equivalent resources" means to purchase or otherwise protect other resources that are similar or related to the injured resource in terms of ecological value, functions, or services provided. For example, one could purchase undamaged and unprotected wildlife habitats as alternatives to direct restoration of injured habitats. Equivalent resources need not be confined to the direct spill area.

The interagency Restoration Planning Work Group has initiated a series of public activities including this Restoration Symposium, several public Scoping Meetings in communities directly affected by the oil spill, and a world-wide review of scientific literature. These activities are the first steps in restoration planning. The process is largely without precedent and it is expected to be long, complicated, and probably controversial. Public comments and ideas are encouraged throughout this process.

An interim report on the restoration planning project is expected to be available for public distribution in July, 1990.

APPENDIX D

QUESTIONS FOR NATURAL RESOURCE DAMAGE ASSESSMENT PRINCIPAL INVESTIGATORS

Principal Investigators:

The following are questions you should take into account as you prepare for the work group discussions at the technical workshop, April 3-4. We are most interested in your thoughts regarding possible restoration activities.

1. What is the importance of the resource to the ecology and/or human services of Prince William Sound and the western Gulf of Alaska?

2. What is the nature, severity, and extent of the damage?

   o What is the pattern of the damage? (The purpose of this question is to determine how the pattern of damage might influence natural recovery of damaged resources.)

   o What is planned for the future? How long will it take to determine additional damage?

3. How was the damage determined? (What studies, approaches, etc.)

4. What is known about what caused the damage?

5. How long do you think natural recovery will take? What is the basis of your estimate?

6. What, if any, restoration activities do you think should be undertaken to restore the resource? How long will it take to see results?

APPENDIX E

FISHERY MANAGEMENT INFORMATION REQUIREMENTS

APPENDIX E

FISHERIES MANAGEMENT INFORMATION REQUIREMENTS

The fish and shellfish technical session participants identified a substantial need for more precise and real-time information to support the effective management of fisheries under conditions of increased uncertainty introduced by the Exxon Valdez oil spill. This appendix represents an attempt to synthesize the session discussion and provide a rational framework for evaluating the requirement for additional information.

In the case of the Exxon Valdez spill, an increase in effort to assess impacts and monitor rates of recovery (natural or in response to restoration actions) will be necessary to acquire better information to permit managers to respond rapidly to detected changes. Failure to commit resources to obtaining this information will result in potentially unwarranted economic loss in near-term fishery yields.

A range of information is needed to permit managers to make knowledgeable decisions about changes in the stock-recruitment relationship of economically or ecologically important fishery resources. Many of these requirements were reflected in the recommended 1990 "restoration" alternatives identified by the fish/shellfish technical session participants. These requirements included data from escapement enumeration, adult tagging, and otolith analysis for salmonid populations; cataloging spawning areas, identifying stocks, and determining biomass for herring populations; and continuing NRDA port sampling for sport fish and trawling surveys for groundfish.

Fishery resource managers are responsible for regulating fisheries in an environment that is characterized by uncertainties in the productive potential of their resources, the consequences of resource exploitation, management budgets, and political decisions (Hilborn 1987). Under normal circumstances, basic information on the effects of normal environmental perturbations and gradually growing fishing effort are used to develop a national regulatory policy. However, potentially catastrophic events such as a large-scale oil spill introduce an additional level of uncertainty into the effects of environmental conditions on fish-stock recruitment. This makes management more complex and subject to greater risk of error, with adverse consequences to the managed populations, and subsequent economic loss. In such cases, a greater degree of basic information is needed to adapt management strategies to protect the stocks from collapse, while maintaining harvests at appropriate levels.

Hilborn (1987) proposed a taxonomy of uncertainty that reflects the decisionmakers knowledge about the states of nature. He identified three progressively uncertain states of nature: "noise," which might describe frequently observed events such as the annual variability in total return of a salmon stock; "uncertain," which describes less known changes, such as long-term changes in the stock-recruitment relationship; and "surprise" or catastrophic events such as the Exxon Valdez spill for which little prior experience is relevant. These categories represent different degrees of knowledge or certainty about the current and future states of nature. As the relative uncertainty about the state of nature affecting a fishery and its harvest increases, a change in management strategy is generally developed to reflect the objective of maintaining sustainable yield without increasing potential stress on the stock.

To protect the resources, Alaska fishery managers must decide how to adjust fishing mortality to account for a new, higher level of uncertainty about factors affecting the stocks. The problem for Alaska fishery managers is that they do not know the probability of the alternative future states of nature. Past information does not include records relating to a "surprise" oil spill of this magnitude in this environment. To obtain better information on the uncertainty or probability of future states of nature, additional monitoring and/or sampling will be necessary.

The variable components of this framework for fisheries management decision making are illustrated in Fig. E-1. These include: 1) states of nature (uncontrollable variables), that are sets of values for a group of factors such as oceanographic, meteorological, and other environmental effects; 2) the strategies (controllable variables) such as regulatory options relating to the level of effort, temporal restriction, or areal closures; and 3) payoffs (dependant variables) such as the harvest levels of individual stocks. The stated objective determines the pertinent strategies and states of nature to be considered in the decision making process and the way the achievement of the objective is to be measured. The decision constitutes the selected regulatory actions needed to implement the decisionmakers' strategy.

A general payoff matrix (Table E-1) illustrates the interaction between the states of nature, alternative management strategies, and resulting payoff variables. The matrix suggests that a range of potential impacts could result from combinations of management strategies and actual levels of oil related effects on the state of nature variable. Examining alternative payoff matrices facilitates the analysis of a management decision by providing a logical format for arranging the possible states of nature, fisheries strategies, and corresponding payoffs of expected utility. Management becomes more difficult as the uncertainty about future state of nature increases.

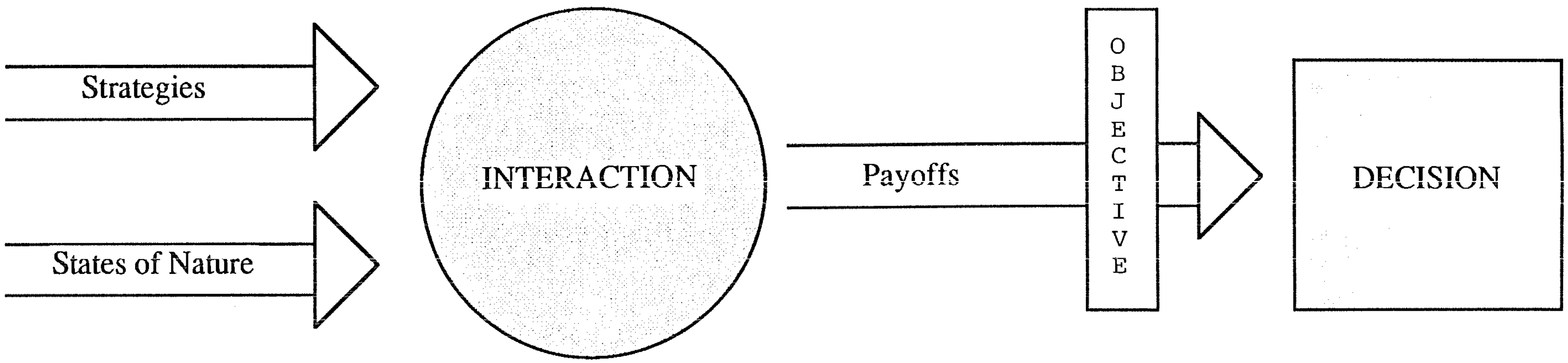

Figure E-1. Simplified fishery management decision-making process

Table E-1. General form of a payoff matrix

Strategy \ State of Nature	State of Nature 1	2	...	State of Nature n
Strategy 1	PAYOFFS			
Strategy 2	PAYOFFS			
. . .				
Strategy n	PAYOFFS			

A hypothetical decision tree (Fig. E-2) provides a simplified visual model of the problem facing Alaska fishery resource managers. The figure illustrates a combination of potential states of nature (stock levels; good, poor, and very poor) and decisionmaker's strategies (high or low levels of fishing effort (mortality) or closure) and potential relative payoffs in some utility measure such as economic value of the fishery for a given stock. The relative payoff values are hypothetical, suggesting the range of potential outcomes. For example, if the state of nature is very poor or catastrophic and the decision maker selects a high level of fishing mortality, the relative near-term payoff would be very low indicating significant economic (and potentially ecological) loss. The fishery managers must either guess or estimate by sampling the state of nature; the value of knowing more about the a current state of nature before making final decisions on setting fishing effort is clear. A decision risk analysis conducted using network simulation methods would aid in assessing the value of additional information on year class size.

As mentioned, the normal range in variation in stock size is usually known with some predictable degree of certainty and is not considered a serious problem because sufficient data exist on this background variability ("noise") to permit effective management. In this case, managers can confidently select a strategy with which to maximize the objective of the expected payoff. Managers facing more uncertain states of nature (risk) must consider both the alternative probability of occurrence of the possible states of nature as well as the payoffs. In this case, two management strategies are generally used: 1) choose a conservative strategy that will perform well given the expected range of possible states of nature or 2) pursue an adaptive management strategy that will allow one to learn about the true state of nature and respond to it. The former strategy trades off short term payoffs for the protection of sustainable payoffs; it is a conservative approach that may reduce fisheries economic benefits in the short term by maximizing the expected return over all possible productivities. The latter adaptive approach (Walters and Hilborn 1976, 1978, Etzioni 1989) requires more current information to permit real-time predictions in productivity and adjustments in exploitation as information is collected.

The relationship between a range of states of nature, management strategies, and information requirements is described in Table E-2. Under "surprise" or low probability and potentially high consequence events, managers can do little except monitor more intensely and respond rapidly with appropriate management actions. The best approach to prepare for such unexpected events is an aggressive broad monitoring program that enables decisionmakers to detect the unexpected as early as possible and respond rapidly. This approach is expensive and hard to justify until

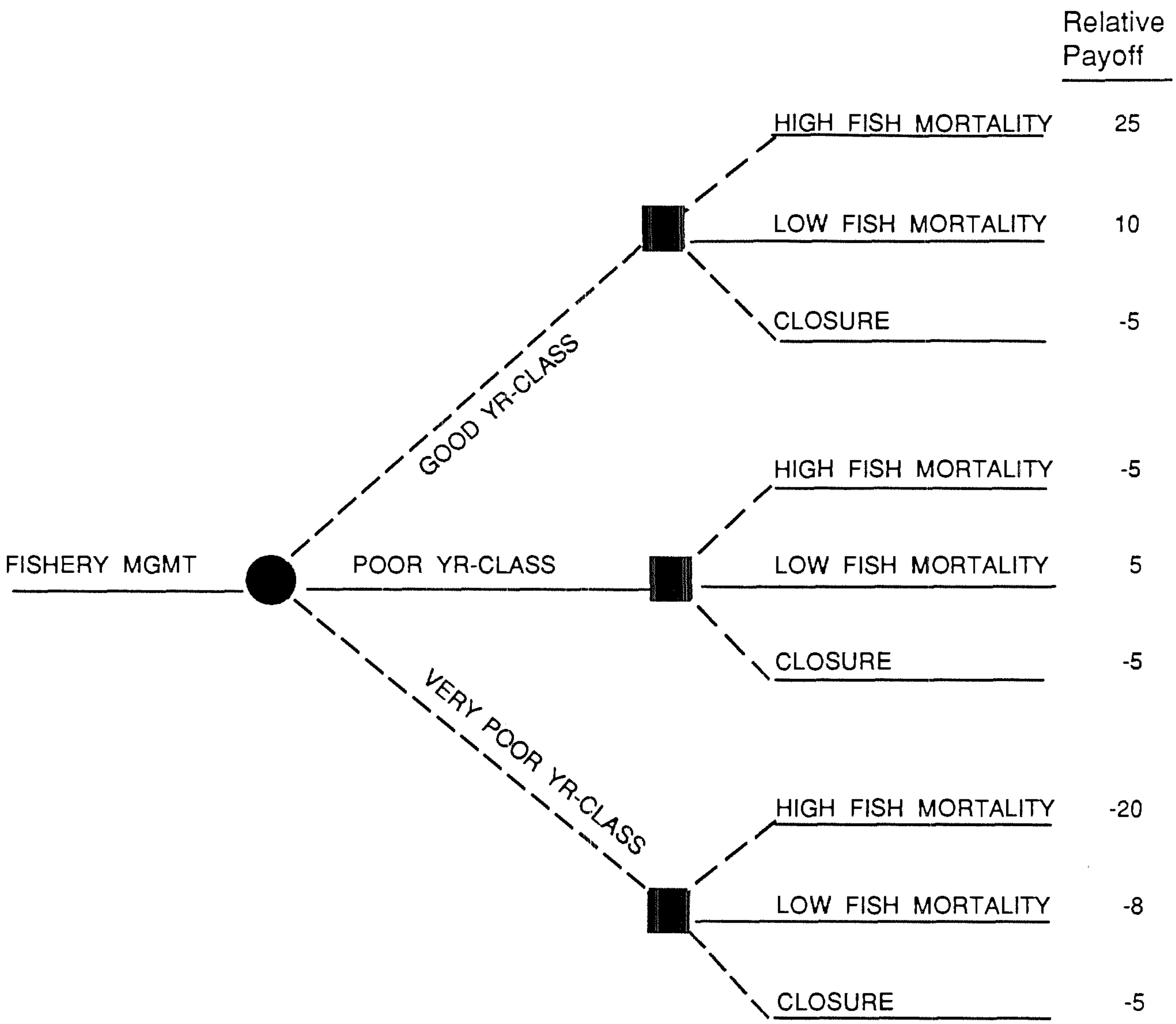

Figure E-2. Hypothetical decision tree for fishery management decisions.

Table E-2. Information needs associated with variations in the States of Nature

States of Nature Category*	Management Strategy*	Information Requirements
"Noise"	Living with variability	Routine
"Uncertain"	Conservative or adaptive	Trends real-time
"Surprise"	Monitor broadly Respond rapidly	Detailed & real-time

*Reference Hilborn, 1987

such a major "surprise" event occurs; as a result, it is rarely implemented. Without more precise and real-time information, prudent managers generally adopt a conservative strategy to protect the sustainable resource. In order to improve near-term economic benefits and simultaneously reduce the risk of further damage to the resources, an investment in more precise and real-time assessment and monitoring to facilitate adaptive management is necessary.

Another management approach to "surprise" events is to keep or place additional resources in reserve to protect against future risks to the fishery. One method of achieving this goal for PWS and Gulf of Alaska fisheries, which are clearly vulnerable to additional impacts from oil transport as well as other development, is to acquire and preserve remaining habitat through direct purchase, acquisition of timber of mining rights, or implementation of other restrictive measures. These measures may reduce the potential impact of future "uncertain" and "surprise" events. Since many potential sublethal effects may not produce impacts on the fishery for some time, this approach may minimize the cumulative anthropogenic impacts on fisheries and preserve future harvest and associated economic and social benefits.

The success of future fishery management actions will be judged in terms of their effect on future harvests and associated economic and social benefits. The perturbation in environmental or ecological conditions introduced by the Exxon Valdez oil spill has increased the uncertainty in the nature of the fish-stock variability. More precise and real-time information is, therefore, needed to gain insight into the response of these exploited resources to the potential increased perturbation induced by the oil spill. Failure to obtain this information may result in future economic loss from reduced harvests due to either stock declines or required conservative management. The need for information is not restricted to the targeted species but includes the trophic food web that supports these fisheries. The problem of predicting population variability depends not only on an understanding of a particular group of fish on the ability to identify, define, and measure the fishes ambient environment (Strebel 1980). Therefore, the fish/shellfish restoration efforts are directly linked to the interaction of these species with their habitats and other elements in the PWS and Gulf of Alaska ecosystem.

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APPENDIX F

RELEVANT LITERATURE

APPENDIX F

RELEVANT LITERATURE

This appendix constitutes the results of a literature search, and encompasses the general subjects of: state-of-the-art for restoration, fate and effects of oil spills, bioremediation, and restoration ecology. A variety of computer searches were employed, including: Aquatic Science Abstracts, Biosis, Cambridge Scientific Abstracts, Enviroline, Pollution Abstracts, and Zoological Record. Various key words in different combinations were used: mitigate, oil spill, habitat, marine, estuarine, salt marsh, subtidal, intertidal captive breeding, restoration, translocation, reintroduction, various species (e.g., otters, seabirds, eagle), nest boxes, Exxon, and Valdez.

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APPENDIX G

ARCHAEOLOGICAL SITE STABILIZATION BIBLIOGRAPHY

APPENDIX G

ARCHAEOLOGICAL SITE STABILIZATION BIBLIOGRAPHY

The following bibliography was compiled by Dr. Robert Thorne, Center for Archaeological Research, University of Mississippi. Dr. Thorne was a participant in the Technical Workshop and distributed this document at the cultural resources work session.

ARCHAEOLOGICAL SITE STABILIZATION BIBLIOGRAPHY

Robert M. Thorne

December 15, 1989

NATIONAL CLEARINGHOUSE FOR ARCHAEOLOGICAL SITE STABILIZATION

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EDITOR'S NOTE

As you will note, this bibliography is dated on the cover page, indicating the last date that additions have been made to the total listing. Since the content of the bibliography is subject to having new citations added on a regular basis, a word processing entry and publication system is being used, thus your receipt of an unbound package. We are currently using PROFESSIONAL WRITE as our main word processing program. If access to multiple copies of the bibliography are desirable, diskette copies are available if the request is accompanied by a blank diskette.

BIBLIOGRAPHY
OVERVIEW

The bibliography which follows is divided into four sections that are intended to support the conceptualization, design and development and implementation of archaeological site stabilization ad preservation projects. The annotations which accompany some of the references are intended to provide a brief but sufficient sketch of the entry. Any references to the stabilization and preservation of standing structures have been intentionally omitted since this subject area is beyond the scope of resources that are considered by the National Clearinghouse for Archaeological Site Stabilization.

Section 1, PHILOSOPHY, provides a philosophical overview for site preservation and stabilization. While the section may appear to omit a number of pertinent articles, it does provide the user with sufficient background to justify, at least philosophically, archaeological site stabilization projects. Direct references to statutory and regulatory support may be found elsewhere.

Section 2, TECHNICAL SUPPORT, begins to draw together a corpus of technical information that is generally unknown to archaeologists. Reliance on and a knowledge of these data are integral to the design of stabilization projects, particularly if cost-effective and innovative stabilization measures are to be put into place.

Section 3, MANAGEMENT RECOMMENDATIONS, contains a mix of projects where site stabilization was not considered the best choice but stabilization efforts were finally selected as the best mitigation approach. References included here should provide the user with an idea of how other projects have been approached.

Section 4, PRACTICAL APPLICATIONS, is devoted to the presentation of specific archaeological site stabilization case histories. Data contained in these case histories will provide an insight into the planning and implementation of stabilization projects that are already in place and can serve as a partial base for the development of new projects.

It is important to note that his bibliography is not all - inclusive since it is in its beginning stages. It will be added to as new references become available or as older projects are brought to the attention of the National Clearinghouse.

SECTION 1

PHILOSOPHY

Adams, William Y.
1973 "Strategy of Archaeological Salvage" in _Man-Made Lakes: Their Problems and Environmental Effects_. Geophysical Union, Washington.

Aten, Lawrence E.
1986 "Planning the Preservation of Archaeological Sites" in _Rescue Archaeology, Papers from the First New World Conference on Rescue Archaeology_, Edited by Rex L. Wilson and Gloria Loyola, National Trust for Historic Preservation, Organization of American States, The Preservation Press.

Dixon, Keith A.
1971 "Archaeological Site Preservation: The Neglected Alternative to Destruction," _Pacific Coast Archaeological Society Quarterly_, Vol. 7, No. 4.

Ford, Richard I.
1983 The Archaeological Conservancy, Inc., the Goal is Site Preservation. _American Archaeology_, Vol. 3, No. 3, pp. 221-224.

Ford discusses the Archaeological Conservancy, describing how it was formed, its objectives, and how it is to function. He also includes a description of how sites are to be preserved through acquisition of properties and their subsequent placement in the public domain. He indicates that the Conservancy is a voluntary organization and is dependent on increased membership and funding.
SITE ACQUISITION

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1986 Conserving American Archaeological Resources, in _American Archaeology Past and Future_, edited by David J. Mitzer, Don D. Fowler and Jeremy A. Sabloff, pp. 135-162. Society for American Archaeology, Washington, D.C.

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1975 "A Qualitative Model for Inundation Studies for Archaeological Research and Resource Conservation," _Plains Anthropologist_, Vol. 20(F), Part I, pp. 279-296.

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Shiffer, Michael B., and George J. Gummerman
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Thorne, Robert M.
1988 Preservation is a Use. Paper presented at the 1988 Society for Applied Anthropology, Tampa and on file at the Center for Archaeological Research, University of Mississippi, University, 38677.

Thorne, Robert M. and J. Bennett Graham
1987 Archaeological Site Stabilization and Protection in the Tennessee River Valley; A Pilot Program. Paper presented to the Third New World Conference on Rescue Archaeology, Carupano, Venezuela.

U. S. Congress, Office of Technological Assessment
1986 Technologies for Prehistoric and Historic Preservation. OTA-E-319, U. S. Government Printing Office, Washington, D.C.

This summary presents the primary findings of an assessment requested by the House Committee on Interior and Insular Affairs. The subcommittee on public lands is carrying out a major review of how federal agencies implement federal preservation policy. This assessment directly supports the committee's review by showing how the uses of certain methods, techniques, as well as tools and equipment can assist federal, state, and local preservation efforts.

The assessment focuses on the applications of preservation technologies rather than preservation disciplines. The laws, regulations and legislation under consideration in the 99th congress which pertain to prehistoric and historic preservation are listed in table form. Participants in this assessment cited the need to

establish a federally funded institution as a mechanism to coordinate research, disseminate information, and provide training about new technologies for preservation. The preservation process and research technologies are discussed, but solutions to preservation problems and the application of specific technologies to specific preservation problems are not discussed.
ASSESSMENT, LAWS, PRESERVATION, FEDERAL GOVERNMENT

U. S. Government
1976 Professional Considerations Surrounding Non-aqueous Burial of Archaeological Sites. Interagency Archaeological Program Administrative Memorandum No. 4; Supplement No. 1. Interagency Archaeological Services, National Park Service. Washington, D.C.

SECTION 2

TECHNICAL SUPPORT

Allen, Hollis H. and C.V. Klimas
1986 Reservoir Shoreline Revegetation Guidelines, Technical Report E-86-13, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report synthesizes the results of revegetation efforts at three lakeshore study sites. Pertinent revegetation concepts are also reviewed and a set of revegetation guidelines for shorelines having fluctuating water levels are presented. Emphasis was placed on reduced costs, proper planning, procurement of plant materials, appropriate planting times and methods, and special planting techniques.
EROSION, VEGETATION, SHORELINE, STABILIZATION

Allen, Hollis, H., and James W. Webb
1983 Erosion Control With Saltwater Vegetation, in Proceedings of the Third Symposium on Coastal and Ocean Management, American Society of Civil Engineers, June 1-4, 1983, San Diego, Ca. pp. 735-748.

Allen, Hollis, H., J.W. Webb, and S.O. Shirley
1984 Wetlands Development in Moderate Wave-Energy Climates, in Proceedings of the Conference Dredging 1984, Waterway, Port, Coastal and Ocean Divison, American Society of Civil Engineers, November 14-16, 1984, Clearwater Beach, Florida.

Andropogon Associates, Ltd.
1988 Earthworks Landscape Management Action Plan for the Petersburg National Battlefield. National Park Service, Mid-Atlantic Regional Office, Phillidelphia, Pa.

This paper describes the processes involved in attempting to solve the problem of the need to maintain stable cover on earthworks while managing them for interpretive purposes. The two parks involved in the study were Richmond and Petersburg National Battlefields. The National Park Serviced hired a private consulting firm, Andropogon, to research the problem. Incorporated in the solution to the problem is the coordination of the action plan with the

maintenance management system (MMS), a computer-coordinated management program which tracks and predicts actual and recommended maintenance needs, highlights performance standards and references and resources for each major activity. Previously MMS had been used only sparingly to deal with landscape maintenance, and it was felt that the work being spent on MMS should, in effect, institutionalize the guidelines of the earthworks landscape management manual. Landscape management recommendations for several units are given along with planning guideline sheets for various maintenance activities. The resulting earthworks management manual is referenced under Andropogon 1989 in this Bibliography.
STABILIZATION, SOIL BIOENGINEERING, NPS, MANAGEMENT

1989 Earthworks Landscape Management Manual; Section 1. Prepared for the Mid-Atlantic Regional Office, National Park Service, Philidelphia, Pa.

The manual's primary focus is to develop management strategies and interpretive guidelines which resolve current conflicts between the requirements for preservation and the impacts of interpretation and visitor use at the earthwork sites. The manual is intended to serve as a guide for all earthworks in the NPS system and for application to similar environments within the NPS system with limited study. A major observation noted during the review of the sites evaluated for the preparation of the manual was that earthwork sites stabilized by healthy, native plant communities are in the best condition, while some current management practices have contributed directly to the degradation of the resource. The manual is divided into 2 major sections. The first section is a review and evaluation of current management practices and an assessment of present vegetive cover types. Recommendations are made for an overall management program aimed at integrating preservation and interpretation objectives. The second section begins with procedures for evaluating and monitoring a site with respect to the proposed guidelines. Since many of the management techniques focus on native plant communities, the management of which is unfamiliar to many park employees, workshops at various levels of NPS employees were held. Actual hands-on instruction sessions were used as a means of both teaching park employees how to

use the soil bioengineering techniques and to begin restabilization and revegetation on damaged ground surfaces which need immediate attention. Critical to the soil bioengineering techniques is the need to prioritize problem areas to include both short term and long term management practices. See Andropogon 1988 in this Bibliography.
MANAGEMENT STABILIZATION, EVALUATION, SOIL BIOENGINEERING, NPS

Anonymous
1984 "Erosion Control Mesh has Environmental Advantages". Grounds Maintenance p. 50.

This article describes Enkamat, a 3 - dimensional nylon mesh, as a replacement for 4 in. concrete, riprap and asphalt lining in ditches and on embankments giving specific examples of its successful use in Georgia, Virginia, New Jersey and Ohio. Installation of Enkamat at $7.50 per square yard compared to $42.50 per square yard for riprap is given for relative cost.
GEOTEXTILES, STREAMBANK PROTECTION

1985 "Riverbank Stabilization". Grist, U.S. Department of Interior, National Park Service, Summer, Volume 29, No. 3, Washington, D.C.

This article presents a brief description of a shoreline stabilization technique that employs large (10 foot) tires laid along the shoreline. Once in place, the tires were filled with waste rock and survived heavy flood with no ill effects. An address is given for a video-tape that illustrates the entire process.
EROSION, TIRES, ROCK

Bishop, Craig T., Laurie L. Broderick and D. Donald Davidson
1985 Proceedings of the Floating Tire Breakwater Workshop 8-9 November 1984. Technical Report CERC-85-9, U. S. Army Waterways Experiment Station, Vicksburg, MS.

This is a compilation of papers presented at the Floating Tire Breakwater Workshop held in Niagara, N.Y. in 1984. Paper topics include field research, design consideration, breakwater performance and maintenance and mooring and fastening alternatives.
BREAKWATERS, TIRES

Bowie, A.J.
1981 Investigations of Vegetation for Stabilizing Eroding Streambanks, Streambank Stability, Appendix C. Report submitted to the U.S. Army Engineers, Vicksburg District. U.S.D.A. Sedimentation Laboratory, Oxford, MS.

This article describes erosion control studies in northern Mississippi where combinations of vegetation, bank shaping and structural materials are being tested. Survival of grasses and woody species has been generally good, with native species surviving better than introduced species. Tested species are identified.
EROSION, STREAMBANK STABILIZATION, RIPRAP, CELLULAR BLOCKS, VEGETATION

Campbell, F.B.
1966 Hydraulic Design of Rock Riprap. Miscellaneous Paper No. 2-777, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

The report addresses the serious need for valid criteria for the hydraulic design of riprap. The treatment of the design of riprap begins with the simplest problem with the least number of independent variables and progresses through a sequence of problems of increasing complexity. The following problems are considered: uniform tranquil flow with fully developed turbulence in straight channels and channel bends; highly turbulent flow (example: immediately downstream from energy dissipators) involving bottom riprap and bank riprap. In other words "the designer needs to determine the effective size of riprap which will be stable for the velocity acting on the rock."
RIPRAP, DESIGN CRITERIA

Comes, R.D. and Timothy McCreary
1986 Approaches to Revegetate Shorelines at Lake Wallula on the Columbia River, Washington-Oregon. Technical Report E-86-2, U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

This is a report of 3 years of field studies completed for the purpose of identifying plant species and revegetation techniques adaptable to reservoir shorelines in the Portaland and Walla Walla Corps of Engineer Districts. Transplanted vegetation was subjected to various inundation treatments and survival and growth responses were evaluated. Twenty-nine native and naturalized riparian species were tested.

Study results indicate that several species have a potential for use in shoreline revegetation.

REVEGETATION, FLOOD TOLERANT VEGETATION, RESERVOIRS

Department of Soil Science

1966 Dune Stabilization with Vegetation on the Outer Banks of North Carolina, Solid Information Series No.8, North Carolina State University, Raleigh, N.C.

Doerr, T.B. and M.C. Landin

1987 Recommended Species for Vegetative Stabilization of Training Lands in Arid and Semi-Arid Environments. Technical Report N-85/15, U. S. Army Construction Engineering Research Laboratory, Champaign, IL.

Fonseca, M.S., W.J. Kenworthy, K.M. Cheap, C.A. Currin, and W.G. Thayer

1985 A Low-cost Transplanting Technique for Shoalgrass (Halodule wrightii) Manatee Grass (Syringodium filiforme). Instruction Report EL-84-1. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report details the steps that have been devised for a low-cost transplanting technique for two species of seagrasses. Mature vegetative sprouts that are free of sediment are employed. Selection of stock, species growth rate and depth of planting are discussed for the benefit of estimating transplanting projects.

VEGETATION, MARINE ENVIRONMENT, SEAGRASSES

Fonseca, M.S., W.J. Kenworthy, G.W. Thayer, D.Y. Heller, and K.M. Cheap

1985 Transplanting of the Seagrasses Zostera marina and Halodule wrightii for Sediment Stabilization and Habitat Development on the East Coast of the United States. Technical Report EL-85-9. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Study sites where these species of grasses occur were located and growth success criteria were identified for transplanting both species.

Site design characteristics for transplanting are presented as are rates of success predictions. Both species have a primary

function of site stabilization rather than site accretion. Seagrass meadow sediment accretion appears to be balanced by sediment erosion.
VEGETATION, STABILIZATION, MARINE, DESIGN CRITERIA

Garfinkel, Alan and Bobby L. Lister
1983 Effects of High Embankment Construction on Archaeological Materials. Office of Transportation Laboratory, California Department of Transportation.

The authors report on a field study conducted by CALTRANS to determine the effects of placing a 75 foot high embankment over an archaeological deposit constructed to simulate a North American Indian site. Two small test units were excavated and artifacts were placed in three layers. The location of all artifacts was carefully plotted and both units were instrumented with soil pressure meters. Access to the test units beneath the fill for monitoring was through a five foot culvert which terminated with a 72 inch "T" section. Ground water levels beneath the fill were monitored through a well drilled into the "T" section. Soil pressure meters were also placed in an actual site on an adjacent project to provide comparative data.

Examination of the buried materials indicated soil compaction around the artifacts, and gross morphological changes in the test materials were noted.

Guidelines and recommendations for future site burial projects are included.
EXPERIMENTAL BURIAL, ARTIFICIAL SITE, GUIDELINES

Gatto, Lawrence, W.
1984 Effects of River Traffic on Bank Erosion, Present Knowledge and Research Gaps. Paper prepared for the ASCE Hydraulics Division Task Committee on the Effects of River Traffic on Bank Erosion. Informal memorandum for limited distribution. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H.

1988 Techniques for Measuring Reservoir Bank Erosion. Special Report 88-3, Cold Regions Research and Engineering Laboratory, Hanover.

"This report summarizes the processes that cause and conditions that contribute to bank erosion along reservoirs, lakes, rivers and coasts. It suggests measurements, techniques and measurement frequencies for four different levels

of bank erosion study. Details on specific procedures for a particular technique must be obtained from references cited. There are neither standard measurements to make nor standard methods to use during erosion studies, but this report can be useful to investigators selecting an approach for future work."
EROSION, RATES, LAKES, RESERVOIRS, RIVERS

Gilbert, Susan
1986 "America Washing Away". Science Digest, Volume 94, No. 8:31.

This article, written in layman's terms, discusses beach erosion in relationship to the destructive effects of wave action aggravated by rising sea levels and intensive coastal development. Diagrams show how waves move sand to form dunes and how the destruction of beaches and barrier islands occurs because of the construction of groins, seawalls and jetties. Dams constructed on the upper reaches of rivers prevents sand from reaching the beaches making them narrower and less able to absorb the energy of the waves. The best solution for beach protection so far is to pile on new sand. Imported sand erodes more quickly for two reasons. The equilibrium of the beach with the seafloor is destroyed since the beach is steeper and absorbs a heavier blow from each wave. Normal beach sand is almost always more coarse than other sands and does not wash as fast as finer grained sand. The study of beach and dune ecosystems show that salt-tolerant beach grasses indicated the inland movement of the high-water line. Using this information construction is moved away from the beaches to allow beaches to move and change naturally.
BEACH EROSION, WAVE ACTION

Godfrey, K.A., Jr.
1984 "Retaining Walls: Competition or Anarchy?" Civil Engineering Magazine ASCE

This article provides a brief summary of a dozen different construction techniques for the erection of stabilizing walls. Some of the summarized designs are centered around a contractors inability to gain construction access to adjacent properties. Design company and supplies addresses are provided. Modifications of these designs might prove useful in archaeological site stabilization.
BULKHEADS, WALLS

Gonzalez, Tania

1989 Study of Soils Buried under Embankments to Determine the Potential of Burial as a Preservation Technique for Archaeological Sites. Masters Thesis submitted to the Office of Graduate Studies of Texas A & M University, College Station, Texas.

The author reports on a study of natural soils buried under engineered embankments in order to develop the effect of burial on soil properties. Soils in the study group had been buried from 40 to 130 years at depths that ranged between 12 cm and 2.8m.

Factors controlling changes in buried soils are localized and include geology, climate, hydrogeology and gemorphology. Parent material for the buried soil controls the original property of the soil which in turn are responsible for the compressibility and permeability of the buried soil as well as its chemical composition. Most changes in buried soils seem to occur shortly after burial.

The results of the investigation suggest that burial protects the site from micro-and macro-organisms. Other parameters to which buried soils may be subjected are increased ground moisture and changes in pH. Organic matter may be better preserved under more moist conditions.

EARTH BURIAL

Grau, Richard H.

1984 Engineering Criteria for Use of Geotextile Fabrics in Pavement and Railroad Construction. Technical Report GL-84-6. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Available literature on the use of geotextiles as separators between granular and subgrade materials is reviewed. Geotextiles tests using a rolling wheel cart are also reported as is an inspection of Corps criteria for geotextile use. Roadway construction is the primary focus of this review and testing report.

GEOTEXTILES, DESIGN CRITERIA

Gray, Donald H. and Andrew T. Leiser

1982 Biotechnical Slope Protection and Erosion Control. Van Nostrand Reinhold Company, New York, N.Y.

1989 Biotechnical Slope Protection and Erosion Control. Robert E. Krieger Publishing Company, Malalbar, Florida.

Gray, Donald H., Anne MacDonald, and F. Douglas Shields, Jr.
1989 The Effects of Vegetation on the Structural Integrity of Levees. Technical Report REMR-EL---, U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS. (in press)

Grissinger, E. H. and A. J. Bowie
1982 Constraints on Vegetive Stabilization of Stream Banks. Paper presented to the American Society of Agricultural Engineers, June 27-30, University of Wisconsin - Madison.

Hafenrichter, A.L., John L. Schwendiman, Harold L. Harris, Robert S. McLauchlan and Harold W. Miller
1968 Grasses and Legumes for Soil Conservation in the Pacific Northwest and Great Basin States. Agricultural Handbook 339, Soil Conservation Service U.S.D.A., Washington, D.C. (updated 1979)

This Handbook was revised in 1979 and is no longer listed as a Handbook. This volume identifies grasses and legumes that are suitable for erosion control, breaking them up according to the projected life of the grass/legume. Each species is discussed and line drawings as well as Agricultural Zone maps are included. Planting directions are a part of each species description and an Appendix lists recommended planting rates. EROSION, VEGETATION

Hamel, G. and K. Jones
1982 Vegetation Management on Archaeological Sites. New Zealand Historic Places Trust, Willington, N.Z.

Heede, Burchard H.
1980 Stream Dynamics: An Overview for Land Managers. U.S.D.A. Forest Service, General Technical Report RM-72, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Co.

Concepts of stream dynamics are presented through a discussion of processes and process indicators. Theory of stream dynamics is minimized except where necessary to explain concepts. A basis for predicting how management actions will affect stream and environmental behavior is presented. This report will help the

inexperienced manager to understand stream mechanics.
STREAM DYNAMICS

Henderson, J. E., and Shields, F. D., Jr.
1984 Environmental Features for Streambank Protection Projects, Technical Report E-84-11, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report provides guidance for incorporating environmental considerations into streambank protection projects. The stability of the streambanks of a channel is related to both site-specific and basin wide stream reach factors. Streambank erosion or failure is a natural fluvial process that is often accelerated by changes in geotechnical or hydraulic factors and especially the activities of man, e.g., reservoir construction or land use changes. Streambank protection projects stabilize the streambank, preventing or stopping erosion. Stabilization results in a range of environmental changes.

An information review was performed to identify environmental features for streambank protection projects. Environmental features are those planning, design, construction, and maintenance procedures or practices that minimize adverse environmental impacts or enhance terrestrial and aquatic habitats and the aesthetic quality of land and water associated with streambank protection projects. Such features include structural and nonstructural designs; construction procedure that are environmentally compatible; maintenance procedures; and institutional, planning and management approaches for streambank protection projects.

Each feature is discussed in terms of concept, the purpose or appropriate use of the feature, environmental considerations, limitations to use of the feature, performance history and cost.
STREAMBANK PROTECTION, VEGETATION, BANK STABILIZATION STRUCTURES.

Hoffman, George R., Stephen G. Shetron, Charles V. Klimas, and Hollis H. Allen
1986 Lakeshore Revegetation Studies at Lake Oahe, South Dakota. Technical Report E-86-3, U.S. Army

Engineers Waterways Experiment Station, Vicksburg, MS.

Jones, C.W.
1970 Effect of a Polymer on the Properties of Soil Cement, Bureau of Reclamation Report No. RFC-OCF-20-18, Denver, Colo.

Keown, Malcolm P.
1983 Streambank Protection Guidelines. U. S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This publication is written in layman terms and is intended to provide general information to the public on the subject of streambank stabilization. The nature of streams and reasons for streambank erosion and failure are discussed. A variety of standard streambank stabilization techniques are presented for consideration.
EROSION, STABILIZATION, STREAMBANKS

Keown, Malcolm P. and Elba A. Dardeau, Jr.
1980 Utilization of Filter Fabric for Streambank Protection Applications. Technical Report HL-80-12. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report presents a state-of-the art literature survey of filter fabric use. Corps of Engineers offices as well as filter cloth manufacturers were queried for both published and unpublished histories of filter fabric use for streambank stabilization. Indications are that if properly selected, filter fabric can serve as a replacement for natural filters. Other possible uses are described. A bibliography is included.
FILTER FABRIC, BIBLIOGRAPHY

Keown, M.P., N.R. Oswalt, B.B. Perry, and B.A. Dardeau Jr.
1977 Literature Survey and Preliminary Evaluation of Streambank Protection Methods. Technical Report H-77-9. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This literature survey emphasizes known streambank protection methods. Mechanisms contributing to streambank erosion are identified and the effectiveness of various methods are evaluated. Appendix B lists commercial concerns that market streambank protection products. A selected bibliography is included.
EROSION, STABILIZATION METHODS, BIBLIOGRAPHY

Kinter, E.B.
1975 Development and Evaluation of Chemical Soil Stabilizers, Federal Highway Administration Report No. FHWA-RD-75-17, Washington, D.C.

A study of chemical stabilization of soils began in 1954 with a program enlisting the aid of chemical industry in the search for effective chemicals. Nineteen firms signed a letter of agreement, and others cooperated on an informal basis. Federal participation consisted mainly of consultation, instruction, development of suitable laboratory evaluation test procedures, and review of test results furnished by cooperators. A number of chemcials, notably phosphoric acid, PDC, Terbec, lignins and quaternary amines, were proposed and evaluated in laboratory and field tests. Many others were given limited examination and laboratory testing.
At about 1965, industry's interest shifted largely toward chemicals affecting compaction and moisture-density relationships of soils. Several proprietary compaction aids were evaluated by laboratory tests and one was the subject of field testing. A report on laboratory evaluation of two compaction aids has been prepared.
No single chemical or combination of chemicals has been found acceptably effective or economical as a major soil stabilizer. However, further work with phosphoric acid and phosphates may make use of some of these substances possible. Prospects are promising for Chemicals to improve moisture-density relationships and to supplement or enhance the effects of the major stabilizers, lime and portland cement.
CHEMICAL STABILIZERS, SOILS

Klimas, Charles V. And Hollis H. Allen
1981 Approaches to Revegetate Reservoir Shoreline of Lake Texoma. U.S. Army Engineer Waterways Experiment Station Information Exchange Bulletin, Vol. E-81-2, Vicksburg, MS.

This brochure describes an experimental shoreline revegetation program. A list of plants tested for flood tolerance is included as are the preliminary results of two years of testing.
EROSION, SEDIMENTATION, VEGETATION

Knutson, Paul L.

1977a Planting Guidelines for Marsh Development and Bank Stabilization. Coastal Engineering Technical Aid No. 77-3. Coastal Engineering Research Center, Fort Belvoir, Va.

This Technical Aid discusses the techniques which may be applied in the regeneration of a marsh enviornment. Site characteristics are discussed as are plant selection, methods of revegetation, the determination of fertilizer requirements and estimations of revegetation cost are presented.
Three Appendices detail techniques for obtaining plants, planting methods and maintenance of the revegetated areas.
MARSH DEVELOPMENT, PLANTING TECHNIQUES, COLLECTION TECHNIQUES

1977b Planting Guidelines for Dune Creation and Stabilization. Coastal Engineering Technical Aid 77-4, Coastal Engineering Research Center, Fort Belvoir, Va.

Beach grasses have been used to stabilize dune systems. Techniques are available to propagate beach grasses. Guidelines, for selecting plants and planting methods, obtaining plants, storing, planting and maintaining plants and estimating labor requirements for dune vegetation projects.
VEGETATION, DUNES, STABILIZATION, COLLECTION TECHNIQUES, PLANTING TECHNIQUES

Lawson, Daniel E.

1985 Erosion of Northern Reservoir Shores, An Analysis and Application of Pertinent Literature. Monograph 85-1. U.S. Army Cold Regions Research and Engineering Laboratory, Hanover, N.H.

"This monograph describes the current state of knowledge of northern reservoir shore erosion, primarily by examining the results of erosional studies on lakes, coasts and rivers. The major erosional processes of reservoir beaches and bluffs and their mechanics are discussed in detail. Thermal and physical parameters affecting the erodibility of shores, the

environmental impacts of erosion, and the basic characteristics of the unique reservoir environment are reviewed. Current models of shore zone development are also presented. This literature analysis revealed that knowledge of erosion and recession in northern impoundments is severely limited. Quantitative analysis of the processes of erosion and their relative importance, parameters determining the nature, rate and timing of erosion, and models to predict the erodibility of a shore for use in minimizing shoreline recession remain in need of basic field research."
EROSION, RESERVOIRS, SHORES, WAVES, COLD REGIONS

Logan, Leon D., et al.
1979 Guidelines for Streambank Erosion Control Along the Banks of the Missouri River from Garrison Dam Downstream to Bismark, North Dakota. USACE Omaha District, U.S. Forest Service, Northern Region, and North Dakota State Forest Service, Missoula, Mt.

Markle, Dennis G. and Mary A. Cialone
1987 Wave Transmission Characteristics of Various Floating and Shallow-Fixed Rubber Tire Breakwaters in Shallow Water. Miscellaneous Paper CERC-87-8, U. S. Army Waterways Experiment Station, Vicksburg, MS.

A two-dimensional, 1:4 scale model of a rubber-tire breakwater was tested. Floating and bottom-fixed models were tested. Incident wave height, wave period, water depth, wave steepness, relative wave height, and relative depth are presented in graphic and tabular form. The concepts are ranked from best to worst relative to wave protection that they appear to provide in shallow water.
BREAKWATERS, TIRES

Mathewson, Christopher C.
1988 Protection and Preservation of Archaeological Sites Through Burial: a Multidisciplinary Problem. Paper presented at the 1988 Society for Applied Anthropology meeting. Paper on file at the Center for Engineering Geosciences, Texas A & M University, College Station, Texas 77843-3115.

1989 Interdisciplinary Workshop on the Physical-Chemical-Biological Processes Affecting Archaeological Sites. Environmental Impact Research Program Contract Report EL-89-1.

U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report, divided into 15 parts and one appendix, is a compilation of paper presented at an interdisciplinary workshop held at Texas A & M in 1987. The purpose of the workshop was to develop an archaeological site decay model, using the physical, chemical and biological processes that affect archaeological deposits. Each of the first 14 chapters addresses a different subject while the last chapter presents the decay model. Inspection of the model, as it is visually portrayed will aid in designing archaeological site stabilization projects.
SITE DECAY, MODELING

Maynord, Stephen T.
1984 Riprap Protection on Navigable Waterways. Technical Report HL-84-3. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS

Three physical models of the use of riprap protection in navigable waterways are investigated. All three locals are in areas of heavy (towboat), high horsepower propellor wash areas. The determination of appropriate riprap size is the primary focus of two of the studies.
RIPRAP, DESIGN CRITERIA

Metzger, Todd R.
1989 Current Issues in Ruins Stabilization in The Southwestern United States, Southwestern Lore, Official Publication, The Colorado Archaeological Society, Vol. 55, No. 3.

This article describes ruins stabilization in the southwest as purely technical in approach using contemporary construction methods that have served to replace the original architecture rather than to preserve it. As a result, most stabilization has been conducted as pure construction projects that have held little regard for the preservation of the features, components and artifactual materials that make an archaeological resource important. In addition there are no suitable standards or guidelines to bring the preservation of the structural fabric of a ruin and the remainder of the archaeological resource of that ruin together in the same preservation effort. Sites thus stabilized retain very little scientific information and their value as interpretive tools and archaeological sites is greatly reduced. Some

problems which contribute to the current negative perception of stabilization are discussed. They include use of incongruous materials and techniques, lack of appropriate documentation, lack of guidance and training, lack of support from professional organizations and conflicting perspectives of the historical preservation community, archaeologists and archaeological resource managers.
STABILIZATION, RUINS

Mills, A.P., H.W. Hayward and L.F. Rader
1955 Materials of Construction. John Wiley Publishing Co. pp. 406.

Morrison, W. R.
1971 Chemcical Stabilization of Soils and Laboratory And Field Evaluation of Several Petrochemical Liquids For Soil Stabilization, Bureau of Reclamation Engineering and Research Center. Report No. REC-ERC-71-30, Denver Colorado.

Laboratory and field evaluations of several petrochemical, liquid soil stabilizers were conducted. Laboratory tests indicated that a sprayable liquid vinyl polymer has excellent properties for stabilizing sandy soil. Initial observations showed that a deep penetrating liquid cutback asphalt was performing satisfactorily in stabilizing dune sand around transmission tower sites along Fort Thompson-Grand Island 345-Kv Transmission Line. A water base acrylic copolymer is providing satisfactory eroson control on test sections of spoil banks at the Tehama-Colusa and Putah South Canals in California. However, the high cost would limit the use of the material to minimum wind and water erosion control. None of 5 protective coating applied to shale seams at Paonia Dam, Colorado, were effective in reducing air-slaking.
CHEMICAL STABILIZERS, SOILS

Morrison, W. R. and L. R. Simmons
1977 Chemical and Vegetative Stabilization of Soils. U. S. Department of the Interior, Bureau of Reclamation, Report No. REC-ERC-76-13, Denver, Co.

This report contains the results of a study on various chemical and vegetative methods of soil stabilization. The three main items of work accomplished under the study are: (1) laboratory studies of 30 liquid soil stabilizers to establish performance requirements; (2)

discussion of where various chemical and vegetative methods have been used in the field; and (3) includes a survey of chemical stabilization of soils and revegetation methods and materials for erosion control. Results of this study indicate the potential effectiveness of chemical and vegetative stabilization.
EROSION, CHEMICAL SEALANTS, VEGETATION, SLOPE PROTECTION, REVEGETATION

Murphy, Thomas E. and John L. Grace, Jr.
1963 Riprap Requirements for Overflow Embankments. Miscellaneous Paper No. 2-552, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report determines riprap requirements for two typical overflow embankments using a series of 1:4 scale model tests. Typically overflow embankments are over topped yearly, consequently riprap was chosen to minimize repair and maintenance costs following each overflow
RIPRAP, EMBANKMENTS, DESIGN CRITERIA

Newcombe, Curtis L.
1978 The Role of Marsh Plants in Shoreline Stabilization, in Proceedings of the International Erosion Control Association Conference IX, pp. 12-14, Irvine, CA.

Newcombe, Curtis L., et al.
1979 Bank Erosion Control With Vegetation, San Francisco Bay, California. Report MR-79-2, U.S. Army Engineer Coastal Engineering Research Center, Fort Belvoir, Va.

Rushmore, Forest Paul, III
1988 Quantifying Breakage parameters of Fragile Archaeological Components to Determine the Feasibility of Site Burial. Masters Thesis submitted to the Office of Graduate of Texas A & M University, College Station, Texas.

The author indicates that site burial is an option for resource protection and indicates that ceramic vessels and osteological remains that have been excavated from various mounds serve as evidence of the viability of the burial technique. He further indicates that ceramic preservation in mounds in contingent on the physical, chemical and biological environment at any give site. Differential setting of mound fill is frequently responsible for the mechanical breakage of ceramics and bone.

Laboratory testing is reported and vessels with an average wall thickness of 6mm buried no deeper than 25 cm would fracture under a surface load of 30 psi. Strain rather than stress forces seem to be the controlling factor. The author indicates that..."site burial - is feasible if the amount of differential settlement is less than the displacement necessary to cause failure of the artifact".
EARTH BURIAL

Schiechtl, Hugo
1980 Bioengineering For Land Reclamation and Conservation. The University of Alberta Press, Edmonton, Alberta, Canada.

This book illustrates how the products of scientific and technical research can be integrated with natural materials to realize effective and economic means of stabilizing, protecting and actually improving the condition of our environment. It is a specific aid in improving co-operation between the civil engineer and bioengineer.

The author begins with a description of the technical preparation, usually done by civil engineers, and shows in succeeding chapters how bioengineering is integrated into these various protection methods to further enhance and protect earthworks and waterways. The criteria for the selection of various plant materials used in bioengineering are fully discussed, as is how, why and where they should be used. A section on the cost of bioengineering is included. The appendices contain a listing of suitable plants, commercially available, for a wide range of environments.
STABILIZATION, NATURAL MATERIALS, PLANTS, STABILIZATION STRUCTURES

Shelford, Victor E.
1974 The Ecology of North America. University of Illinois Press, Urbana.

Sotir, Robin and Donald H. Gray
1989 Soil Bioengineering Methods for Upland Slopes Erosion Protection. Soil Conservation Service Field Manual, Chapter 18, U.S.A./SCS, Washington, D.C.

Thornburg, A.
1982 Plant Materials for Use on Surface Mined Lands in Arid and Semiarid Regions. USDA Soil Conservation Service, Washington, D.C.

Thorne, Robert M.

1988a Filter Fabric: A Technique for Short-term Site Stabilization. Archaeological Assistance Program, Technial Brief No. 1, U. S. Department of the Interior, National Park Service, Washington, D.C.

This report briefly discusses what filter fabrics are and their usual applications. The advantages and disadvantages of filter fabric are discussed. A specific example of the application of filter fabric to an archaeological site is given, and the details of the processes involved in choosing the specific stabilization technology which was applied to the site are fully discussed. The actual installation of the filter fabric is described in detail. Installation monitoring is explained. A video tape (VHS) of the installation process is available on a loan basis.
STABILIZATION, LACUSTRINE EROSION, GEOTEXTILES, VIDEO TAPE

1988b Guidelines for the Organization of Archaeolgical Site Stabilization Projects: A Modeled Approach. Technical Report EL-88-8, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This set of guidelines is designed to identify means for evaluating archaeological site preservation technical options and to set up a procedure for selecting the proper options to be employed in specific situations.

In the absence of any prior guidelines, these guidelines are based on interviews with Federal and State archaeologists with direct personal experience on specific site preservation siutations. The guidelines were tested at a prehistoric mound site on Huffine Island, Tennesse, and those efforts are presented as a case study in site preservation.
STABILIZATION, MODEL, GUIDELINES, TEST CASE, FILTER FABRIC

1989 Intentional Site Burial: A Technique to Protect Against Natural or Mechanical Loss. Archaeological Assistance Program, Technical Brief No. 5, Department of the Interior, National Park Service, Washington, D.C.

This is the second technical brief in the series on site stabilization and maintenance.

The object of this report is to provide guidance on the design of an effective project for intentional site burial. It identifies the processes which must be addressed by an archaeological program manager considering intentional site burial. These processes include evaluation of the components of the site in terms of Mathewson's Matrix, which considers how a sites's artifact and ecofact components have and will react to their physical and chemical environments through time. The measurement of potential impacts, including decay processes, against the goals for protecting the site is covered, as is assessing the benefits of intentional site burial. Specifying the methods and procedures to be used in the project include a discussion of the actual mechanics of burying a site, the process of establishing a monitoring program and the triggering mechanism for the program and how to price out site burial.
STABILIZATION, SITE BURIAL, TECHNOLOGY

Thorne, Robert M., Fay, P. M. and Hester, James J.
1987 Archaeological Site Preservation Techniques: A Preliminary Review. Technical Report EL-87-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report indicates that the combination of civil engineering techniques with a knowledge of the characteristics of archaeological site in an effort to stabilize and preserve a resource is an emerging approach to resource management. Research on site preservation technology is based on questionnaires sent to over 400 archaeologists, principally in the federal service. Results of the survey indicated little first-hand experience, few published cases of preservation action, and little past installation evaluation.

Site impacts were divided into naturally and culturally stimulated. Techniques that are available to counter these effects are divided into manmade or natural and further subdivided into vertical and horizontal and each is discussed.
STABILIZATION

U.S. Army Engineer Waterways Experiment Station
1942 Investigation of the Unconfined Compressive Strength of Soil-Cement Mixtures, Technical Memorandum No. 187-1, Vicksburg, MS.

U.S. Army Coastal Engineering Research Center
1981 Low Cost Shore Protection: A Property Owner's Guide, Washington, D.C.

1984 Shore Protection Manual, Volumes I and II. U.S. Army Eengineers Waterways Experiment Station, Vicksburg.

This manual, divided into two volumes (Chapters 1-5 and Chapters 6-8 with Appendices A-D), has become the standard reference for the engineering design of shoreline erosion protection projects since its initial publication in 1973. It addresses both the natural and man-induced changes in the coastal zone, the structural and non-structural protection against these changes, and the desirable and adverse impacts of possible solutions to problem areas on the coast. Since no two coastal problems are alike, the approach taken by the manual is to thoroughly study and clearly define each problem. The solutions are then evaluated in terms of physical and environmental effects, advantageous and detrimental, and compares these with cost, maintenance and benefits to arrive at the solution.

"The shore protection manual provides sufficient introductory material and engineering methodology to allow a person with an engineering background to obtain an understanding of coastal phenomena and to solve related engineering problems. The manual includes detailed summaries of applicable methods, techniques and useful data pertinent to the solution of coastal engineering problems."

COASTAL EROSION, STABILIZATION, DESIGN CRITERIA

U.S. Army Corps of Engineers
1987 Historic Preservation Program. Engineering Regulation 1130-2-438, Department of the Army, U.S. Army Corps of Engineers, Washington, D.C.

U.S. Army Engineer Waterways Experiment Station
1986 Field Guide for Low Maintenance Vegetation Establishment and Management. Instruction Report R-86-2, U.S. Army Engineers Waterways Experiment Station, Vicksburg, MS.

1988 The Archaeological Sites Protection and Preservation Notebook. Environmental Impact Research Program, Environmental Laboratory, Vicksburg, MS.

This notebook has been prepared in looseleaf form and contains a series of technical notes that are synopses of articles and publications that deal with archaeological site preservation and protection. Eleven subject areas are included and cover: 1. Impacts; 2. Site Burial; 3. Structural Stabilization; 4. Soil and Rock Stabilization; 5. Vegetative Stabilization; 6. Camouflage and Diversionary Tactics; 7. Site Stabilization; 8. Stabilization of Existing Structures; 9. Faunal and Floral Control; 10. Signs; 11. Inundation. As additional notes are printed they can be added to the notebook. TECHNICAL NOTES

U.S. Department of Agriculture
1976 Plant Materials Study: A Search for Drought-Tolerant Plant Materials for Erosion Control, Revegetation, and Landscaping Along California Highways. Soil Conservation Service Research Project USDA/SCS LPMC-1, Davis, CA.

U.S. Department of the Interior
1982 Laboratory and Field Studies in Soil Stabilizers, Volume IV. U.S./U.S.S.R. Joint Studies on Plastic Films and Soil Stabilizers, U.S. Department of the Interior, Bureau of Reclamation, Denver Federal Center, Denver, Co.

Vogel, Willis G.
1981 A Guide for Revegetating Coal Mine Soils. General Technical Report NE-68 U.S. Forest Service, Northeastern Forest Experiment Station, Berea, Kentucky.

This report provides information, recommendations, and guidelines for revegetating land in the eastern United States that has been disturbed by coal mining regions in the east, and a discussion of minesoil properties and procedures for sampling, testing, and amending minesoils. Plant species that have been used for revegetating surface - mined lands are identified and described. Selection criteria for plant species and methods and requirements for seeding and planting are explained. Some of the data on tree species used in reforestation were obtained from recent surveys of 30-year-old experimental planting in several eastern states. Included are maps showing the eastern coal regions or portions of them where a plant species has been used successfully, or its use is recommended. STABILIZATION, GRASS, TREES, SHRUB MAPS, SOIL TESTING, CLIMATE DATA

Ware, John A.
1989 Archaeological Inundation Studies: Manual For Reservoir Managers. Contract Report EL-89-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

"Development and operation of freshwater reservoirs create a variety of potential impacts on archaeological resources. These impacts accrue from several sources, including mechanical, biochemical, and human and other processes associated with the reservoir environment. This report summarizes the findings of the National Reservoir Inundation Study, a multi-agency project designed to assess the range of effects of inundation on archaeological resources. Potential effects are discussed within three discrete zones of differential impact: (a) the conservation pool, (b) the fluctuation zone, and (c) the backshore zone."
ARCHAEOLOGICAL SITES, INUNDATION IMPACTS, RESERVOIR PROCESSES

Warnock, Robert A., Lila Fendrick, Barbara E. Hightower and Terry Denise Tatum
1983 Vegetative Threats to Historic Sites and Structures. U.S. Department of the Interior, National Park Service, Park Historic Architecture Division, Washington, D.C.

Westmacott, Richard
1985 "Box and Mattress Gabions". Landscape Architecture, Volume 75, No. 3, May/June.

This article briefly describes several gabion shapes, the material of construction and the characteristic methods of using them. Advantages and disadvantages of gabions are presented as are suggestions about how these stabilization techniques can be employed. Cost estimates for gabion use are also included.
STABILIZATION, GABIONS

White, Dewey W., Jr.
1981 Evaluation of Membrane-Type Materials for Streambank Erosion Protection. Miscellaneous Paper GL-81-4. U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

"The objective of this study was to investigate new materials and construction techniques for streambank protection by preventing erosion of the banks. The specific materials used were: T15, Laminated vinyl-coated nylon; T16, Neoprene-coated nylon; Hypalon, Synthetic rubber-coated 5x5 and 10x10 Polyester scrim membranes; and Bidim C-34 and C-38, Spunbonded, continuous polyester filament filter fabrics." Laboratory tests were conducted to determine the physical characteristics of the materials. The membrane materials were installed in two different locations by three different construction techniques. Riprap placed over the filter fabrics were used as the standard for comparing the performance of all test materials.

The test results indicated that all membrane materials used performed satisfactorily in protecting streambanks and riverbanks from erosion during normal streamflows as long as the banks remain stable.
STABILIZATION, FILTER FABRICS, RIPRAP, MEMBRANE ENCAPSULATED SOIL LAYER (MESL)

Whitlow, Thomas H. and Richard W. Harris
1979 Flood Tolerance in Plants: A State-of-the-Art Review. Technical Report E-79-2, U. S. Army Waterways Experiment Station, Vicksburg, MS.

Both basic aspects of flood tolerance and applied aspects of establishing vegetation are discussed. Tables by common name and scientific name are included. This information would be useful in planning shoreline stabilization/revegetation efforts. Out of Print - Available from NTIS. FLOOD TOLERANCE, PLANTS, RESERVOIRS, VEGETATION

Young, W. C.
1973 Plants for Shoreline Erosion Control in Southern Areas of the United States, modified by W.C. Ackerman, G.F. White, E.B. Worthington in Man-Made Lakes: Their Problems and Environmental Effects. Geophysical Monograph Series No. 17. American Geophysical Union.

This paper discusses various species of plants that have been tested for their adequacy in stabilizing eroding shorelines. Maiden cane is specifically identified as a good choice for across the water line protection.
EROSION, MAIDEN CANE, VEGETATION

SECTION 3

MANAGEMENT RECOMMENDATIONS

Advisory Council on Historic Preservation

1980 Treatment of Archaeological Properties, A Handbook. GPO-875-937, Washington, D.C.

1982 Manual of Mitigation Measures (MOMM). Advisory Council on Historic Preservation, Washington, D.C.

1984 Memorandum of Agreement between the Advisory Council on Historic Preservation and the Federal Highway Administration, Jefferson City, Missouri. Final Document transmitted on April 18, 1984.

While the original Memorandum of Agreement did not call for site burial, an amendment submitted to the Advisory Council recommended that portions of site 23LN104 be buried rather than excavated. One-half of the total number of features identified would be left at least 50% in situ. Selected features were to be left completely intact. Missouri Highway and Transportation Department design specifications were modified to accommodate the burial of the site under four inches of sand and the subsequently placed road fill. Three research questions regarding site burial are incorporated into the Memorandum of Agreement.
SITE BURIAL

Barnes, Mark R.

1983 Archaeological Site Preservation Through Interagency Cooperation: A Model From the San Juan Basin. American Archaeology, Vol. 3, No. 3.

This article reports on the formation of an interagency Archaeological committee whose goals are to insure timely and research oriented compliance and to create preservation options based on state-of-the-art research. Elements necessary for the identification and evaluation of resources have been developed. Primary emphasis of the program is interagency cooperation in the face of unprecedented growth.
PRESERVATION PLAN, INTERAGENCY COOPERATION

Carlson, David L. and Frederick L. Briuer
1986 Analysis of Military Training Impacts on Protected Archaeological Sites at West Fort Hood, Texas. Archaeological Resource Management Series, Report Number 9, U.S. Army Fort Hood. (see this same entry under the practical applications section)

Carrell, Toni, Sandra Rayl and Daniel Lenihan
1976 The Effects of Freshwater Inundation of Archaeological Sites Through Reservoir Construction: a Literature Search. U.S. Department of Interior, National Park Service, Cultural Resources Management Division, Washington, D.C.

Garrett, Susan E.
1983 Coastal Erosion and Archaeological Resources on National Wildlife Refuges in the Southeast. Archaeological Services Branch, National Park Service, Southeastern Region, Atlanta, Georgia.

This report provides a synthesis of erosional impacts to coastal wildlife refuges and is designed to serve as the basis for the development of a management and preservation plan. Potentially useful control measures are discussed including both structural and non-structural techniques from the perspective of applicability and cost-effectiveness in comparison to data recovery.
COASTAL EROSION, STABILIZATION, COST-EFFECTIVENESS

Phillips, John C.
1986 Archaeological Data Recovery From 22LA545, Lafayette County, Mississippi. Report submitted to U.S. Army Corps of Engineers, Vicksburg, MS.

Sisson, David A.
1983 "Lower Salmon River Cultural Resources Management Plan," U.S. Department of the Interior, Bureau of Land Management, Cottonwood Resource Area, Idaho.

Recommended measures for use in the protection of cultural resources along the Lower Salmon are divided into two categories: physical measures and administrative measures. The former category includes the use of structural stabilization, vegetation, buried obstructions, electronic surveillance, barriers, patrolling, signing and monitoring among others. A brief

discussion of each of these potentially useful approaches is included.
STRUCTURES, VEGETATION, BURIED OBSTRUCTIONS, ELECTRONICS, BARRIERS SIGNS

Smith, Gerald P.
1982 The Rock Creek Archaeological Project: Natchez Trace Parkway, Colbert County, Alabama. Report submitted to Southeast Archaeological Center, National Park Service, Tallahassee, Fla.

Chapter Five of this report includes recommendations for the protection of sites 1CT44 and 1CT45. Only the latter is of interest here and Smith recommended grassing the site over and if agriculture is to be allowed, he recommends the use of hay crops only. He makes passing mention of burial of the site but discourages the possibility. (Ed. Note: This site was ultimately buried under 12 inches of topsoil over an intervening and compacted 3-4 inch level of clay-gravel. See Larson (Practical Applications) in this bibliography).
STABILIZATION, GRASS

U.S. Army Corps of Engineers
1982 Walth Bay Archaeological Site Bank Stabilization; Missouri River, Oahe Dam - Lake Oahe, South Dakota and North Dakota, Design Memorandum No. MO-217, Omaha, Nebr.

This document is a draft copy of the Design Memorandum for protection of the Walth Bay site and is not in final form. The document contains a brief description of the site as well as a discussion of the mechanisms leading to the ultimate loss of the resource: vandalism, recreational development, and erosion. Four alternatives for protection of the site are considered and include: (1) doing nothing and three design plans for the use of stone facing (riprap). The document also includes copies of correspondence from the various agencies who must ether approve or permit the use of riprap to protect the site. Cost estimates and specifications are included.
VANDALISM, RECREATION, EROSION, RIPRAP

U.S. Army Engineer District, Omaha
1981 Crow Creek Archaeological Site, Lower Bank Slope Protection, Missouri River, Fort Randall Dam - Lake Frances Case, South Dakota, Design Memorandum No. MR-130 (revised April 1981), Omaha, Nebr.

Erosion of the Crow Creek site is defined as the cause of the resource loss. Excavation is considered as are five alternatives for upper bank protection and four alternatives for lower bank protection. The set of five alternatives include: a training dike, a gabion wall, sheet piling, tiebacks, a fence wire basket. Alternatives for lower slope protection include: slope flattening, longards, excavation, and riprap. Discussions of the advantages and disadvantages of each approach are included. The document also incorporates copies of correspondence from the various agencies who must either approve or permit the use of riprap to protect the site.

EROSION, TRAINING, DIKE, SHEET PILING, TIEBACKS, FENCE WIRE BASKET, LONGARDS, RIPRAP

SECTION 4

PRACTICAL APPLICATIONS

Anderson, W.J., Jr.

1982 Letter correspondence to Groton, Conn. housing officer regarding alterations to size of area at Baldwin Ridge Archaeological Site Preservation and retaining of certain trees.
(see Soulsby this section)
HOUSING DEVELOPMENT, SITE BURIAL, SAND, TOPSOIL

Anonymous

1901 Sixteenth Annual Report. Ohio Archaeological and Historical Publications, Vol. 9. (Indicates tax status).

Barnes, Mark

1979 Examples of Site Protection Across the Nation, in Vandalism of Cultural Resources: The Growing Threat to Our Nation's Heritage, compiled by Dee F. Green and Steven LeBlanc. Cultural Resources Report No. 28, USDA Forest Service, Southwestern Region, Albuquerque, N.M.

Barnes points out that while site preservation was once synonymous with visitor center development, the concept now extends to in situ protection, excavation, as well as the use of a site for public interpretation. He further indicates that site preservation now derives as a result of an appropriate decision making process. He cites as examples coastal sites in Maine, Cahokia Mounds, Bear Butte in South Dakota, Mimbres Valley sites in New Mexico as well as sites in Puerto Rico, California and Texas. The role of the Nature Conservancy and the Galivan Foundations are also discussed.

Brookes, Samuel O.

1976 The Grand Gulf Mound; Salvage Excavation of an Early Marksville Burial Mound in Claiborne County, Mississippi. Archaeological Report No. 1, Mississippi Department of Archives and History, Jackson, MS.
FENCING

Brown, Margaret Kimball
1983 Mothballing Albany Mounds. American Archaeology, Vol. 3, No. 3.

The Albany Mound site, consisting of some 40-50 mounds and three village areas, is owned by the Illinois Department of Conservation. Preservation of the site, with a very limited budget was a multidisciplinary effort. Invasion species were removed from the site and prairie grasses and brush and trees that would have been a part of the original prairie community were left to grow to maturity. Management of the prairie environment will be through controlled burns and the expense of maintenance will be minimized.
VEGETATION

Calabrese, Francis A.
1986 Personal Communication Concerning Bank Stabilization Project, Knife River Indian Villages National Historic Site. Memoranda and Correspondence on file at Midwest Archaeological Center, National Park Service, Lincoln, Nebraska.

The National Park Service and U.S. Army Corps of Engineers cooperated in an effort to stabilize a portion of the riverbank fronting on the Knife River Indian Village National Historic Site. The construction consisted of approximately 1,680 linear feet of revetment type bank protection and is an example of long term preservation of archaeological resources. Acquisition of certain plots of land was also necessary before installation of the protective measures could be undertaken. The actual structure includes an earth-fill berm, protected on the riverward side with a stone-fill toe and riprap blanket placed upon the upper bank. The visible surface voids of the riprap and toe were filled with gravel. The entire crown and riverward slope were then covered with a layer of top soil and vegetation, including native grasses and shrubs. Photographs taken after the completion of the project show that efforts to preserve the natural appearance of the terrain by varying the structure crown widths and elevations were quite successful.
RIPRAP, REVEGETATION

Carlson, David L. and Frederick L. Briuer
1986 Analysis of Military Training Impacts on Protected Archaeological Sites at West Fort Hood, Texas. U.S. Army Fort Hood Archaeological Resource Management Series, Research Report Number 9, Fort Hood, Texas.

This report presents a statistical analysis of data gathered during site monitoring in a program of site protection designed to decrease the impact of military maneuver training on archaeological sites. Site protection measures were designed on a case-by-case basis for each site. Sites were monitored over an eighteen month period. Protection measures were successful, but better methods of measuring on-going impact are needed.

One very significant conclusion is that "site protection measures are more cost effective than data recovery in those instances where the flow of military training can be successfully directed around archaeological sites."
STRUCTURES, SITE BURIAL, SIGNS, WIRE, MONITORING FORMS

Chace, Paul G.
1981 "Perspectives on Archaeological Site Capping". Contract Abstracts and CRM Archaeology (Now American Archaeology). Volume 3, No. 1, Atechison, Inc., Albuquerque.

This article presents a cogent argument for capping archaeological sites as a means of stabilization. Chace discusses four considerations in the decision making process for selecting capping as a preferred alternative. A limited bibliography dealing with site capping is included and planning requirements are discussed.
SITE BURIAL, PLANNING GUIDELINES

Chapman, Lloyd N.
1982 Letter correspondence from National Park Service to U.S. Navy regarding Baldwin Ridge Archaeological Site, Groton, Conn.
(see Soulsby this section)
HOUSING DEVELOPMENT, SITE BURIAL, SAND, TOPSOIL

Dallas, Herb
1988a Site Midden Stabilization/Protection, Andrew Molera State Park. Statewide Resource Management Project Status Report, California Department of Parks and Recreation, Monterey, CA.

This report describes the efforts to stabilize and revegetate an 800 square meter blowout in a sand dune environment caused by eolian erosion. Extended use by park visitors (foot traffic) caused a loss of protective vegetation on a portion of archaeological site CA-MNT-73 in the Andrew Molera State Park.

A wooden causeway was built across the blowout area to redirect and contain foot traffic. Trail barriers and signs were built from railroad ties at appropriate spots to control erosion. Railroad ties were also used to control erosion on unstable segments of the park trail which traversed the site. Snow fence was placed on either side of the wooden causeway to catch sand and reduce wind velocity. Native plants are currently being cultivated and will eventually be used to replant portions of the blowout area. Total cost $6500.42.
EOLIAN EROSION, DUNES RAILROAD TIE BARRIERS, SNOW FENCE, SIGNS, VEGETATION, MONITORING

1988b Archaeological Midden Stabilization, and Nuevo State Park. Statewide Resource Management Program Project Status Report, California Department of Parks and Recreation, Monterey, CA.

This report describes the efforts to stabilize archaeological site CA-SMA-18 which is located in an active dune area in Nuevo State Park. Eolian erosion and destruction of the dune vegetation by elephant seal traffic resulted in the exposure of artifacts, including two human burials. Three sources of impact to the site are noted: erosion, park visitors and elephant seals.

The following measures were taken to lessen the impacts. First, the area was closed to visitor traffic by directing the seal tours away from the archaeological site. The area was posted by means of an area closed sign. The site was then carefully buried under 3 to 4 feet of sand by pushing sand from the edge inward. Snow fencing was used to enclose the affected area of the site. The bare sand inside the fence was planted with bunches of straw to prevent wind erosion of the sand directly covering the site. Revegetation of the site with native plants will begin in the fall of the year. Total cost $2472.
EOLIAN EROSION, DUNES, SIGNS, SNOW FENCE, VEGETATION, MONITORING

Ebert, James I., Eileen L. Camilli and Lu Ann Waudsnider
1989 Reservoir Bank Erosion and Cultural Resources: Experiments in Mapping and Predicting the Erosion of Archaeological Sediments at Reservoirs Along the Middle Missouri River With Sequential Historical Aerial Photographs. Contract Report EL-89-3, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

This report reviews remote sensing capabilities for assessing archaeological site erosion using sequential, historical aerial photographs. The use of photointerpretation for bank erosion measurement is used to document the rates of archaeological site loss and to model differential rates of erosion between and within sites. Historical photographs (aerial) are used to establish this medium as an important time-rate of loss techniques.
REMOTE SENSING, RESERVOIR SHORELINE EROSION, CULTURAL RESOURCE PROTECTION

Fay, Patricia, M.
1987 Archaeological Site Stabilization in the Tennessee River Valley Phase III. Archaeological Papers of the Center for Archaeological Research - Number 7, University, Mississippi and Tennessee Valley Authority Publications in Anthropology Number 49, Chattanooga, Tn.

This report is the second in a continuing series of reports dealing with the experimental program of site stabilization in the Tennessee River Valley. The author reports on monitoring efforts on projects first reported in 1985 as well as some additional experimentation. Future stabilization recommendations are also presented. An Appendix discusses the short-term stabilization of an eroding mound by installing a covering of non woven filter fabric.
EXPERIMENTAL STABILIZATION, MONITORING, RECOMMENDATIONS, FILTER FABRIC

Ferguson, Albert and Christopher Turnbull
1980 Ministers Island Seawall: An Experiment in Archaeological Site Preservation. In Proceedings of the 1980 Conference on the Future of Archaeology in the Maritime Provinces, ed. by D.M. Schemabuku. Occasional Papers in Anthropology No. 8, Department of Anthropology, St. Mary's University, Halifax, Nova Scotia.

This report details the construction of a gabion wall 35 meters in length. Monitoring of the rate of site loss by erosion took place for about 6 months before construction of the gabion wall began. Preparation of the beach-front of the site involved a small amount of normal archaeological excavation. A bulldozer was then used to level the front of the site. The footing for the wall, which was slanted at 8 degrees was prepared, and a trench dug along the entire length of the wall. Filter cloth (trade name - Typar) was used to line the trench, the shelf between the trench and wall and the wall itself. The filter cloth was anchored in the trench by riprap which extended to the foot of the gabion wall. 3'x3'x12' wire mesh gabions were used for the wall which when finished measured 40 meters in length by over 2 meters high in some places. The top of the gabion wall was carried above the site and then backfilled. Cost of the project is $300 per meter of shoreline protected.

Hurricane David, which struck during the last stages of construction, buried the wall in sand, thus rebuilding the former beach contour and adding to the riprap protection. Monitoring is implied.

BEACH EROSION, STABILIZATION, GABIONS, RIPRAP, GEOTEXTILES

Galm, Jerry R.
1978 The Archaeology of the Curtis Lake Site (34Lf-5A), Leflore County, Oklahoma. Research Series No. 2, Appendix E, Archaeological Research and Management Center, University of Oklahoma.

Preservation of the Curtis Lake Site (34LF-5A) in Leflore County Oklahoma is proposed through the use of a spray-on cement mixture. This Appendix includes design plans for the project as well as a statement of the appeal of such an approach. [Ed. Note: This project is said to have been completed although no published report is available].

CEMENT, GUNITE

Hatoff, Brian
1977 "Cultural Resources Management at Grimes Point," Nevada Archaeological Survey Reporter, Vol. 10, No. 2.

Hughes, David F.
1980 The McCutchan-McLaughlin Mound (34Lt-11) Stabilization Project: Archaeological Site Preservation in Oklahoma. Report submitted to the Oklahoma Historical Society and Oklahoma Archaeological Survey.

This mound site was gradually being destroyed as a result of erosion from the adjacent creek and total loss of the site was estimated to be completed within 20-30 years unless some means of protection was installed. A riprap retaining wall was selected as the best alternative after consideration of other approaches. Drawings of the proposed project indicate the use of a silt and gravel filter below the riprap facing.
STREAM EROSION, RIPRAP

Jensen, Peter M.
1976 Archaeological Investigations at CA-MER-27. The First California Site For Which Total Coverage With Soil Has Been Agreed to as Partial Mitigation. Report prepared for U.S. Bureau of Reclamation, Sacramento, California.

Jensen presents the results of archaeological investigations that were conducted prior to the burial of CA-MER-27. He includes a ten page discussion of the future burial of the site and raises a series of questions regarding the validity of site burial as a reasonable mitigation measure. He concludes what appears to be a negative view of site burial by indicating that the limited nature of archaeological data is sufficient justification for site preservation.

More importantly, Appendix 2 describes the proposed burial activity and includes, as part of that description, portions of the Bureau of Reclamation's original burial proposal, and data that deals with compaction, settlement and slumping that is the basis for predictions on how the archaeological component will react to being buried under a three-foot protective covering. This appendix provides a great deal of insight into the planning and testing that is required prior to the burial of an archaeological property.
SITE BURIAL

Klinger, Timothy C.
1982 The Mangrum Site, Mitigation Through Excavation and Preservation. Arkansas Archaeological Survey Research Series No. 20, Fayetteville, Ar.

The majority of this report deals with the excavation of a portion of the Mangrum Site but does include a minimal statement regarding burial of undisturbed portions of the site during levee construction. One of the goals of the project is to assess site burial as a preservation technique. There is a brief discussion of the projected impact of burial and a recommended schedule of evaluation over a forty-six year period. Klinger further recommends publication of the results of the evaluation program in American Antiquity.
SITE BURIAL, MONITORING

Larson, Jon R.
1982 Letter on file Natchez Trace Parkway referring to covering of archaeological site in Colbert County, Alabama. Tupelo Office, Natchez Trace Parkway, Tupelo, Ms.

This letter contains the request for permission to bury 1CT45 under a protective soil layer and indicates that the proposed blanket be between 8 and 12 inches in depth. (Ed. Note: The blanket was ultimately put into place over the site once a 3-4 inch thick level of clay gravel had been compacted in place. This letter appears to represent the only evidence that the project was completed. Post hole testing of the site some five years after Parkway completion indicated that the overburden was not being adversely effected by farming at that time).
SITE BURIAL

Lenihan, Daniel J.
1981 The Final Report of the National Reservoir Inundation Study. Volume I - Summary. U.S. Department of the Interior, National Park Service, Southwest Cultural Resources Center, Santa Fe, N.M.

1981 The Final Report of the National Reservoir Inundation Study. Volume II - Technical Reports. U.S. Department of Interior, National Park Service, Southwest Cultural Resources Center, Santa Fe, N.M.

Lynott, Mark J.
1984 Stabilization Plan: Clyde Creek Archaeological Site (21Ls35). Midwest Archaeological Center. National Park Service, Lincoln, Neb.

This report describes the program of site stabilization at the Clyde Creek site. The site was being destroyed by raised lake levels because of a dam built in the early twentieth century. Stabilization efforts included limited salvage excavation, removal of some vegetation, protection by filter cloth, a layer of soil covered with turf stabilization mat sowed with grass seeds. A band of riprap was used to anchor the turf mat at the elevation of summer high water level.
EROSION, GEOTEXTILES, VEGETATION, RIPRAP

1988 Stabilization Riprap of Shoreline Archaeological Deposits at the Sweetnose Island Site, 21SL141, Voyageurs National Park, Minnesota. Midwest Archaeological Center, National Park Service, Lincoln, Neb.

Stabilization of the Sweetnose Island Site was initiated in 1985. Vegetation was removed and sediment was piled on the bank to reduce the severity of the slope. Filter fabric was laid over this fill which was covered in turn with six-inch layer of soil. Grass seeds were planted in the newly placed soil and a turf stabilization mat was used to hold the seeds in place. Riprap was laid along the foreslope to the height of the summer high water levels.
EARTH FILL, RIPRAP, EROSION

Maclean, J.P.
1939 Ancient Works at Marietta, Ohio. _Ohio Archaeological and Historical Publications_, Vol. 12.

Nielson, Jerry J. and Bennie C. Keel
1983 A Case Study in Historic Preservation Strategy: Roods Creek Mounds, Georgia. _American Archaeology_, Vol. 3, No. 3 1983, Albuquerque, pp. 211-213.

The Roods Creek Mounds are situated on the shore of the Walter F. George Reservoir in west central Georgia. Creation of the Reservoir created an erosional environment that would eventually lead to the loss of the site. Several stabilization alternatives were considered and

included cantilevered sheet piling, a log boom, and riprap were presented in 1973. Installation of the piling was undertaken during 1976 and 1977. A history of pricing of the project is included as an example of how agencies can cooperate in stabilization efforts and how costs can be shared.
EROSION, BULKHEAD, SHEET PILING

Putnam, Frederick Ward

1887 The Serpent Mound Saved. Ohio Archaeological and Historical Publications, Vol.

1890 The Serpent Mound of Ohio. Century Magazine, Vol. 39, April 1890, pp. 871-888.

Putman describes his first visit to the Great Serpent mound and the various activities which led to its acquisition for purposes of preservation. He indicates that the passage of tax relief legislation by the Ohio legislature was the first preservation law passed in the U.S. and by footnote indicates that federal protection of Casa Granda followed and was the result of the efforts of some of the same ladies who raised money for the Serpent Mound purchase.
PRESERVATION LAW, TAX RELIEF

Ramiller, Neil and David A. Fredrickson

1983 Archaeological Site Protection Warm Springs Dam - Lake Sonoma. Draft report prepared for the U.S. Army Corps of Engineers, San Francisco, Ca.

The author reports on the burial of two archaeological sites at Lake Sonoma. Both sites would be inundated for a majority of the time with only infrequent periods of exposure. Following adequate testing, the surface of both sites were brought to a relatively smooth surface configuration. Both sites were covered with a woven filter cloth (Mirafi 100) and then covered with a minimum of one foot of gravel. Gravel was chosen as the covering agent that would best resist hydraulic action. Monitoring of the effectiveness of the stabilization is recommended.
SITE BURIAL, GRAVEL, FILTER CLOTH

Rispoli, J.A. LCDR

1982 Letter correspondence to Connecticut SHPO regarding Baldwin Ridge Archaeological Site, Groton, Connecticut.
(see Soulsby this section)
HOUSING DEVELOPMENT, SITE BURIAL, SAND, TOPSOIL

Rolingson, Martha A.
1986 Erosion Control Methods and Practices, Toltec Mounds State Park, Arkansas. Paper on file at Toltec Mounds State Park and at the Center for Archaeological Research, University of Mississippi, University, Ms. 38677.
REVEGETATION, SHORELINE STABILIZATION WITH TIMBERS

Snethkamp, Pandora E.
1983 Archaeological Investigations on San Miguel Island: 1982 Erosion Control and Site Stabilization Treatments. Draft report submitted to the Western Region, National Park Service, San Francisco.

Seven archaeological sites on San Miguel Island were incorporated into an eolian erosion stabilization program that included the placement of datum markers; photographic recording; establishment of paper recording of erosion; and placement of horizontal and vertical measurement devices to determine artifact movement. Sandbags were used to stabilize five sites, four of which also employed a woven filter fabric. Biodegradable matting was also used in four locations. Some problems of accelerated erosion around the sandbags is reported.
EOLIAN EROSION, SANDBAGS, FILTER CLOTH, NETTING, MONITORING TECHNIQUES

Soulsby, Mary G., Robert R. Gradie and Kevin A. McBride
n.d. Phase II Archaeological Survey, U.S. Navy Housing Project, Groton, Connecticut. Report prepared for the U.S. Department of the Navy by Public Archaeological Survey Team, Inc., University of Connecticut.

Archaeological testing demonstrated that the Baldwin Ridge Site in Groton, Conn. was eligible for admission to the Register and the recommendation was made that the site should be entirely excavated. The Conn. SHPO, NPS, and the Navy Department chose to stabilize and protect the site through burial with sand and topsoil.
HOUSING DEVELOPMENT, SITE BURIAL, SAND, TOPSOIL

Strickland, Clark J.
1982 Letter correspondence to U.S. Navy from Connecticut SHPO regarding Baldwin Ridge Archaeological Site, Groton, Connecticut. (see Soulsby this section)
HOUSING DEVELOPMENT, SITE BURIAL, SAND, TOPSOIL

Thorne, Robert M.
1981 Archaeological Data Recovery and Preservation of Hurricane Mound (22LA516), Lafayette County, Mississippi. Report submitted to the Vicksburg District Office, U.S. Army Corps of Engineers, Vicksburg, MS.

This report describes the mitigation effort taken to preserve a pyramidal mound being eroded mostly by wind generated waves. The mound was subjected to an annual innudation cycle dependent on rainfall. The mitigation measures were completed in 2 stages: (1) archaeological date recovery and (2) covering of the mound. The archaeological data recovery consisted of surface collections, scraping of the mound to reveal surface features, aerial photography and three backhoe trenches to reveal the extent of the mound. The initial step in covering the mound was to trench completely around the periphery of the area to be covered. Sheets of filter cloth in 42' x 100' sections were then laid over the mound surface and the edges were tucked into the trenches and backfilled. Overlapping sheets of filter cloth were pinned to the mound surface using 18 inch long steel pins. Riprap was then spread over the area covered with filter cloth and beyond its edges by several feet on all four sides for a total dimension of 148 (n-s) x 109 (e-w) feet.
LACUSTRINE EROSION, GEOTEXTILES, RIPRAP

1985 Preservation is a Use: Archaeological Site Stabilization, An Experimental Program in the Tennessee River Valley. Archaeological Papers of the Center for Archaeological Research No. 5. University of Mississippi, Tennessee Valley Authority Publications in Anthropology, Number 40, Chattanooga, Tn.

This report discusses potential means for stabilizing archaeological sites from the perspective of established stabilization technology. The second chapter chronicles reported cases of archaeological site stabilization as a background for efforts to stabilize a variety of sites across the nation. The third chapter details experimental site stabilization efforts in The Tennessee River Valley.
STABILIZATION TECHNIQUES, EROSION, LOOTING, VANDALISM, EXPERIMENTAL STABILIZATION

1987 "Archaeological Site Stabilization on Huffine Island Watts Bar Lake, Tennessee" in Archaeological Site Stabilization in the Tennessee River Valley Phase III, by Patricia M. Fay, Archaeological Papers of the Center for Archaeological Research - Number 7, University of Mississippi, and Tennessee Valley Authority Publications in Anthropology, Number 49, Chattanooga, Tn.

Lateral lacustrine erosion of a mound on Huffine Island has been an ongoing process since the closure of the dam on Watts Bar Lake. Protection of the vertical cutbank on a short-term basis was determined to be the most expedient approach as a long-term approach was identified and put into place. A covering of non-woven filter fabric was placed over an underliner of black plastic. Regular monitoring of the effectiveness of the applied material and upgrading of the material is declared to be an intergal part of the stabilization process.
EROSION, LACUSTRINE EROSION, FILTER FABRIC, MONITORING

U.S. Army Corps of Engineers
1984 Reconnaissance Report: Poverty Point State Commemorative Area, Bayou Macon, West Carroll Parish, Louisiana. U.S. Army Corps of Engineers, Vicksburg District, Vicksburg, MS.
RIPRAP

U. S. Department of Agriculture
1988 River Point Resort Archaeological Site Erosion Control Project Specification. U. S. Forest Service, Superior National Forest, Kawishiwi Ranger District, Duluth, Mn.

The majority of the work to be completed under this plan/Request for Proposal is to be accomplished while the lake shore is iced in. A layer of filter cloth is to be anchored to the shoreline and laid out on the ice where a line of tires will be laid on the filter cloth which will then be doubled back over the tires. Class IV riprap will be placed in the tires on top of the filter fabric. Class II riprap will be placed between the Class IV stone and the bankline. As the ice melts, the stabilizing materials will settle to the bottom. A second class of

geotextile will be laid over about 1/2 of the width of the Class II riprap as a barrier between topsoil to be placed on the bank and the riprap. The newly placed topsoil is to be seeded.
EROSION, TIRES, RIPRAP, GEOTEXTILES, VEGETATION

Wilkie, Duncan C., Michael T. Aide, and Ray Knox
1986 Testing for the Impact of Burying Sites Under a Highway; Phase III, Archaeological Mitigation of Archaeological Sites 23BU239 and 23BU241. Report submitted to the Missouri Highway and Transportation Department, Jefferson City, Mo.

The authors summarize both the Phase I and II work completed at these two sites and the Scope of Work for the project that they will report on. Site burial and artifact reburial are included as basic components of the mitigation plan. They further indicate that the research design for Phase III work be based on an improvement of the CALTRANS site burial test project. Both the authors of the report and the Scope of Work indicate that the present project is experimental. Portions of both sites were excavated with the unexcavated portions of both sites scheduled to be covered as a part of the construction phase of Route 60. Features were treated similarly, with partial excavation and artifacts were recovered for analysis. Following detailed analysis of the recovered artifacts, representative examples were returned to the site and reburied in their original locations.

Recommendations for measuring burial impact include soil chemistry testing on two year intervals and reexcavation of both the unexcavated features and reburied artifacts after a 10 year interval. This period of time should allow the detection of any impacts that burial and reburial will have on the site and its contents.

Neither the Scope of Work, its responding proposal nor the report of archaeological efforts contain a description of the engineering design that was used in the burial of these two sites. One is left to assume that standard Missouri Highway and Transportation Department engineering and construction design was used. Complete physical, chemical and some soil compaction data was gathered to serve as a baseline in future studies.
SITE BURIAL, EXPERIMENTATION, MONITORING