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9-11-90

Notes from J.N.'s Damage Summaries

I. Fish + Shellfish.

- No immediate kills - studies designed to det'n indirect effects on Pop's, + sublethal, directed @ spp. most likely affected: salmon, herring, D-V, crab, shrimp, clams (No pollock, halibut, rockfish, other forage fish or gen'l benthic)

- [Salmon] - pot'l ongoing: - egg→fry mort (1989 eggs, not 1990 = 17% vs 11%
  1990 fry - increased abnormalities
  1989 wild stock est = 9 mil. adults. (vs 40 mil hatchery return)
  CWT study det. limit ≥ 6%, though.
  Juv - growth rates ↓ oiled areas.
  1990 "record harvest" = hatchery stock. Wild stock returns not record, + in fact are somewhat depressed over x̄ historical.
  Greater impact possible next yr (this yr's returns were fry during spill, not eggs)

- Overescapement - esp. prob. for sockeye on Kodiak. (5x ADF+G goals)

-(Nothing in on subsistence yet)

- [Herring] - signif. ↑ mort, + deformities of eggs + larvae.
  5x diff eye tumors oiled vs unoiled areas

- [D-V] - extensive use of intertidal for feeding, so indicator (not just rec'l importance). Bile H-C's highest of any fish studied in NRDA.

- [Crab] - too few to study effects inside PWS. Outside study ongoing

- [Spot Shrimp] - prelim - some ↑ mort of eggs in oiled areas

- [Clams] - lit - several years to purge of H-C's in oiled areas. High H-C levels in subsistence areas.

- [Other Fish] - rockfish, sole, halibut, herring, pac. cod, pollock - all show elevated bile HCs. "Particularly signif" that bottomfish exposed, since suggests oil sinking into deep water. ADF+G says found 5 RF died from oil, but never said how proven. END.

9-11-90

Notes from J.N.'s Damage Summaries

(Otters)

- Body count ≈ 980 dead oiled otters. Necropsies: 68.5% = likely mort (27% =) by oil, 27.5% inconclusive, 4% unlikely mort by oil.
- high # pregnant ♀s + lactating ♀s, combined w/ low # pups found ⇒ higher direct mort than 980. Also scavenging, sinking and drifting out of sound = likely for some, so # probably higher still. Expect proving 2,000 = likely.

(H. Seals) - 39 dead oiled recovered. Sink, so = small fraction.

(K. Whales) - several pods lost members - AB missing 7, AE missing 4, + AN missing 22 (but AN = transient, could have split) AB loss of 7 = more signif - 2 = ♀s left calves behind.
↳ = 19.4% mort = unprecedented; even by "fishery interactions"

(Other Whales) - larger than normal #s beached, but increased surveillance, too.

(Long-Term effects) - more difficult - best evidence = sea otters + hbr seals. (Otters) - overall mort in oiled ≈ 3X in unoiled. High mort of treated + released otters (110/198), + transmitter study = 5 morts/55 in oiled vs 1/41 in unoiled. Elevated blood parameters ⇒ HC exposures, + some evidence of reduced reprod rates. (H Seals) - pop ↓ 40% 1984-1988. 70%+ seals seen were oiled. Signif decline in pop'n levels, oiled vs unoiled: 40% ↓ oiled 16% ↓ unoiled. (several hundred fewer animals, prediction). Oiled area seals ↑ brain + nervous system lesions; + signif. ↑ in bile HCs.

(Other Marine Mammals) - (humpback) - repro rate in 1989 = lowest in 8 yrs of study (no evidence for why).

(Sea Lion) - no statistical evidence of further decline from spill over genl decline. (but Stellers = listed threatened, so sublethal studies (ongoing) may be signif.

END.

cost, incl. logistics support, etc.] **Cost-effectiveness:** Direct, on-site in-kind measureusing established technology; assumed highly cost-effective (without addressing "grossly disproportionate" test).

- Estuarine/salt marsh restoration: **Feasibility:** techniques proven elsewhere (fertilization and transplanting), moderate success rates, may require re-work depending on degree of remnant oiling. **Benefit:** to feeding birds and fish, terrestrial mammals, local water quality, erosion in sheltered embayments. **Cost:** $10,000,000 [$500,000/acre full restoration (adjusted for Alaska based on $300,000/acre N.J. experience) for 10 acres plus $5,000,000 total for less intensive restoration wor(limited replanting, fertilization, monitoring for up to 10 years, and reapplication) on up to 100 acres]

Coastal Hab
Injury (from Carol)
Inter / Subtidal
— diversity lower in oiled areas, w/ greater #'s of chitons, starfish, other hardy spp + fewer #'s of limpets/periwinkles (although in 1990 periwinkles invasion increasing, possibly via floating fucus)
— Algal diversity ↓ in oiled sites
— Fucus heavily damaged, most obviously in ~~upper~~ upper.
Fucus size in some areas (eg Herring Bay) skewed to all small plants. Est. recovery to climax fucus then = 3-4 yrs. (Caused by oil + cleanup)
— Sediments - (anecdotal) - is oil in seds. One trap pulled just to check process - fingerprinted w/ PB crude.
Air Water 2 saw sheen in sieves @ some heavily oiled sites
— Supratidal - greater crop Elymus + Carex 1989 (nothing for 90 yet)

streams ↑ intertidal feeding
Harl: Goldeneyes - Surf Scoters - Black + white wing scoters - more pelagic not stressed

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Strategies

Bald Eagles

Injury:

Restoration Strategies: Habitat Preservation & Enhancement
Food Supply Enhancement
Aquisition of Equivalent Resources
Avoid habitat fragmentation
Reduce disturbance in Nesting Areas
Natural Recovery

Kittiwakes

Injury: Food has become scarcer as evidenced by increased foraging range and increased time off the nest. Nesting success has decreased possibly for the same reasons. Population decline within PWS which had a stable population prior to spill. Injury due to

Restoration Strategies: Food Supply Enhancement
Acquisition of Equivalent Resources
Natural Recovery

Alcids

Injury: Murres (common and thick-billed)
Morgue numbers totalled more than 11,000 birds. Major decrease in population numbers second year in a row. Murres that are left no longer have synchronized nesting schedules making their nests and eggs more vulnerable to predators that disturb the rookery. Although there were no specific age class studies done, it is possible to speculate that the older birds, which have the more established pair bonds, were the ones most heavily impacted by the spill because the older birds generally return and nest earlier (and more successfully) than the younger birds. This hypothesis is further supported by the fact that the closest the rookery comes to synchronized nesting is approximately one month late which would correspond to the return and nesting activities of younger, less experienced birds.

It has been estimated that it will take more than 70 years for the population to return to normal nesting patterns. The colony will have to slowly evolve the normal synchronized nesting strategy without the older, more successful breeders to conduce the appropriate nesting behavior.

Restoration Strategies: Nesting decoys similar to Atlantic Puffins
Natural Recovery

- high seas drift net use

Injury: Marbled Murrelets

Restoration Strategies: Habitat Preservation & Enhancement
Food Supply Enhancement
Aquisition of Equivalent Resources
Avoid habitat fragmentation

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REGION 7
1011 E. TUDOR ROAD
ANCHORAGE, ALASKA 99503
FAX NUMBER: Commercial (907) 786-3350
FTS 869-3350

TO: BRIAN ROSS	**DATE/TIME:** ~~3:30~~ 4:00, 8/30/90
FROM: CAROL GORBICS	**CALL** ______ **TO HAVE PICKED UP**
SUBJECT: ~~COMPILATION OF MORGUE ANIMALS~~ SAMPLE PAGE	

FAX# 271-2467

9-5 VERSION RPWG F

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Strategies

Bald Eagles

Injury: Approximately 150 bald eagles are catalogued in the morgue. However, it is likely that this represents a small fraction of the total number becauseeagle carcasses typically do not end up on the beach, but in forested areas where it is unlikely that they would be recovered. Preliminary results show egg shells, egg contents and prey remains as being contaminated by crude oil. Some of the blood work shows high concentrations of hydrocarbons associated with crude oil.

Restoration Strategies: Habitat Preservation & Enhancement
Food Supply Enhancement
Aquisition of Equivalent Resources
Avoid habitat fragmentation
Reduce disturbance in Nesting Areas
Natural Recovery

Kittiwakes

Injury: Food has become scarcer as evidenced by increased foraging range and increased time off the nest. Reproductive success has decreased possibly for the same reasons. Population decline within PWS which had a stable population prior to spill.

Restoration Strategies: Food Supply Enhancement
Acquisition of Equivalent Resources
Natural Recovery

Alcids

Injury: Murres (common and thick-billed)
Morgue numbers totalled more than 11,000 birds. Major decrease in population numbers second year in a row. Murres that are left no longer have synchronized nesting schedules making their nests and eggs more vulnerable to predators that disturb the rookery. Although there were no specific age class studies done, it is possible to speculate that the older birds, which have the more established pair bonds, were the ones most heavily impacted by the spill because the older birds generally return and nest earlier (and more successfully) than the younger birds. This hypothesis is further supported by the fact that the closest the rookery comes to synchronized nesting is approximately one month late which would correspond to the return and nesting activities of younger, less experienced birds.

It has been estimated that it will take more than 70 years for the population to return to normal nesting patterns. The colony will have to slowly evolve the normal synchronized nesting strategy without the older, more successful breeders to conduce the appropriate nesting behavior.

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Restoration Strategies: Predator control of natural predators such as glaucous winged gulls
Restriction of fisheries for forage fish (caplin and sandlance are prime forage but not commercially used)
Control of human disturbance
Eradication of fox, ground squirrel & rats on historic colony sites
Aquisition
Natural Recovery

Injury: Marbled Murrelets
Restoration Strategies: Habitat Preservation & Enhancement
Food Supply Enhancement
Aquisition of Equivalent Resources
Avoid habitat fragmentation
Reduce disturbance in Nesting Areas
Natural Recovery

Seaducks
Injury: Harlequin Ducks
Populations in the oiled area of PWS are sparse and patchy. No broods have been spotted in 1990 in PWS. Approximately 25 percent of the necropsied birds from oiled areas are characterized by poor physiological condition with minimal adipose tissue while approximately 98 to 99 percent of the birds in the non-oiled area appeared healthy. Preliminary analysis of bile samples from harlequin ducks show hydrocarbon contamination.

Scoters
The three species of scoters feed in progressively deeper water with the surf scoters primarily in the intertidal area, the black scoters in the intertidal and nearshore area and the white-winged scoter in the deepest water. The surf scoter relies the most heavily on subtidal organisms such as blue mussels in their diet while the white-winged scoter relies most heavily on benthic organisms such as scallops. The preliminary analysis of tissue sampling and gross necropsy shows those scoters feeding predominantly in the intertidal areas and subtidal area (blue mussels) in the oiled area were the most physiologically stressed with minimal adipose tissue. Preliminary analysis of bile samples shows some hydrocarbon contamination.

Restoration strategies: Food supply enhancement (mariculture)
Acquisition of Equivalent Resources
Natural Recovery

MARINE MAMMALS

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Otters

Injury: Populations of otters within the oiled area continues to remain lower when compared to pre-spill data and to non-oiled areas. Early season data indicates that there may be a continuing decline of otter numbers in oiled areas. Very preliminary post-mortem findings on autopsies conducted on the otters found dead following the oil spill indicates that at exposure to oil was the cause of death in at least 68.5% and not the cause of death in only 4%. The cause of death in the remaining 27.5% of the otters will have to be determined based on toxilogical results. It should be noted, however, that oil as the cause of death for the remaining 27.5% has not been ruled out. Preliminary analysis of liver and bile samples indicate hydrocarbon contamination, however additional analysis is needed to completely explain the results. Preliminary analysis of blood data indicates that there may be a significant effect on otters based on location and presumably, exposure to oil.

Restoration strategies: Food supply enhancement
Control human disturbance
Habitat Preservation & Enhancement
Aquisition of Equivalent Resources
Natural Recovery

Harbor Seals

Injury: Tissue sample analysis of seals showed high hydrocarbon concentration in tissue and bile samples. Population decline was greater in oil spill areas during 1989.

Restoration strategies: Food supply enhancement
Control human disturbance
Habitat Preservation & Enhancement
Aquisition of Equivalent Resources
Natural Recovery

Killer Whales

Injury: Population numbers have decreased. Thirty to forty animals missing from within PWS.

Restoration strategies: Food supply enhancement
Control human disturbance
Habitat Preservation & Enhancement
Aquisition of Equivalent Resources
Natural Recovery

Humpback Whales

Injury: Low reproductive rate in 1989. No cow/calf pairs had been observed in 1990 as of August, 1990.

Restoration strategies: Food supply enhancement
Control human disturbance
Habitat Preservation & Enhancement
Aquisition of Equivalent Resources
Natural Recovery

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9-4- Version

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Strategies

Bald Eagles

Injury: Approximately 150 bald eagles are catalogued in the morgue. However, it is likely that this represents a small fraction of the total number becauseeagle carcasses typically do not end up on the beach, but in forested areas where it is unlikely that they would be recovered. Preliminary results show egg shells, egg contents and prey remains as being contaminated by crude oil. Some of the blood work shows high concentrations of hydrocarbons associated with crude oil.

Restoration Strategies: Habitat Preservation & Enhancement
Food Supply Enhancement
Aquisition of Equivalent Resources
Avoid habitat fragmentation
Reduce disturbance in Nesting Areas
Natural Recovery

Kittiwakes

Injury: Food has become scarcer as evidenced by increased foraging range and increased time off the nest. Nesting success has decreased possibly for the same reasons. Population decline within PWS which had a stable population prior to spill. Injury due to

Restoration Strategies: Food Supply Enhancement
Acquisition of Equivalent Resources
Natural Recovery

Alcids

Injury: Murres (common and thick-billed)
Morgue numbers totalled more than 11,000 birds. Major decrease in population numbers second year in a row. Murres that are left no longer have synchronized nesting schedules making their nests and eggs more vulnerable to predators that disturb the rookery. Although there were no specific age class studies done, it is possible to speculate that the older birds, which have the more established pair bonds, were the ones most heavily impacted by the spill because the older birds generally return and nest earlier (and more successfully) than the younger birds. This hypothesis is further supported by the fact that the closest the rookery comes to synchronized nesting is approximately one month late which would correspond to the return and nesting activities of younger, less experienced birds.

It has been estimated that it will take more than 70 years for the population to return to normal nesting patterns. The colony will have to slowly evolve the normal synchronized nesting strategy without the older, more successful breeders to conduce the appropriate nesting behavior.

Restoration Strategies:
- Predator control of natural predators such as glaucous winged gulls
- Restriction of fisheries for forage fish (caplin and sandlance are prime forage but not commercially used)
- Control of human disturbance
- Eradication of fox, ground squirrel and rat on historic seabird colony sites
- Aquisition
- Natural Recovery

Injury: <u>Marbled Murrelets</u>

Restoration Strategies:
- Habitat Preservation & Enhancement
- Food Supply Enhancement
- Aquisition of Equivalent Resources
- Avoid habitat fragmentation
- Reduce disturbance in Nesting Areas
- Natural Recovery

Seaducks

Injury: <u>Harlequin Ducks</u>

Populations in the oiled area of PWS are sparse and patchy. No broods have been spotted in 1990 in PWS. Approximately 25 percent of the necropsied birds from oiled areas are characterized by poor physiological condition with minimal adipose tissue while approximately 98 to 99 percent of the birds in the non-oiled area appeared healthy. Preliminary analysis of bile samples from harlequin ducks show hydrocarbon contamination.

<u>Scoters</u>

The three species of scoters feed in progressively deeper water with the surf scoters primarily in the intertidal area, the black scoters in the intertidal and nearshore area and the white-winged scoter in the deepest water. The surf scoter relies the most heavily on blue mussels in their diet while the white-winged scoter relies the least heavily on blue mussels. The preliminary analysis of tissue sampling and gross necropsy shows those scoters feeding predominantly in the intertidal areas on blue mussels in the oiled area were the most physiologically stressed with minimal adipose tissue. Preliminary analysis of bile samples shows some hydrocarbon contamination.

Restoration strategies:
- Food supply enhancement (mariculture)
- Acquisition of Equivalent Resources
- Natural Recovery

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MARINE MAMMALS

Harbor Seals

Injury: Tissue sample analysis of seals showed high hydrocarbon concentration in tissue and bile samples. Population decline was greater in oil spill areas during 1989.

Restoration strategies:
- Food supply enhancement
- Control human disturbance
- Habitat Preservation & Enhancement
- Aquisition of Equivalent Resources
- Natural Recovery

Killer Whales

Injury: Population numbers have decreased. Thirty to forty animals missing from within PWS. (Killer whales worth $500,000+ each to aquaria.)

Restoration strategies:
- Food supply enhancement
- Control human disturbance
- Habitat Preservation & Enhancement
- Aquisition of Equivalent Resources
- Natural Recovery

Humpback Whales

Injury: Low reproductive rate in 1989. No cow/calf pairs had been observed in 1990 as of August, 1990.

Restoration strategies:
- Food supply enhancement
- Control human disturbance
- Habitat Preservation & Enhancement
- Aquisition of Equivalent Resources
- Natural Recovery

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FAX# 271-2467

27 [illegible]

Table 1. Cumulative migratory bird and sea otter deaths accounted for by the Fish and Wildlife Service and summary of wildlife rehabilitation efforts (October 12 - October 18, 1989). Number in parenthesis is tally change from previous week's briefing report.

	Kodiak	Homer	Seward	Valdez
BIRDS				
A. Rehabilitation Center				
1. Rec. live directly from field	221	190*	1099	382
2. Transf. in from other Centers	0	0	11	36
3. Transferred out from Center	172	141*	69	9
4. Deaths at Center / # euthanized	46/0	30/3*	386/89	289/71
5. Released	3	19	655	120
6. Presently holding	0	0	0	0
B. Dead from field to FWS	22578	5797	3248	3173
C. Cumulative dead: (4+B)	22624 (+0)	5827 (+3)*	3634 (+0)	3462 (+0)
		*Correction in previous data		
SEA OTTERS				
A. Rehabilitation Center				
1. Rec. live directly from field	24	17	184	139
2. Transf. in from other Centers	0	99	0	34
3. Wild otters captured near rehab pen	0	5	0	1
4. Births	0	4	7	3
5. Transferred out from Center	22	14	142	25
6. Deaths at Center / # euthanized	1/0	3/0	30/12	82/9
7. Released	1	103	19	70
8. Presently holding	0	0	0	0
B. Dead from field to FWS	195	103	99	490*
C. Cumulative dead: (6+B)	196 (+0)	106 (+0)	129 (+0)	572 (+1)*

*State crews recovered 1 de otter which has been sent Anchorage for necropsy

see corrected version

	Kodiak	Homer	Seward	Valdez
EAGLES				
A. Rehabilitation Center				
1. Rec. live directly from field	19	1	22	12
2. Transf. in from other Centers	6	0	1	0
3. Transferred out from Center	18	1	10	11
4. Deaths at Center / # euthanized	1/0	0/0	0/0	1/0
5. Released	6	0	13	0
6. Presently holding	0	0	0	0
B. Dead from field to FWS	61	15	20	46
C. Cumulative dead: (4+B)	62 (+0)	15 (+0)	20 (+0)	47 (+0)
D. Cumulative dead other raptors	4 (+0)	6 (+0)	2 (+0)	6 (+0)

EAGLE REHAB. CENTER, ANCHORAGE

A. Received live . . . . 21 (+0)
B. Deaths at Center / # euthanized . . . . 7/2 (+0/+0)
C. Released . . . . 0 (+0)
D. Holding . . . . 12 (+0)
E. Transferred out . . . . 2 (+0)
(One eagle subsequently died.)

MISCELLANEOUS CATEGORY

Gore Pt. . . . 631 birds
King Salmon . . 23 birds, 2 otters
Puale Bay . . . 100 birds

SELECT CUMULATIVE GRAND TOTALS:

All dead birds	36471	(+5); corrects arithmetic error of two birds.
All live birds held	13	(+0); includes one eagle transferred to facility in lower 48
All birds released	816	(+0)
Dead otters	1016	(+1); includes 11 deaths at other facilities.
Live otters held	22	(+0); includes 22 held at other facilities.
Otters released	193	(+0)

TOTAL MARINE BIRDS RETRIEVED FOLLOWING THE EXXON VALDEZ OIL SPILL

As of 25 September, computer records indicate a total of 35,279 birds were recovered from all areas. As of 27 September, an additional 892 birds died at rehabilitation centers (832 were released alive), and 31 oiled birds were retrieved from Middleton Island. The grand total of birds retrieved therefore equals 36,202. This differs slightly from the 'official' tally appearing on 'cumulative migratory bird deaths' weekly tallies, which totaled 36,460 birds by 27 September. The manually tallied weekly summaries included some birds that were identified and counted in the field, but not processed or entered on computer at receiving stations. --Compiled by John Piatt on 29 September, 1989.

Table 1. Species composition and number of birds retrieved from oiled areas and processed at U.S. Fish and Wildlife receiving stations as of 25 September, 1989.

Species	Total	Valdez	Seward	Homer	Kodiak
Total	35,279	3,360	3,503	5,778	22,638
Unidentified bird	2,927	476	414	916	1,121
Unidentified loon	69	27	6	25	11
Common Loon	216	142	23	32	19
Yellow-billed Loon	87	72	5	3	7
Pacific Loon	18	8	5	0	5
Red-throated Loon	5	3	1	1	0
Unidentified grebe	65	27	8	11	19
Red-necked Grebe	120	79	22	12	7
Horned Grebe	277	233	15	22	7
Northern Fulmar	426	0	22	12	115
Unidentified shearwater	579	5	22	14	538
Sooty Shearwater	360	4	80	34	242
Short-tailed Shearwater	2,460	1	84	4	2,371
Unidentified petrel	69	2	24	14	29
Fork-tailed Storm-petrel	363	1	50	19	293
Leach's Storm-petrel	12	0	9	0	3
Unidentified cormorant	219	76	27	56	60
Double-crested Cormorant	38	19	10	0	9
Pelagic Cormorant	418	277	65	29	47
Red-faced Cormorant	161	90	29	9	33
Great Blue Heron	1	1	0	0	0
Unidentified swan	3	0	2	1	0
Emperor Goose	2	0	0	0	2
Canada Goose	1	0	0	1	0
Brant	3	0	1	2	0
Unidentified duck	30	4	6	20	0
Unidentified seaduck	112	63	2	11	36
Mallard	11	2	4	1	4
Northern Pintail	4	0	3	1	0
Green-winged Teal	5	0	5	0	0
Unidentified Scaup	4	1	3	0	0
Greater Scaup	27	2	21	4	0
Lesser Scaup	2	0	2	0	0
Unidentified Goldeneye	25	8	2	14	1
Common Goldeneye	6	3	0	2	1
Barrow's Goldeneye	33	19	9	4	1
Bufflehead	21	17	1	0	3
Oldsquaw	185	131	43	6	5

Table 1. Species composition and number of birds retrieved from oiled areas and processed at U.S. Fish and Wildlife receiving stations as of 25 September, 1989. (Cont'd)

Species	Total	Valdez	Seward	Homer	Kodiak
Harlequin Duck	213	148	10	35	20
Unidentified Eider	3	0	0	3	0
Stellar's Eider	4	4	0	0	0
Common Eider	17	5	0	2	10
King Eider	9	0	0	0	9
Unidentified Scoter	162	23	17	51	71
White-winged Scoter	342	164	13	137	28
Surf Scoter	175	45	28	9	6
Black Scoter	132	112	4	8	8
Ruddy Duck	1	0	1	0	0
Unidentified merganser	3	1	0	0	2
Common Merganser	2	2	0	0	0
Red-breasted Merganser	33	30	1	1	1
Sandhill Crane	2	1	1	0	0
Black Oystercatcher	9	2	2	0	5
Golden Plover	1	0	0	1	0
Unidentified sandpiper	11	1	5	1	4
Unidentified turnstone	1	0	0	0	1
Common Snipe	1	0	0	1	0
Semipalmated Sandpiper	1	0	1	0	0
Lesser Yellowlegs	2	0	0	2	0
Western Sandpiper	5	0	0	5	0
Baird's Sandpiper	1	0	0	0	1
Least Sandpiper	4	0	2	0	2
Surfbird	3	3	0	0	0
Short-billed Dowitcher	1	0	0	0	1
Red Phalarope	2	0	0	2	0
Red-necked Phalarope	7	1	3	0	3
Long-tailed Jaeger	1	0	0	0	1
Unidentified gull	99	6	34	39	20
Glaucous-winged Gull	555	33	188	28	213
Herring Gull	8	3	5	0	0
Mew Gull	33	0	3	3	27
Black-legged Kittiwake	1,225	8	214	74	929
Arctic Tern	3	1	1	0	1
Aleutian Tern	1	0	0	0	1

Table 1. Species composition and number of birds retrieved from oiled areas and processed at U.S. Fish and Wildlife receiving stations as of 25 September, 1989. (Cont'd)

Species	Total	Valdez	Seward	Homer	Kodiak
Unidentified alcid	173	24	0	15	134
Unidentified murre	8,851	21	775	2,101	5,954
Common Murre	10,428	399	523	1,353	8,153
Thick-billed Murre	669	16	142	73	438
Pigeon Guillemot	614	136	109	155	214
Unidentified murrelet	413	21	37	121	234
Marbled Murrelet	612	289	97	82	144
Kittlitz's Murrelet	67	23	19	21	4
Ancient Murrelet	311	3	40	73	195
Cassin's Auklet	48	0	36	2	10
Least Auklet	5	0	0	1	4
Parakeet Auklet	31	1	2	1	27
Rhinoceros Auklet	141	0	31	31	79
Unidentified puffin	46	0	7	4	35
Horned Puffin	139	0	32	13	94
Tufted Puffin	361	0	29	15	317
Bald Eagle	125	31	20	15	59
Unidentified raptor	7	1	3	2	1
Peregrine Falcon	2	0	0	0	2
Willow Ptarmigan	1	0	0	0	1
Unidentified owl	1	0	0	1	0
Great-horned Owl	3	0	0	3	0
Unidentified woodpecker	1	0	0	1	0
Cliff Swallow	3	0	3	0	0
Violet-green Swallow	1	0	1	0	0
Unidentified passerine	9	1	7	1	0
Stellar's Jay	1	1	0	0	0
Magpie	7	1	0	0	6
Common Raven	18	1	4	0	13
Northwestern Crow	34	6	3	3	22
American Robin	2	0	2	0	0
Varied Thrush	1	0	0	0	1
Hermit Thrush	1	0	1	0	0
Unidentified warbler	1	0	0	0	1
Yellow Warbler	3	0	3	0	0
Pine Grosbeak	1	0	0	0	1
Unidentified sparrow	15	0	10	2	3
Savannah Sparrow	1	0	1	0	0
Golden-crowned Sparrow	4	0	3	0	1
White-winged Crossbill	8	0	0	6	2

EVOS 13.1

CJ 7/30/90

DTS/0550B

May 22, 1990

SUMMARY OF SEA OTTER RESCUE INVENTORY

	Zone of Origin			
	PWS Zone	Kenai Zone	Kodiak Zone	Total
Captured from Wild	158	219	59	436
Released/Escaped from Boats	-14	-42	-31	-87
Died on Boats	- 3	- 2	0	- 5
Sent to shore alive	141	175	28	344
Died in Seward or Kodiak w/o entry		- 1	- 2	- 3
Released from Kodiak Temp. Care Fac.			- 1	- 1
Shipped to SORC but not logged in!			- 1	- 1
Born in Captivity	+ 2	+16	+ 0	+18
Total in Bio-Data Base	143	190	24	357
In VORC Bio-Data Base (assigned VA#s)	143	13		156
In SORC Bio-Data Base (assigned SW#s)		163	24	187
In Bio-Data Base retaining H#s		14		14
Total in Bio-Data Base	143	190	24	357

Balancing the Temporary Care Facilities (TCF) Inventory

In Kodiak Inventory (assigned K#s)			28
In Homer PRF inventory (assigned H#s)	26		
Total arrived from field to TCF	18		28
Thru Homer to VORC w/o H#s (VA#s)	-2		
Thru Homer Assigned H#s	16		
To VORC from Homer PRF (VA#s)	-4		
Plus one died in route (H#)	-1		
To SORC from Homer PRF (SW#s)	-7		
Died at TCF (H#) (K#s)	-1		-2
To Jakolof directly (H#s)	-3		
Born at Homer TCF to Homer mothers(H#)	+1		
Total given H#s at Homer TCF	18		
Total assigned H#s at Jakolof PRF		8	
Born at Jakolof to Homer mothers		+1	
Born at Jakolof to Seward mothers		+2	
Rogues at Jakolof in Inventory		+5	
Released from Kodiak Temp. Care Fac.			- 1
Shipped to SORC but not logged in!			- 1

DTS/0550B

May 22, 1990

SUMMARY OF SEA OTTER RESCUE INVENTORY (page 2)

	Zone of Origin			
	PWS Zone	Kenai Zone	Kodiak Zone	Total
To SORC from Homer TCF, given SW#s		8		8
To SORC from Kodiak TCF, given SW#s			24	24
From field direct to SORC, given SW#s		143		143
Born in captivity, given SWP #s		12		12
In SORC Bio-Data Base (assigned SW#s)		163	24	187
To VORC from Homer TCF given VA#s		6		6
To VORC via Seward pre-SORC given VA#s		7		7
To VORC from PWS capture boats	139			139
To VORC from Cordova citizen (VA#)	1			1
Rogue volunteer at VORC (VA#)	1			1
Births at VORC given VA#s	2			2
In VORC Bio-Data Base (assigned VA#s)	143	13		156
Transferred from SORC to VORC(kept SW#)	21	-19	-2	
Transferred from SORC to Jalolof PRF		99		

Summary of Births in Captivity

	PWS Zone	Kenai Zone	Kodiak Zone	Total
Born at:				
Seward ORC		11		11
Valdez	2	1		3
Homer Temp. Care Facility		1		1
Jakolof Pre-Release Facility		3		3
Totals	2	16	0	18

Summary of Deaths in Captivity

	PWS Zone	Kenai Zone	Kodiak Zone	Total
Died at: Valdez ORC	81	3	0	84
Seward ORC	0	29	6	35
Died at Jakolof PRF		2		2
Died at Homer TCF		1		1
Died enroute Homer to VORC		1		1
Total	81	36	6	123

DTS/0550B (continued) May 22, 1990

SUMMARY OF SEA OTTER RESCUE INVENTORY (page 3)

	Zone of Origin			
	PWS Zone	Kenai Zone	Kodiak Zone	Total
Received at VORC (exclusive of 21):				157
Arrived directly from field	139			141
Orca Inlet non-spill otter	1			
Valdez Harbor "volunteer"	1			
Thru Seward pre-SORC		7		7
Arrived from Homer TCF		6		6
Born at VORC to mothers from	2	1 (SW#)		3
Received at SORC (exclusive of one pup):				188
Arrived directly from field		146	2	148
Arrived from Homer TCF		7		7
Arrived from Kodiak TCF			22	22
Born at SORC to mothers from		11		11
Received at Jakolof				12
Direct from Homer TCF		4		4
Born at Jakolof PRF		3		3
Rogues captured at Jakolof PRF		5		5
TOTAL "arrived alive inventory"	143	190	24	357
Died at facilities:				
Valdez ORC	81	3	0	84
Seward ORC	0	29	6	35
Died at Jakolof PRF		2		2
Died at Homer TCF		1		1
Died enroute Homer to VORC		1		1
Total	81	36	6	123
Less deaths at facilities	-81	-36	- 6	-123
Available for release or aquaria	62	154	18	234
Shipped to Aquaria:				
Died in Anchorage	1			1
Died at Aquaria thru 2/01/90	8	1	2	11
Alive at Aquaria 2/02/90	15	7	3	25
Total	24	8	5	37
Less aquaria candidates	-24	- 7	- 5	-37
Available for release/escape	38	146	13	197

DTS/0550B (continued) May 22, 1990

SUMMARY OF SEA OTTER RESCUE INVENTORY (page 4)

	Zone of Origin			
	PWS Zone	Kenai Zone	Kodiak Zone	Total
Escaped/Released into Wild from:				
SORC TOTAL		18	1	19
Implant transmitters to PWS		7*		7*
Not-implants to Harris Bay		4		4
Not-implants to Taylor Bay		6	1	7
Non-implants to Picnic Harbor		1		1
VORC Octagon Pre-release Fac. TOTAL	38	32		70
Escaped into Valdez Harbor	4	6		10
Flipper radios to Simpson Bay	6	1		7
Implant radios to PWS	10*	13*		23*
Non-implant radios to PWS	18	12		30
Jakolof Pre-Release Facility TOTAL		96	12	108
Implant radios to PWS		13*	2*	15*
Non-implants to PWS		6		6
Non-implant to Harris Bay		24	1	25
Non-implants to James Lagoon		21	3	24
Non-implants to Nuka Bay		7		7
Escaped/Rel. in L. Jakolof Bay		20	6	26
Rogues released to Kachemak Bay		5		5
2 re-released in Dog Fish Bay (not in Bio-data base)				
Totals Available for release/escape	38	146	13	197

* Indicated sea otters with implant radios.

DTS/0550B (continued) May 22, 1990

SUMMARY OF SEA OTTER RESCUE INVENTORY (page 5)

SUMMARY OF DEAD OTTER INVENTORY

	Zone of Origin			
	PWS Zone	Kenai Zone	Kodiak Zone	Total
Dead from Field *	490	188	198	876
Est. to have died before spill	69	15	7	91
Rated for degree of oiling	238	108	33	379
Number judged oiled	235	75	30	340
Oiled Status Unknown	183	65	158	406
Died at rehabilitation facilities **	81	36	6	123
Valdez ORC	81	3		84
Seward ORC		29	6	35
Died at Jakolof PRF		2		2
Died at Homer TCF		1		1
Died enroute Homer to VORC		1		1
Died at aquaria by 2/1/90 **	9	1	2	12
Died in Anchorage in transit	1			1
Died at Sea World, San Diago	4			4
Died at Pt. Defiance, Tacoma	2	1	2	5
Died at Vancouver	2			2
Cummulative Dead Recovered	580	225	206	1,011

Note: These data superceed previously released data.
* Data quality controlled by Calvin Lensink.
** Data quality controlled by Keith Bayha.

Needs to be updated w/ 1990 deaths

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COASTAL HABITAT SYNTHESIS MEETING NOTES
(Includes discussions of injury findings only)

Intertidal and Subtidal Injuries

--Intertidal and subtidal diversity lower in oiled areas with greater numbers of chitons, starfish and other hardy species and fewer numbers of limpets and periwinkles (invasion is occuring by periwinkles which are maybe coming in on floating fucus)

--Algal diversity lower in oiled sites

--Fucus heavily damaged with the most obvious damage in upper intertidal. Example: Herring Bay (oiled) fucus size is skewed to many small plants. Recovery to climax fucus forest suggested to be 3 to 4 years. Fucus damage caused by:

(a) Oil sticking to fucus making it susceptible to mechanical damage

(b) Clean-up operations

Supratidal Injuries

--Greater standing crop of Elymus sp. and Carex sp. possibly because of reduced grazing because of oiling or fertilization by oil components (1989 only)

Sediments

--There is evidence that oil is in the sediment:

(a) One sediment trap was pulled to check study progress (DEC) and it did have fingerprinted North Slope crude oil

(b) Anecdotal: As AW#2 study pulls sieves, they see an immediate sheen in at least 3 of the sites that were heavily oiled.

Mussels

--Clean mussels were deployed in the water column of areas that had low or undetectable levels of hydrocarbons. The mussels bioaccumulated hydrocarbons detectable levels of hydrocarbons

MARINE MAMMAL SYNTHESIS MEETINGS
(Includes discussions of damage findings only)

Humpback Whales

--1989 Reproductive rate 2nd lowest since studies began in 1980. As of synthesis meeting, no cow/calf pairs were observed in PWS.

Killer Whales

--1989 population estimates in PWS lower than in previous years.

--AB pod missing 7 animals since 1989, AE pod missing 4 animals in 1990, AN pod missing 22 animals since 1989.

--Killer whales worth $500,000 apiece to aquariums (?)

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Harbor Seals

--Seals were oiled, sometimes entirely covered with the only clean areas around eyes and nipples of lactating females. Pups, in some cases, were totally oiled within hours of birth probably from contact with oiled fucus. (Did not appear to affect bonding and growth.)

--Very preliminary data analysis showed very high concentrations of hydrocarbons in the tissue and bile of harbor seals within PWS when compared to harbor seals in the Gulf of Alaska. (However, this initial analysis does not differentiate between oiled and non-oiled areas, only geographic areas.)

	Prince Wm Sound	Gulf of Alaska
tissue samples	n=7	n=6
Low molecular weight aromatic hydrocarbons (LAC)	50.3	2.7
High molecular weight aromatic hydrocarbons (HAC)	22.2	0.6
bile samples	n=11	n=6
phenanthrene	41,955	2,822
naphthalene	72,200	8,317

--Population decline has been occuring since 1984, however, decline was equal in all areas of the sound through 1988. In 1989, decline was greater in oiled areas.

--Some oiled harbor seals were observed to be lethargic and unwary which is atypical seal behavior.

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JULY 25, 1990
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MEMORANDUM

SUBJECT: COASTAL HABITAT STUDIES MEETING OF JULY 23 & 24, 1990

FROM: KIRSTEN BALLARD, ~~AOO/A~~

TO: BRIAN ROSS, RESTORATION PLANNING TEAM LEADER, AOO/A

John Strand, through Linda, requested that I attend the above mentioned meeting since he would not be able to attend for the work group. The following is a brief summary of some of the highlights of the workshop.

-Many of the NRDA studies are seriously backlogged in sample sorting, processing, analysis and data interpretation. Most will not have initial information from samples taken in 1989 until December of 1990. This could have serious repercussions if the case goes to court before all data is processed. However, the case is not scheduled to go to court until April of 1991 (currently). This should present no problem for the 1989 data. Comparing 1989 data to 1990 data may be a problem, however.

-Most to all samples being analyzed are currently undergoing GC/MS (gas chromatography/mass spectrometry). It was proposed to use ultraviolet florescence (UVF) as an initial screen. It is as or more sensitive than GC/MS for detecting the presence of petroleum hydrocarbons and will flag which samples really need to undergo the extensive data interpretation of GC/MS. UVF has the additional advantage of not destroying the sample. Using UVF should shorten sample processing considerably. Let's hope this procedure is implemented.

-Several groups went out ahead of the spill and collected pre-spill data, and other pre-spill data also exists. It was proposed that all pre-spill data be compiled and/or catalogued for easy reference for the group.

-It has been noted that although the shorelines are being recolonized by the heartier species (fucus, mussels, barnacles, etc.), the diversity of both flora and fauna on oiled sites is not at pre-spill conditions. Spp. such as limpets, littorines and some algae have not returned to some areas. The physiological condition and reproductive potential of some of the spp. that have returned, are considered to be poor.

-A study is being conducted where rocks are being scraped clean of all algae, etc. and observations/time lapse photography is being used to measure the degree and order of recolonization.

-Much effort and consideration has been given towards matching control sites and oiled sites regarding freshwater influence, beach type, etc. Many control sites have been dropped from many of the studies because of saline difference/fresh water influence.

-Mechanical damage has been noted on an eel grass bed in Sleepy Bay. This may be worth looking at in terms of a restoration project.

-The dramatic differences between control sites and oiled sites noted last year has been noted to be less dramatic this year in the subtidal study.

-Subsistence sampling of little neck and butter clams in PWS has demonstrated "significant levels" of hydrocarbons. It was noted, however, that the levels of hydrocarbons in the clams sampled does not exceed the levels of hydrocarbons in smoked clams.

-The levels of petroleum hydrocarbons noted in the water column in the "Distribution of Hydrocarbons in the water column" study by NPS, NOAA and DEC has been noted to be in the <5-10 parts per trillion range upon chemical analysis. Concurrent with the chemical analysis of the water column is the placement of mussel cages at varying depths. Analysis of the mussel tissues has shown a bioaccumulation of petroleum hydrocarbons in the parts per million range. It could be hypothesized that although there "is no evidence of oil in the water column in water chemical surveys", there is oil in the water column below chemical detection limits which has a propensity towards bioaccumulation.

-There is evidence that pink salmon fry have ingested oil. Since they are surface feeders, it is likely that they gulped the oil at the surface. This was noted as "other information".

-DEC has placed sediment traps in various bays, to measure to some degree whether or not there is oil at the bottom. Some traps will be placed in conjunction with the NOAA mussel cages, others near berm relocation sites. Some of the traps were left out over the winter this last year and have registered some oil after chemical analysis.

-The final Microbiology report from Lindstrom, Brockman, Bradock & Brown has been issued to NOAA. 44 sites were visited with the *Fairweather* and sampled for the presence of oil consuming microbes and degree of activity. No adjustments were made for fresh water influence, some site selection was made so that sampling would improve the chance of finding bacteria (sampling sandy/muddy areas instead of cobbles and boulders). A shift in the population to hydrocarbon degraders is apparent using the MPN.

-Other information: Mussel bivalve studies have indicated that the oxidation products of crude oil/petroleum hydrocarbons are present in higher concentrations than parent compounds. These are less florescent than the parent compounds and analytical techniques are in need of being refined for better study of these oxidation products.

-A new study for 1990 to measure the toxicity, the persistence and existence of oil shows that contamination can be measured to 20 m in sediments under water. Visible oil has been noted to depths up to 6 m in North West Bay and Bay of Isles and Herring Bay (sheen noted upon screening of sediments).

-The statistical workgroup will make themselves available to all PI's as needed. There is the possibility of gearing up to do statistical analysis on Exxon data once obtained in the discovery process. They will be looking for Type I and Type II statistical errors. They also recommend that all existing literature be looked at critically from a statistical standpoint.

-Dave Gibbons asked everyone what their reaction would be if they cut funding tomorrow. You can guess what happened. The final standpoint was that if the government stopped funding right now, then from a legal standpoint, it would discredit the entire government effort and damage case (since there are no more studies, there must not be any more damage), as well as the loss of qualified data, personnel and information for other studies.

-It was suggested that the science group examine and critique the validity of the Exxon document *Natural Recovery of Cold Water Marine Environment after an Oil spill.* Whether and how the group should respond was not determined at this meeting.

-Liza McCracken discussed the time scale for court, preliminary stage of discovery, acceptable degrees of scientific certainty for court, that the burden of proof is on the government, that circumstantial evidence may be ok in court, and that the Exxon theory of Natural Recovery time and how it relates to restoration dollars and the number of years to recovery. Basically, it all boiled down to we should have gone to court/settled already and the longer we wait, the more it will probably cost the restoration effort. No one really knows what will happen in court.

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8/22/90

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MEMORANDUM

SUBJECT: Marine Mammal Synthesis Meeting, 8/15/90

FROM: Kirsten Ballard, AOO/A

TO: Brian Ross, Restoration Planning Team Leader, AOO/A

The meeting started at 9:00am. I was attending the weekly FOSC Ops meeting until 9:30. Nancy Menning took notes of the first half hour. The first half hour consisted of the why's and how it all fits into the Damage Assessment (DA) process and how it builds our case.

One member of the Marine Mammal DA team was not able to attend due to weather. The participants agreed to cut the meeting down to one day only (rather than the day and a half which was originally planned).

Harbor Seals

The different ways that seals could encounter oil was evaluated first.

- -Through oil on the water's surface, both thick and thin.
- -Along shoreline (this is where most seal-oiling occurred)
  - -Oiled fucus. This especially occurred on pups over the summer of 1989.
  - -Oiled rocks.

It was further observed that :

- -The eyes of seals, and the nipples of lactating females, were often the only clean areas on oiled harbor seals.
- -Seals which were in the habit of frequenting an area would continue to frequent that same area. Consequently, oiled animals were not observed to move from an oiled area to an un-oiled area. The animals did not avoid the oil, as was hoped.
- -Animals were affected by cleanup activities. They would not haul out in areas where increased human activity was taking place. This further complicated matters since they would not just "go to another area".
- -"Sick seals" visibly oiled and un-oiled animals, would allow people to approach closely. This is highly unusual behavior for these cautious creatures.

-Some opacity was noted in the eyes of some animals (possibly indicating cataracts, which is common when mammals encounter petroleum products). It was also noted that blind seals have been noted to function quite well in the wild.

Population counts are typically performed in PWS in the fall when seals molt. It is assumed that most of the seals are hauled out during this time and population counts will, therefore, be optimum. Spring is another time when surveys are performed (in other areas) to measure the spring pup to adult ratio. No spring numbers are available for PWS, although a population count was performed in 1990.

Tissue samples taken from seals were compared between PWS and Gulf of Alaska animals:

		PWS		Gulf	
Livers	LAC	50.3	(n=7)	2.7	(n=6)
	HAC	22.2 (mostly pups found dead)		0.6	
	Bile, PHN	41,955	(n=11)	2822	(n=6)
	Bile, NPH	72,200		8317	

(LAC-Low molecular weight aromatic hydrocarbons; HAC-High molecular weight aromatic hydrocarbons; PHN-phenanthrine; NPH-napthaline)

A 40% general population decrease has been noted from 1984-1988. The population decrease in 1989 was greater (relatively speaking) in oiled areas and greater than the general average population decrease that has been measured.

The numbers of seals this year appears to be about the same as last year based on this year's spring count.

It has been recognized that the samples taken in 1989 are irreplaceable. All are being saved.

A plea for toxicology experts was made. Interpretation of toxicological effects on seals, and other animals, may be best if performed by toxicologists.

Grey Whales

Much of the data collected in the field has yet to be compiled. The grey whale report consisted of a body count comparison. Out of 37 total cetaceans found beached in 1989, 26 of them were grey whales. This year, 1990, 22 grey whales have been beached so far.

Humpbacks and Killer Whales (Orcas)

Humpbacks

50-60% of the approximately 1500 total estimated population of Humpback whales come to Alaska. Of these animals, an average of 30-40 animals make their home in PWS. 59 individuals were counted in the sound in 1989. It is believe that most of the loss and injury which has occurred for the Humpback in PWS is through displacement.

The study involves the counting and identification of individuals in PWS and southeast Alaska (SEAk) (there is some movement of individuals between PWS and SEAk). Then the objective is to test whether or not the that the distribution and abundance of Humpback whales has changed.

A change in the distribution of the 59 individuals observed in 1989 may have been noted. The whales were observed in 1988 to spend most of their time in lower Knight Island Passage. In 1989, there was a noted decrease in usage of that area. This may have been due to the increased boat activity. No whales were observed in oil, and the decrease in usage of Knight Is. Psg. may have been due to the whales avoidance of the oil.

No cow-calf pairs have been observed this year. However, all the field data is not in yet.

Orcas

Have been sighted throughout oiled areas. They did not avoid the oil. In fact, it was reported that even when a boat was placed in the Orca's path to try to prevent them from swimming through oil, the Orcas would swim under the boat and then through the oil.

260-280 Orcas have been observed to frequent PWS. Of these, there are resident an transient pods. The resident pods spend a greater percentage of their time in a particular area of the sound. The transients will move about a home range which can include areas from Kodiak to SEAk. The resident Orcas have been known to steal fish from long-line gear, are found with mostly fish remains in their stomachs (when animals have been beached or taken) and are less intimidated by the presence of humans. Transient animals have been found with sea lion remains in their stomachs and tend to interact less with humans.

Objectives of the DA study are to identify individuals, lost members (from historical data) distribution and abundance-did it change-, measure the pod structure and integrity, mortality and natality.

Of the 8 resident pods which represent 143 animals in 1990, and the 4 transient pods with 34 individuals, 177 total animals were observed in PWS this year. The percentage of resident to transient remains the same, but the total number of animals is down from previous observations.

Measuring animals missing from resident pods is more infallible than those of transient pod since more is known about resident pods. For example, 7 animals from AB pod are missing. Of the 34 animals in this pod, 2 of the missing animals were reproductively active females who left behind 2-3 year old calves. This represents a mortality of 19.4%, which is unheard of. The integrity of Orca pods is intense. There is little to no communication between pods, and no individuals have been observed to pod-jump. A mother Orca can be observed with all her offspring, and her offspring's offspring. If one is in doubt about the identify of an individual in a pod, that individual can often be identified purely by its association with another animal. Therefore, it is highly unusual that these missing animals should have just "gone on vacation", and if they do not return by the end of this season, they most probably are deceased. 24 years of data collected on Orcas in British Colombia (BC) and several years of data collected in PWS support this hypothesis.

Another assumption which can be made, however, is that since many of the resident animals are know to steal fish from fishermen, they are sometimes shot at. It is difficult to kill a killer whale, though, and there are records of beached animals which have bullets in them gauged to be there for 10 years or more. In other words, they're hard to kill. The other problem with supposing that the total of approximately 32 animals missing were shot, is that there were no fishing seasons in 1989. Also, with the increased presence of humans, enforcement personnel and environmental activists, someone shooting killer whales would not have gone unnoticed.

A total of 5 pods were observed to be in oil. Greater numbers of animals or pods could have been oiled.

Usually, in September, all the Orca pods get together in the lower part of PWS. Perhaps this is where genetic exchange occurs. This annual "Orca party" did not occur in 1989.

3 Orcas have been stranded/beached this year. This number is 2-3 times the usual number of strandings which usually occur (based on BC data). Tissue samples have been taken, and 2 of the animals have been tentatively identified.

Typically, muscle tone keeps an Orca's dorsal fin erect. Two adult males have been observed with flopped-over dorsal fins. This has been observed in captivity, and occasionally in the wild. It is not a common occurrence. Whether or not it is the result of exposure to crude oil is not clear at this point.

An Orca rubbing beach at point Nowell (near Eshamy Bay on the SW side of Knight Island) was oiled, and whales have been observed rubbing there.

One goal of the DA study is to catalogue the life history of each individual and every pod, as has been done in BC.

An acoustic study is being performed on animals in captivity. This is to obtain some indication of the effect that the increased vessel activity of 1989 and 1990 may have had on Orcas. An audiogram of "normal" captive whale sounds will be made first. Then the animals will be exposed to recordings of cleanup activity, boat sounds, etc. Another audiogram will be compared to the first to see how the cleanup sounds may have affected the ability of the whales to produce, receive, etc. sounds and communicate in general.

Sea Lions

Most of the data on sea lions has yet to be compiled.

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IMMEDIATE IMPACT OF THE "EXXON VALDEZ" OIL SPILL ON MARINE BIRDS

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ABSTRACT.—On 24 March 1989, the oil tanker "Exxon Valdez" spilled 260,000 barrels of crude oil in Prince William Sound, Alaska. Oil eventually drifted over 30,000 km² of coastal and offshore waters occupied by approximately one million marine birds. More than 30,000 dead birds of 90 species were retrieved from polluted areas by 1 August 1989. Of those identified, murres (74%), other alcids (7.0%), and sea ducks (5.3%) suffered the highest mortality from oil, and most (88%) birds were killed outside of Prince William Sound. A colony of 129,000 murres at the Barren Islands was probably devastated. Another 7,000 birds were retrieved between 1 August and 13 October, but most of those birds appeared to have died from natural causes. This later die-off was composed largely of shearwaters and other procellariids (51%), gulls (22%), and puffins (14%). Based on aerial and ship-based surveys for populations at risk, and extrapolating from the number of dead birds recovered, we estimate that the total kill from oil pollution was from 100,000 to 300,000 birds. *Received 8 September 1989, accepted 27 December 1989.*

THE NORTHERN Gulf of Alaska, including Prince William Sound and Cook Inlet (Fig. 1), hosts some of the largest populations of marine birds in North America. Millions of pelagic seabirds, including fulmars, petrels, cormorants, kittiwakes, murres, and puffins, breed at major colonies on or near the Kenai and Alaska peninsulas and Kodiak Island (Bailey 1976, 1977; Sowls et al. 1978; Hatch and Hatch 1983). Millions of Short-tailed and Sooty shearwaters (*Puffinus tenuirostris* and *P. griseus*) migrate through the area in summer (Gould et al. 1982). Hundreds of thousands of coastal marine birds, including loons, grebes, sea ducks (e.g. scoters, eiders, Oldsquaw [*Clangula hyemalis*]) and murrelets, winter in Prince William Sound and sheltered bays throughout the area (Forsell and Gould 1981, DeGange and Sanger 1986).

On 24 March 1989, the oil tanker "Exxon Valdez" went aground in Prince William Sound and spilled more than 260,000 barrels of Alaska North Slope crude oil. That constituted the largest oil spill in North America to date, and the largest spill ever to occur in an arctic environment. During the weeks that followed, currents and prevailing winds pushed oil out of Prince William Sound and into the Gulf of Alaska, where it eventually drifted 750 km to the southwest. Approximately one million marine birds occurred in the affected region. Initially, the oil formed a large fluid slick that coated all shorelines and wildlife in its path. Later, oil mixed with seawater to form a "mousse" emulsion and broke up into numerous smaller patches.

The magnitude of bird mortality after an oil spill depends on the size of local bird populations, their foraging behavior, whether populations are aggregated or dispersed at the time of the spill, and on the quantity of oil spilled and its persistence (NRC 1985). After contact, oil can kill birds by removing the insulative property of their feathers (causing hypothermia) and through toxicological effects after ingestion (Peakall et al. 1982, Fry and Lowenstine 1985). The most vulnerable birds include loons, grebes, sea ducks, and alcids because these species spend most of their time swimming on the sea surface and often aggregate in dense flocks.

We report here on the movement and distribution of oil following the "Exxon Valdez" spill, marine bird populations at risk, and the number

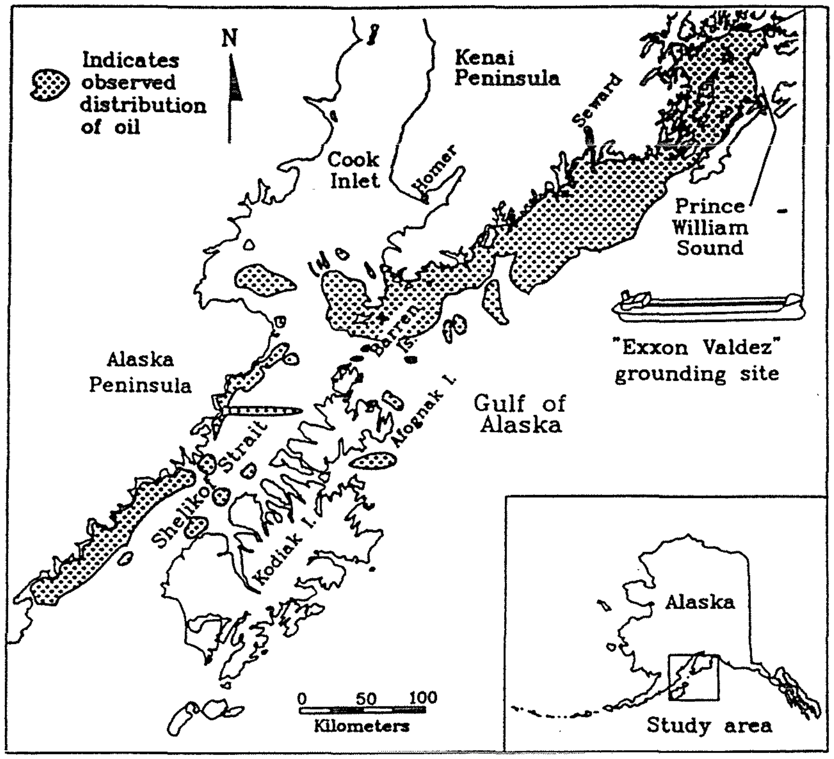

Fig. 1. Composite map of the distribution of "Exxon Valdez" oil observed on aerial overflights between 24 March and 20 May, 1989. Absence of oil on map does not necessarily mean that oil did not occur in an area—only that it was not observed (e.g. due to weather constraints on flying or visibility).

and species composition of dead birds retrieved from the affected area. We speculate on the limits of total mortality.

Methods

Dead birds were retrieved from shorelines and open waters in Prince William Sound, and along the Kenai Peninsula, Kodiak Island, and Alaska Peninsula, by fishermen under contract to Exxon Oil Company and personnel from the U.S. Fish and Wildlife Service (USFWS), Alaska Department of Fish and Game, National Parks Service, Alaska Department of Environmental Conservation (ADEC), and the International Bird Rescue Center. Corpses were identified (Ainley et al. 1980) and processed by USFWS and Minerals Management Service personnel at receiving centers in Valdez, Seward, Homer, and the town of Kodiak between 25 March and 13 October, 1989. Numbers of dead birds were grouped for illustrative purposes (Fig. 2) according to their proximity to major islands or bays. Only birds retrieved before 1 August, and birds after 1 August known to be oiled, were included in Figure 2.

Assessments of species and populations at risk are based on historical surveys (Dwyer et al. 1975; Bailey 1976, 1977; Sowls et al. 1978; Manuwal 1980; Forsell and Gould 1981; Gould et al. 1982; Hogan and Murk 1982; Hatch and Hatch 1983; Nishimoto and Rice 1987), and on aerial and boat-based surveys of the affected area initiated by the USFWS after the spill. An aerial survey of all shoreline habitats in Prince William Sound, using methods described by Hogan and Murk (1982), was begun on 28 March 1989 and completed by 1 April. Shoreline habitats in the sound that became oiled after the first survey (Fig. 1), and adjacent un-oiled shorelines, were resurveyed on 8 April. The same shorelines were surveyed for a third time on 20 April. An aerial survey of all shoreline habitat on the Kenai Peninsula from the western edge of Prince William Sound to Homer, including the Barren Islands, was completed on 6 April. An aerial survey (456 km) of waters $\leq$40 km south of the Kenai Peninsula, consisting of seven parallel north-south transects from Prince William Sound to the Barren Islands, was completed on 29 April. Correction factors were applied to aerial survey bird counts to adjust for visibility bias of different species (W. Butler unpubl. data). Ship-based surveys (408 ten-min transects) were conducted south of the Kenai Peninsula, in lower Cook Inlet,

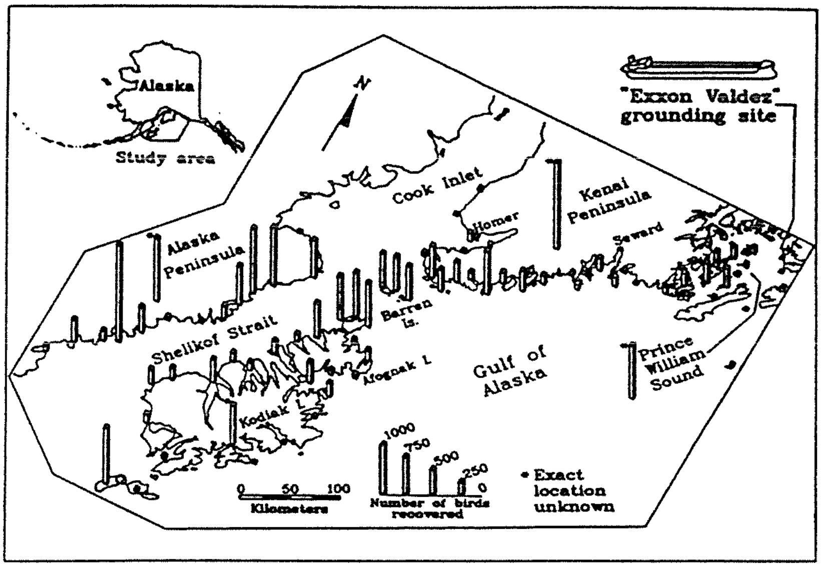

Fig. 2. Distribution and abundance of dead birds retrieved from areas affected by the "Exxon Valdez" oil spill. Bars with asterisks indicate the number of birds retrieved from regions (e.g. Prince William Sound) without specific information on where they were found. Figure includes only those birds recovered before 1 August 1989 (see Table 1).

and in Shelikof Strait from the USFWS vessel "Tiglax" between 1 and 7 May 1989 using a standard protocol for counting birds at sea (Gould et al. 1982).

Historical data on the distribution and abundance of marine birds in the Gulf of Alaska were collected between 1975 and 1986 as part of the Outer Continental Shelf Environmental Assessment Program (OCSEAP). Data collected in the months of March, April, and May were used to estimate numbers of marine birds at risk in a 30,052 km^2 area delimited by the farthest extent of oiling observed in the Gulf of Alaska. Mean bird densities were calculated for 30′ latitude-longitude blocks, and numbers of birds within a polygon defined by the spill were estimated using CAMRIS (Computer Aided Mapping and Resource Inventory System, Ecological Consulting Inc., Oregon). Survey data were available for 76% of blocks enclosed or intersected by the perimeter of the spill zone.

A corpse drift experiment was initiated on 6 May 1989 by releasing 100 tagged seabird carcasses into the water 10 km northeast of the Barren Islands. The heavily oiled carcasses (89 murres, 6 murrelets, 2 guillemots, 1 scoter, 1 cormorant, and 1 kittiwake) were obtained 1-3 days earlier from beaches on the Alaska Peninsula. Birds were tagged with notecards encased in plastic and attached to a leg with nylon string.

The movement of oil was monitored on more than 300 aerial surveys by the Alaska Department of Environmental Conservation and the National Oceanic and Atmospheric Administration (NOAA). Maps of oil distribution were updated regularly at ADEC headquarters in Valdez (by Kendziorek). We used overflight observations made until 20 June 1989 to generate our composite map (Fig. 1). Weather information was provided by NOAA and the U.S. Coast Guard. Information on ocean currents in the northern Gulf of Alaska was obtained from Schumacher and Reed (1980) and Royer (1981).

Results

Prince William Sound.—The "Exxon Valdez" grounded and began leaking oil in the northeastern corner of Prince William Sound shortly after midnight on 24 March 1989. Prevailing currents and light to moderate northeast winds on 24–26 March, and strong northeast winds on 27–28 March, pushed oil rapidly through and out of the southwestern corner of the sound (Fig. 1). The slick engulfed several small islands and portions of larger islands in its path. During this phase, the oil remained fluid, and coated shorelines and birds with a smooth and liquid layer.

Approximately 41,000 live birds were counted along the entire shoreline (coast and islands) of Prince William Sound during aerial surveys conducted between 28 March and 1 April 1989. Half were in the area affected by oil. Similar species and numbers (44,000) were found on comparable aerial surveys conducted in 1971 (Hogan and Murk 1982), suggesting little change in the bird fauna during the 17-yr interval between surveys. However, bird numbers are generally underestimated on aerial surveys (Bajzak and Piatt 1990) and our aerial surveys covered little open-water habitat in Prince William Sound. Therefore, boat-based surveys of both shoreline and open-water habitats of the sound in 1972–1973 (Dwyer et al. 1975) provide a better indication of species and populations at risk at the time of the spill. Boat-based shoreline surveys conducted in 1984–1985 (Irons et al. 1988) corroborate the surveys of Dwyer et al. (1975). The majority of birds (346,000 ± 58,000) observed in spring on boat-based surveys were sea ducks (37.2%), gulls (25.2%), cormorants (6.4%), murrelets (6.3%), grebes (3.3%), murres (1.8%), loons (1.4%), and guillemots (1.2%). On all surveys, bird populations were dispersed throughout Prince William Sound, although gulls and sea ducks (other than Harlequin Ducks, *Histrionicus histrionicus*) were concentrated at the heads of bays and inlets.

Approximately 3,400 birds were retrieved from areas engulfed by oil in Prince William Sound (Fig. 2). Most carcasses were completely coated by oil. Although the first dead, oiled birds were retrieved from near the spill site (Bligh Island) on 25 March 1989, it took several days for the oil to affect bird populations to the southwest, and several more days for investigators to mount a search of remote shorelines. Hundreds of birds were recovered weekly over the period 5 April to 6 June, but after 6 June only 64 decomposed birds were retrieved from Prince William Sound.

The species composition of dead birds (Table 1) was different than the composition of populations at risk (above). Proportionately fewer gulls and sea ducks, and proportionately more loons, grebes, cormorants, murres, and murrelets, were killed by oil than were present in the sound. We saw Bald Eagles (*Haliaeetus leucocephalus*) scavenge dead and dying oiled birds, and many of the 32 eagle carcasses returned to Valdez were oiled. Although we also saw gulls scavenge carcasses, and we saw hundreds of gulls with oiled plumage, relatively few were found dead.

Between one precontact (28–30 March 1989) and two postcontact (8 and 20 April) aerial surveys around heavily oiled islands, local populations of loons, grebes, cormorants, and sea ducks declined by 44–84%, whereas those of gulls and eagles increased by 87–240%. In unoiled bays and inlets of the affected area, all species increased in abundance (24–340%), except for Bald Eagles, which declined by 21% on the second postspill survey.

Kenai Peninsula.—Between 31 March and 6 April, approximately 2 million gallons of oil escaped from Prince William Sound into the Gulf of Alaska. Oil was entrained in the Alaska Coastal Current and, aided by moderate north and northeast winds, spread to the west but remained 20–30 km offshore of the south coast of the Kenai Peninsula. Between 7 and 9 April, light to moderate south and southwest winds pushed oil north to engulf offshore islands, capes, and headlands along the full length of the south Kenai Peninsula (Fig. 1). In the early part of this phase, oil remained liquid and formed a nearly continuous slick. Later, oil began to emulsify, and the slick broke up into several large patches.

At least 36,250 birds occupied coastal habitats of the southeastern Kenai Peninsula (east from Gore Point) during a precontact aerial survey conducted on 6 April. Historical surveys (Bailey 1977, Sowls et al. 1978) recorded ca. 116,000 seabirds at colonies in the same region during summer. Postcontact aerial surveys conducted on 29 April revealed densities of ca. 10 birds/km^2 in offshore waters up to 40 km south of the Kenai Peninsula.

Sea ducks (41.9% of all coastal birds) were abundant near shore, and murres (mostly Common Murres, *Uria aalge*) were numerically important species in both coastal (34.1%) and offshore (19.5%) waters. Gulls (21.9%) and cormorants (6.0%) were common inshore, whereas procellariids (13.4%), gulls (14.8%), phalaropes (11.4%), and other pelagic species predominated offshore. Approximately 28,000 Common Murres breed at three colonies on the southeast Kenai Peninsula (Sowls et al. 1978), and murres were observed attending these colonies by 9 April (precontact). Although tens of thousands of Tufted and Horned puffins (*Fratercula cirrhata* and *F. corniculata*) breed at colonies along the coast (Sowls et al. 1978, Nishimoto and Rice 1987), they evidently did not arrive in the area much before 29 April, when Tufted Puffins made up 16.6% of birds observed offshore.

Approximately 6,200 birds were found dead

TABLE 1. Proportions (%) and total numbers of birds retrieved from Prince William Sound (PWS), Kenai Peninsula (KP), Barren Islands (BI), Kodiak (KOD), and the Alaska Peninsula (AP) between 25 March and 13 October, 1989.

Species group	Area					Total before 1 Aug[a]	Total after 1 Aug
	PWS	KP	BI	AP	KOD		
Loons	8.7	1.8	0.3	0.4	<0.1	1.5	<0.1
Grebes	11.8	1.6	0.2	0.3	0.1	1.7	<0.1
Procellariids	0.4	4.8	0.7	1.1	4.9	2.9	50.7
Cormorants	16.0	4.3	0.4	0.6	0.7	3.0	1.0
Sea ducks	24.9	8.4	0.7	1.6	0.7	5.3	0.3
Gulls	1.8	5.5	0.5	1.2	2.4	2.4	21.6
Murres	15.2	58.1	88.3	89.0	84.6	73.7	7.1
Murrelets[b]	11.6	4.9	3.7	0.6	0.5	2.2	2.0
Guillemots	4.7	4.6	1.2	1.6	0.8	2.2	0.4
Puffins	0.0	1.5	0.2	0.2	1.4	0.9	13.8
Other alcids	0.8	1.6	3.6	3.3	2.9	1.7	1.7
Other birds	4.1	2.9	0.7	0.1	0.9	2.5	1.3
Total numbers							
Retrieved	3,358	6,225	2,163	8,881	8,548	29,175	6,940
Identified	2,882	5,174	1,922	8,691	8,200	26,869	6,238

[a] Includes 167 old carcasses that were oiled and apparently killed before 1 August, but retrieved after 1 August. Total does not include 31 oiled birds found on Middleton Island and 1,091 birds that died at oiled-bird rehabilitation centers.
[b] *Brachyramphus* murrelets only.

on shorelines or floating in the water along the Kenai Peninsula between 12 April and 1 August (Fig. 2). At least 31 dead, oiled birds were retrieved from Middleton Island, ca. 150 km south of Prince William Sound. After 1 August, most of the 664 birds recovered along the Kenai Peninsula were not oiled and appeared to have died from natural causes (see below).

As in Prince William Sound, the species composition of birds recovered from the Kenai Peninsula (Table 1) was different from the composition of populations at risk (above). More diving species than aerial species were killed. In contrast to Prince William Sound, there was a marked decrease in the proportions of loons, grebes, cormorants, and sea ducks killed along the Kenai Peninsula, and an increase in the proportions of murres and procellariids (mostly shearwaters) killed.

Barren Islands.—On 10–11 April, a storm in the Gulf of Alaska generated strong northeast winds that dispersed and emulsified the oil. During a period of variable light winds between 12 and 16 April, oil reached the southwestern tip of the Kenai Peninsula, where currents moved it north into Cook Inlet and southwest toward the Barren Islands. Another period of moderate south winds between 17 and 21 April pushed oil into bays and fjords along the Kenai Coast, and drove more oil north into Cook Inlet. Oil lingered in a large area surrounding the Barren Islands and became more weathered and emulsified into "mousse" toward the end of this phase.

Aerial surveys (6 April) indicated that before oil contamination, at least 21,000 marine birds (mostly sea ducks, gulls, and murres) were present along the southwestern Kenai coast (west of Gore Point), and 123,600 birds (79% murres, 20% gulls) occurred near the Barren Islands. Historical surveys indicated that ca. 13,000 seabirds (mostly puffins and Black-legged Kittiwakes [*Rissa tridactyla*]) breed in colonies along this portion of the Kenai coast, whereas much larger populations (150,000 Fork-tailed Storm-Petrels [*Oceanodroma furcata*], 135,400 puffins, 118,000 Common Murres, 11,000 Thick-billed Murres [*Uria lomvia*], and 46,600 kittiwakes) breed at the Barren Islands (Bailey 1976, Manuwal 1980). Coastal and offshore waters around the southwestern Kenai Peninsula and the Barren Islands usually support high densities of marine birds in spring (Bailey 1976, Gould et al. 1982). When oil reached this area, it appears that few puffins had arrived at colonies, whereas murres were gathered in large prebreeding aggregations (Tuck 1961) around the Barren Islands.

Of the 6,200 birds retrieved from the Kenai Peninsula, most came from the southwestern tip (Fig. 2). An additional 2,163 birds (mostly murres) were retrieved from the Barren Islands

(Table 1) between 14 April and 22 August (only 22 birds after 26 May). Ship-based (2 May) and aerial (29 April) surveys conducted near the Barren Islands after oil exposure revealed no large aggregations of murres. However, a flock of ca. 25,000 murres was observed offshore from one of the islands on 22 May (Bailey 1989). Murre densities (1.4 birds/km^2) were lower on post-contact ship-based surveys near the Barren Islands than in any other area surveyed from the south Kenai Peninsula (9.9 murres/km^2) to the Alaska Peninsula (20.6 murres/km^2). Census data obtained in summer 1989 indicates that murre attendance at colonies on the Barren Islands was 62% lower in 1989 than in 1979.

Kodiak and the Alaska Peninsula.—Between 22 and 28 April 1989, moderate to strong southeast winds limited oil tracking surveys in lower Cook Inlet and Shelikof Strait. However, it was apparent that winds and prevailing currents drove oil into Shelikof Strait during this period because aerial surveys on 28 April found mousse concentrations along 300 km of the Alaska Peninsula (Fig. 1). In subsequent aerial and shoreline surveys, oil mousse had washed up on beaches throughout the area, sometimes in thick mats which blanketed large portions of the shoreline. On 8–9 May, strong northwest winds drove mousse southeast across Shelikof Strait and deposited it on western shorelines of Kodiak and Afognak islands.

Postspill (3–6 May) ship-based surveys revealed densities of 28.4 birds/km^2 along the coast of the Alaska Peninsula, 14.6 birds/km^2 in Shelikof Strait, and 65.4 birds/km^2 near the Semidi Islands (ca. 120 km southwest of Kodiak Island). Extrapolating from areas (Gould et al. 1982) of ca. 7,000 km^2 along the coast (<200 m depth) and 6,600 km^2 in the strait, ca. 295,000 birds occupied Shelikof Strait. Again, murres dominated (65%) among species observed, followed by procellariids (15.4%, mostly Northern Fulmars [*Fulmarus glacialis*]), and Glaucous-winged Gulls (4.4%, *Larus glaucescens*). Sowls et al. (1978) recorded 308,000 seabirds breeding at colonies along the eastern Alaska Peninsula and 38,615 seabirds on Afognak Island. Predominant species included murres, Tufted Puffins, gulls, and kittiwakes. In addition to seabirds, several hundred thousand sea ducks (mostly Oldsquaw, scoters, eiders, and Harlequin Ducks) winter in coastal habitats of the Kodiak Archipelago and Alaska Peninsula (Forsell and Gould 1981).

A total of 17,429 birds were found dead on beaches of the Alaska Peninsula and the Kodiak Archipelago before 1 August (Table 1, Fig. 2). The proportion of murres among the birds recovered was higher than in other regions. Only 6 of 802 birds we examined on 3–5 May were fresh kills; the rest were old, mousse-coated carcasses deposited in greatest numbers where mousse was concentrated on beaches. It appeared that birds and mousse had drifted together. An additional 6,199 birds were recovered after 1 August, but most apparently died of natural causes (see below).

Three of 100 tagged carcasses released on 6 May northeast of the Barren Islands were recovered 240 km southwest on the Alaska Peninsula 12, 30, and 55 days later. All three carcasses (murres) were recovered on the same beaches (in Puale Bay) from which they had been retrieved before tagging.

Mortality of birds during summer and autumn.—In June and July, small patches of mousse, sheen, and tar balls were observed at sea as far southwest as the Shumagin Islands (ca. 400 km southwest of Kodiak) and throughout the entire contaminated area. However, no large oil patches were observed at sea after May. It appeared that relatively few birds were killed by oil after May because recoveries of affected species diminished greatly in June and July (Fig. 3, note that processing lagged mortality by several weeks in the early stages of the spill).

During August and September, hundreds of seabirds were recovered weekly on Kodiak Island and along the Alaska and Kenai peninsulas (Fig. 3). Some of these recoveries (totaling 6,940) were old, decomposed birds that were probably killed by oil in April and May (e.g. 702 unidentifiable sea ducks and 440 murres), but most had died more recently. The die-off contained chiefly surface-feeding species that were little affected by oil in April and May (e.g. 2,751 shearwaters, 331 storm-petrels, 362 *Larus* gulls, and 984 Black-legged Kittiwakes). Most of the 863 puffins recovered were recently fledged young (Sanger 1989). Field observations (D. Zwieflehofer and G. Sanger pers. comm.) and preliminary results of necropsies and contaminant analyses (E. Robinson-Wilson and T. Early pers. comm.) indicated probable death from starvation (no fat, low body mass, empty stomachs) rather than from oil contamination (no trace of external oil or internal hydrocarbon residues).

Populations at risk in the entire spill zone.—We estimated populations at risk from three independent data sources.

1. In aerial and boat-based surveys conducted after the spill (discussed above), at least 585,000 marine birds were present in the region from Prince William Sound to south of Shelikof Strait. From that total, we subtracted those species that were only slightly affected by oil (125,000 fulmars, petrels, dabbling ducks, gulls, kittiwakes, puffins, etc.), and added ca. 200,000 sea ducks that winter in coastal areas of Kodiak and the Alaska Peninsula (Forsell and Gould 1981). We estimate that 660,000 birds in high-risk species were in the region. Oil slicks covered approximately half of this region. Therefore, ca. 330,000 marine birds with high vulnerability to oil were in areas heavily polluted by oil.

2. Using historical OCSEAP data on marine bird densities in the Gulf, we estimated that 982,600 marine birds were in a 30,052 km² area circumscribed by the spill perimeter outside of Prince William Sound. However, procellariids (51.4%), gulls (12.3%), and puffins (8.5%) accounted for most of that total. Approximately 273,000 birds were at high risk (0.7% loons, 0.2% grebes, 6.1% cormorants, 16% sea ducks, 71% murres, 4.1% murrelets, and 1.8% guillemots). Combined with historical data from Prince William Sound (Dwyer et al. 1975), the latter estimate indicates that 370,600 birds of high-risk species were in the oil-impact zone.

3. Most of the birds affected were colonial seabirds and historical colony census data obtained during summer months (Sowls et al. 1978) can be used to estimate seabird populations at risk in spring 1989 because many species (e.g. murres) were observed attending colonies during the weeks immediately following the spill. Approximately 878,000 seabirds breed at colonies directly affected by the spill. We subtracted the numbers of low-risk species to estimate that 283,000 seabirds (of which 243,000 were Common Murres) were at high risk.

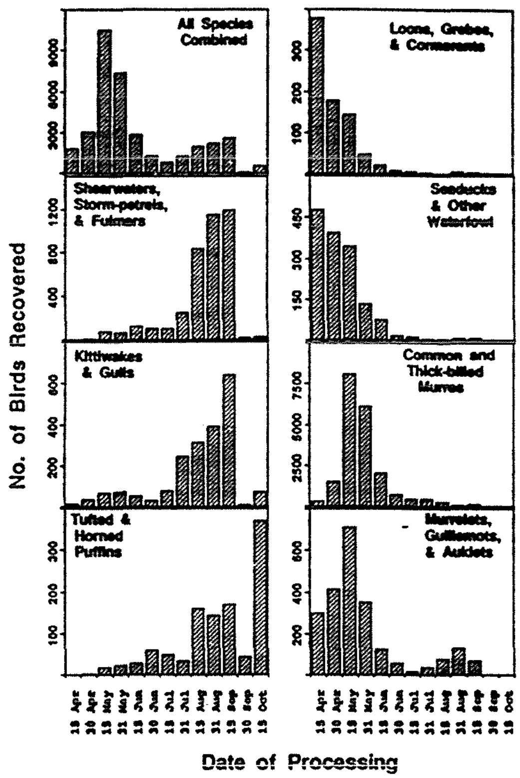

Fig. 3. Numbers of different bird taxa recovered and processed at USFWS receiving centers from April to October, 1989. Note that processing dates usually lagged recovery dates by 1–3 weeks, and that recovery dates lagged mortality by 0–4 weeks. Dates of processing given on the *x*-axis include the 2-week interval preceding the date shown.

Discussion

Bird recoveries.—Between 25 March and 1 August, ca. 30,000 oiled birds were retrieved from the entire affected area. However, it is likely that some of these birds died of natural causes and were exposed to oil while on beaches or floating at sea (Ford et al. 1987). Of 1,888 birds brought to oiled-bird rehabilitation centers, 1,091 died and the remainder were treated and released. Field observations, videotape recordings, and anecdotal reports also indicate that several thousand oiled birds are unaccounted for in our analysis because they were buried, burned, or lost during beach-cleaning and oil-skimming operations. Thus it is impossible to determine the exact number of birds that were killed by "Exxon Valdez" oil and later found, but we conclude that 30,000 is a minimum number.

Most birds retrieved after 1 August were unoiled individuals of surface-feeding species that apparently died of starvation. The observed mortality was similar to a seabird die-off that occurred in Gulf of Alaska and Bering Sea waters in 1983 (Nysewander and Trapp 1984, Lobkov 1986). In that event, tens of thousands of adult shearwaters, kittiwakes, and other seabirds died of starvation during the months of August and September, and kittiwakes exhibited near-total breeding failure throughout their range in Alaska (Hatch 1987). Widespread breeding failure of kittiwakes has occurred in other years before and after 1983, including 1989 (pers. obs., S. Hatch and A. L. Sowls pers. comm.). Thus, neither the kittiwake breeding failure nor the die-off of adult seabirds and young observed in August and September 1989 should be confused with the known effects of the oil spill.

Most birds (88%) killed by oil were retrieved outside of Prince William Sound. We conclude that the distribution and species composition of birds recovered in the Gulf of Alaska were largely determined by the diminished lethal effects of oil after late April (when oil emulsified into mousse), and because most birds found on Alaska Peninsula and Kodiak Island beaches before 1 August were killed near the Barren Islands and southwestern Kenai Peninsula in April and drifted subsequently with mousse patches to the beaches on which they were found.

Several lines of evidence support our conclusions. First, there was little difference in the species composition of birds retrieved from the Barren Islands, Alaska Peninsula, and Kodiak Archipelago despite major differences in composition of local avifauna (e.g. approximately 100 times more murres and 10 times fewer cormorants breed on the Barren Islands than the Kodiak Archipelago). Second, if significant oil mortality had occurred after April, we would have observed far more cormorants and puffins among recoveries in the Gulf because they were abundant and vulnerable in May through July. Third, most bird carcasses recovered from Alaska Peninsula and Kodiak Island beaches were decomposed. Presumably they had died some weeks before and drifted to those beaches. Carcasses dropped at the Barren Islands in our drift experiment were all recovered weeks later on the Alaska Peninsula. Finally, 60% of all dead birds were recovered from Kodiak Island and the Alaska Peninsula before 1 August, but only 8% of all live birds were recovered there by that date.

Estimated total losses.—The number of birds recovered on beaches after an oil spill represents a fraction of the actual mortality (Ford et al. 1987). Once killed at sea, birds may drift away from coasts and never wash ashore, sink before reaching shore, wash up on inaccessible shorelines and not be discovered, wash up on accessible beaches but get buried or scavenged before discovery, or wash up on a beach but be overlooked (e.g. because of small size or encasement in heavy oil). If search effort and all the above variables were quantified, it would be possible to calculate accurately the number of birds killed at sea from the number recovered on beaches. Although we presently lack estimates for most variables, we can make a preliminary assessment based on data obtained after this spill and from other studies.

It is known from drift experiments conducted elsewhere (Coulson et al. 1968; Hope-Jones et al. 1970, 1978; Bibby and Lloyd 1977; Bibby 1981; Page et al. 1982; Threlfall and Piatt 1983) that relatively few birds killed at sea ever reach shore. Experiments with crude-oil saturated seabirds (Burger 1989) indicated that many oiled carcasses sink in salt water, and buoyancy decreases with time (21% of heavily oiled alcid carcasses sank 21–25 days after oiling, 44% after 25–35 days, and 63% after 50–60 days). Freshly oiled alcid corpses may sink at rates of ca. 15% per day (Ford et al. 1987). Wind speed, its direction relative to land, and ocean currents are additional factors that determine the proportion of birds deposited on beaches. In the Gulf of Alaska, prevailing winds between 1 April and 15 May usually (22 of 35 days) had a northerly component that undoubtedly pushed many carcasses away from land. Conversely, the Alaska Coastal Current carried corpses in a southwesterly direction toward the Alaska Peninsula.

The value of our corpse drift experiment was limited by several factors. We delayed releasing any oiled carcasses until 6 weeks after the spill because of concern for Bald Eagles and other scavengers. Furthermore, we used old carcasses retrieved from beaches, and search effort in the Gulf diminished after May. Thus, the actual corpse recovery rate in the Gulf must have been considerably higher than the 3% we observed in our drift experiment.

Outside of Prince William Sound, logistics and geography precluded a thorough and repetitive search of affected coastlines. Only accessible beaches were surveyed systematically, and even those were checked so infrequently that many beached birds must have disappeared before they could be recovered. On the Barren Islands, repeated surveys of two beaches in early May indicated that carcasses were disappearing at rates of 16–20% per day (Bailey 1989, Jones 1989). Other studies indicate disappearance rates of 3–40% per day depending on wave intensity and tide ranges between surveys (Ford et al. 1987, Burger 1989).

Based on the above considerations, we estimate tentatively that the number of oiled birds recovered represents only 10–30% of the actual kill, which was probably between 100,000 and 300,000 birds. Three independent estimates indicated that between 283,000 and 370,000 marine birds were at high risk in the spill zone, but we know from postspill surveys that they were not completely eliminated and high-risk species were relatively abundant in Shelikof Strait after the spill. Thus, our estimates of birds killed and birds at high risk are of the same order of magnitude. However, population estimates based on aerial and boat-based surveys represent static counts of bird abundance and do not account for the flux of birds in and out of census areas (Ford et al. 1987). Thus, the number of birds at risk might have been larger than we calculated and postspill counts may have been biased upwards.

Population effects.—The alcids suffered the greatest losses, as they usually do when oil is spilled in arctic or boreal waters (NRC 1985). Perhaps 10% of the existing Gulf of Alaska population of Common Murres and >50% of the population at the Barren Islands were killed. To put those losses in perspective, it should be noted that the total Alaskan population of Common Murres exceeds 5 million birds (Sowls et al. 1978), and it is not unusual for tens or hundreds of thousands of murres to die *en masse* from natural causes (Tuck 1961, Bailey and Davenport 1972) or chronic oil pollution (McKnight and Knoder 1979, Piatt et al. 1985). Thus, although local populations may have been seriously reduced, it may prove difficult to identify sources of population variability beyond the first year (Stowe 1982, Dunnet 1987). Populations should fully recover in 20–70 yr, or sooner if birds emigrate from unaffected colonies (Ford et al. 1982, Samuels and Lanfear 1982).

Local populations of Pigeon Guillemots (*Cepphus columba*) and Marbled Murrelets (*Brachyramphus marmoratus*) were also decimated by the spill, but Gulf populations may be in the low hundreds of thousands (Sowls et al. 1978). Puffins appear to have avoided serious losses because they did not return to colonies until after the oil had passed. Nonalcid species that may have suffered high losses relative to the size of local populations included Yellow-billed Loons (*Gavia adamsii*), Pelagic Cormorants (*Phalacrocorax pelagicus*), Harlequin Ducks, and Bald Eagles.

Bird mortality following the "Exxon Valdez" oil spill represents an unprecedented toll of marine birds from acute oil pollution (Piatt and Lensink 1989). The magnitude of losses was predictable given the size and species composition of marine bird populations in the region (Lensink 1984). Losses could have been much greater if the spill had occurred in summer or autumn. The immediate effect of the spill was to reduce the size of some local breeding bird populations in 1989, and that effect will persist as both production and recruitment are diminished for the future (Ford et al. 1982). For birds that survived oiling but ingested oil, or whose nest sites were contaminated, breeding success may have been reduced in the 1989 and future breeding seasons (Clark 1984, Fry et al. 1986). Long-term effects of the spill on marine birds are subject to continuing investigation by the U.S. Fish and Wildlife Service and other agencies.

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