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December 22, 1998

The Honorable John A. Kitzhaber
Governor of Oregon
State Capitol
Salem OR 973 10

The Honorable Brady Adams
Oregon Senate President
State Capitol
Salem OR 973 10

The Honorable Lynn Lundquist
Oregon House Speaker
State Capitol
Salem OR 973 10

Gentlemen:

Enclosed is Technical Report 1998-2 of the Independent Multidisciplinary Science Team on pinniped and seabird predators. The Team is sending the report to you, the appointing authority for the Team, and by copy of this letter to the Joint Legislative Committee on Salmon and Stream Enhancement, and to Mr. Roy Hemmingway, Manager of the Oregon Plan for Salmon and Watersheds. The Governor's Natural Resources Office is making arrangements for further production and distribution of this report.

This report concludes the work the IMST initiated on our predator project. While it is possible that other work by IMST may be needed in this area, we have none planned at this time.

The IMST is pleased to have this opportunity to be of service to the people of Oregon.

Sincerely yours,

Logan A. Norris, Chair
Independent Multidisciplinary Science Team

LAN:grs

Enclosure

cc: JLCSSE, with enclosure
Roy Hemmingway, with enclosure

Pinniped and Seabird Predation: Implications for Recovery of Threatened Stocks of Salmonids in Oregon Under the Oregon Plan for Salmon and Watersheds

Technical Report 1998-2

A report of the
Independent Multidisciplinary Science Team,
Oregon Plan for Salmon and Watersheds

December 22, 1998

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Pinniped and Seabird Predation: Implications for Recovery of Threatened Stocks of Salmonids in Oregon Under the Oregon Plan for Salmon and Watersheds

December 22, 1998

Executive Summary

The Independent Multidisciplinary Science Team (IMST) was directed to evaluate the extent of predatory impacts of marine mammals and seabirds on salmonids and to recommend actions to mitigate impacts. To carry out this assignment, we focused on the Oregon Department of Fisheries and Wildlife (ODFW) Action Plans because they provide the programmatic direction for the State in the context of the Oregon Plan for Salmon and Watersheds (Oregon Plan).

Marine mammals and seabirds have been considered detrimental to salmon production for a long time, and extensive control programs are part of the history of salmon management. Unfortunately we have not invested in enough research to accurately define the dimensions of the problem. Uncertainty regarding predators of salmonids by pinnipeds and birds is expressed in the following five science questions, which guided our evaluation:

1. What is the magnitude of predation by pinniped and seabirds on Oregon salmonids, and how is predation distributed among life-history stages and habitats?
2. How does availability of alternative prey and ocean conditions affect predation on salmonids?
3. What role has habitat modification played in changing salmonid prey-predator relationships?
4. How has management of fisheries and hatcheries affected predation on wild stocks of salmonids?
5. What is the impact of predation on escapement of adults and recovery of Oregon's wild stocks of salmonids relative to other factors?

We conclude that California sea lion, Pacific harbor seal, Caspian tern and cormorant populations along the Oregon coast have all increased in recent years, coinciding with historic lows in salmon abundance. Predation by these species may be a factor in the lack of recoveries of some depressed salmonid stocks but there is no compelling scientific evidence that predation has been a primary cause for recent decline of salmonids. No comprehensive studies have been conducted to evaluate the importance of predation on escapement of wild stocks relative to other factors.

In general, the recent declines in salmonid abundance are related to unfavorable ocean and fresh water conditions. Ecosystem changes in the Northeast Pacific Ocean have likely resulted in decreased availability of forage fishes that were the major prey for many of these predators.

The IMST concludes that predation by pinnipeds and seabirds can affect salmonid stocks and their recovery, but compelling evidence for a significant effect on the escapement of wild salmonids is lacking. Further, we conclude that:

a. the current base of information is insufficient to conclude that predation has a significant impact on adult escapement of Oregon salmonids

b. other factors (e.g. habitat modification, ocean conditions, dams) may be equally or more important than predation

c. management actions related to predators should be delayed until sufficient information is obtained to confirm the magnitude of a specific problem, and we know enough about the problem to recommend an effective course of action

d. given this uncertainty, current efforts and resources of the Oregon Plan for Salmon and Watersheds should be focused on other areas that are more effective in achieving recovery of stocks.

The ODFW Draft Action Plans (ODFW 1998a,b) include summaries of the state of knowledge concerning pinniped or avian predation on salmonids in Oregon. They are analytical in their approaches and identify many of the critical elements embodied within the Science Questions addressed by IMST. We endorse the actions proposed by ODFW, finding them consistent with the recommendations of the IMST.

Our recommendations (in our order of their priority) are:

1. **Determine the factors influencing high predation rates on salmonid smolts in the Columbia River estuary.**

2. **Improve the estimates of the impact of pinniped predation on salmonid stocks and on the recovery of depressed stocks**.

3. **Improve estimates of the impacts of seabird predators on wild salmonids.**

4. **Test the feasibility of relocation of Caspian terns to other nesting sites and evaluate the consequences of tern relocation on all salmonids stocks in the area.**

5. **Evaluate the effectiveness of cormorant hazing in Oregon's estuaries**

6. **Use modeling of pinniped and avian predation in risk assessment.**

7. **Improve coordination with monitoring activities under the Oregon Plan, and coordinate with research projects on pinniped predation along the northwestern coast of North America**.

Error! Bookmark not defined.**Introduction**

The Memorandum of Agreement (MOA) between Oregon and the National Marine Fisheries Service (NMFS) directed the IMST to evaluate the extent of predatory impacts of marine mammals and seabirds on salmonids and to recommend actions to mitigate impacts. In addition the IMST was specifically requested to address this issue by Oregon's Joint Legislative Committee for Salmon and Watersheds. In June 1988 ODFW submitted their Draft Action Plans for inclusion in the Oregon Plan for Salmon and Watersheds (Oregon Plan), and we have reviewed their recommendations.

The IMST responds to these directions and requests in this report. Our report has two purposes. The first is to respond to the MOU, the request of the Joint Legislative Committee and the request to provide a peer review of the ODFW Action Plans. The second is to determine if the proposed management actions are adequate to resolve the predation problem or understand the magnitude of its impact.

In our report we focus on the ODFW Action plans because they provide the programmatic direction for the State in the context of the Oregon Plan for Salmon and Watersheds (OPSW). In addition however, we also give an overview of predation and its impact as a means of providing a broader perspective on the issues involved than are apparent in the ODFW Action Plans alone.

Scope of This Project and Informational Resources

The Oregon Plan (1997, Measure 17B, Section 4) identifies predation by pinnipeds and seabirds as a factor in the decline of salmonid stocks. It also recognizes the widespread public concern about the effects of these predators, the lack of scientific data on predation effects, and most importantly, the possible impacts of locally abundant predators on the recovery of depressed salmonid stocks. Other predators, such as exotic fish species also affect salmonid stocks but the IMST has declined to address this aspect of predation at this time because of the higher priority it gives to other areas of investigation.

The work of IMST on this project was greatly facilitated by information prepared by the Oregon Department of Fish and Wildlife (ODFW) and National Marine Fisheries Service (NMFS), which is included in the following reports:

1. Investigations of Scientific Information on the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and the Coastal Ecosystems of Washington, Oregon, and California (NMFS 1997);
2. Recommendations for Addressing the Impacts of California Sea Lions and Pacific Harbor Seals on Salmonids and West Coast Ecosystems. Draft Report to Congress (NMFS and Pacific States Marine Fisheries Commission: NMFS-PSMFC 1997);
3. Summary of a planning meeting on studies of pinniped predation on salmonids (Brown 1997);

4. Avian Predation on Juvenile Salmonids in the Lower Columbia River. (Roby et al. 1998);
5. Predation Action Plans for Pinnipeds and for Avian Species (ODFW 1998a,b).
6. IMST also received helpful briefings on pinniped predation from Robin Brown (ODFW) and Joe Scordino (NMFS) in August 1998.

Collectively, these sources of information provided the IMST an excellent review of current scientific knowledge, an overview of critical management issues, and a basis for identification of critical research needs. These documents are technically sound and widely available; thus we do not repeat their findings here. This report of the IMST provides only a brief review of scientific information relevant to marine mammal and avian predation for perspective on the issues involved.

The science questions we address and the recommendations we make are done so within the context of the OPSW and in our evaluation of the ODFW Draft Action Plans for pinniped and avian predators.

Organization of this Report

This report begins with an introduction to concepts of predator-prey relationships, and to the pinniped and seabird predators that are the focus of the report. It then identifies the specific science questions addressed by the Team, giving first our detailed answers and then a summary of the answers to each science question. The report concludes with our evaluation of the ODFW Action Plans and the specific recommendations of IMST and the literature cited in the report.

Predator-Prey Relationships – Some Concepts

Predators of juvenile and adult salmonids occur naturally throughout the salmon's extended ecosystem. They consume salmon at all life stages: eggs, fry, fingerling, smolts and adults. Predation is a significant source of mortality for juvenile salmonids in fresh water and early marine life (Foerster and Ricker 1941; Hunter 1959; Parker 1971; Fresh et al. 1980; Fresh 1997; Roby et al. 1998). Predation processes are usually density-dependent and greater for young, more abundant life-history stages, and decrease with increasing size and age. However predation on adult life stages of salmonids by pinnipeds is well documented.

In general, mortality of salmon at any life stage potentially diminishes their abundance and future spawning potential, although predation on smolts has much less impact on the population of spawners than predation on the same number of returning adult salmon. This is because survival rates generally increase with size and age of the fish. The rate of mortality is also affected by population density. For example, the higher the density of fry in freshwater, the higher the mortality rate will be from predation or other causes. Thus low population size may be compensated by a higher rate of survival. This could result in similar population levels of salmon from quite different population levels of

juveniles. Predation is often compensatory in another sense as well. Prey not consumed by one type of predator will often be eaten by another, especially if the prey population is above the carrying capacity of its habitat.

There are some situations where the percent predation mortality decreases with prey abundance. This inverse relation, called depensatory mortality, is related to the swamping effect on predators by large numbers of prey for the size of the population of predators. As an example, a given bird population can only eat so many fish per day, regardless of how many are available.

It is important to remember that salmonids have co-evolved with predators. In spite of the large number of predators, salmonids have survived and remained productive for thousands of years. Predation is not usually the primary cause of population declines (Fresh 1997). When stocks are at low population levels from other causes, however, predation could contribute to the risk of extinction of specific stocks.

Marine mammals and seabirds have been considered detrimental to salmon production for a long time, and extensive control programs are part of the history of salmon management. Unfortunately we have not invested in enough research to accurately define the dimensions of the problem, or to learn if any control measures used in the past were effective.

Population Trends

Pinnipeds – Through various control measures used by humans, it is believed that the populations of both the California sea lion (*Zalophus californianus)* and the Pacific harbor seal (*Phoca vitulina)* were both reduced by commercial hunting until the late 1960's (ODFW 1998a). These control efforts were an attempt to increase the number of salmonids that could be taken by humans through a reduction in the number that were taken by pinnipeds. The numbers of pinnipeds have increased substantially since the passage of the Marine Mammal Protection Act (MMPA) in 1972. The ranges of both species have expanded. Since the passage of the MMPA, they have become more obvious and contact with humans has increased, as have interactions with human activities such as fishing.

California sea lions have increased at a rate of about 5-6% per year since the mid-1970s when systematic surveys were initiated. Peak counts in Oregon reached 5,000 to 8,000 in the 1990s. Male California sea lions migrate into Oregon waters from September to May, coinciding with the spawning runs of many salmonid stocks (NMFS 1997).

Harbor seals have increased at 5-7% per year and the total population in Oregon is estimated to be about 10,000 (NMFS 1997; ODFW 1998a). Harbor seals are year-round residents off Oregon and are commonly seen hauled out in large numbers on sandbars and beaches along the coast.

Seabirds –Juvenile salmonids are preyed upon by many species of birds, including cormorants (*Phalacrocorax* spp.), terns (*Sterna* spp.), brown pelicans (*Pelecanus occidentalis*), sooty shearwaters (*Puffinus griseus*), common murre (*Uria aalge*), mergansers (*Mergus* spp.), gulls (*Larus* spp.), belted kingfisher (*Megaceryle alcyon*), grebes and loons (*Gavia* spp.), herons (family Ardeidae), osprey (*Pandion haleaetus*) and bald eagles (*Haliaeetus leucocephalus*).

The common murre is the most abundant seabird in Oregon. The breeding population of murres has remained fairly stable, at between 700,000 and 740,000, between 1988 and 1995 (Lowe and Pitkin 1996), but since 1996 the breeding population has declined (R. Lowe, pers. comm.).

The double-crested cormorant is common in the lower Columbia River estuary where the number of breeding pairs has been increasing in recent years (about 7,000 in 1997 according to Roby et al. 1998). This species nests on man-made nest sites and is known to consume juvenile salmonids during the nesting season in the Columbia River and other coastal estuaries.

Caspian terns nest on Rice Island in the Columbia River estuary, an island created from dredge spoils by the U.S. Corps of Army Engineers. This tern colony has increased by more than 600% since it was first established in 1987, and is now the largest Caspian tern colony in North America, at over 8,000 pairs (Gill and Mewaldt 1983; Roby et al. 1998).

Gulls are common predators of juvenile salmonids in the Columbia River, especially near dams, hatcheries, and barge release points (Ruggerone 1986). Their populations along the Columbia River have increased in recent years.

In summary -The abundance and visibility of these avian and pinniped species, and their interactions with humans, are likely the reasons why more than half the coastal residents surveyed believe that reducing marine predation by seals, sea lions and cormorants is important for restoration of salmon (Smith et al. 1997). The emphasis of the work of IMST is to document what is known about the impact of pinniped and seabird predators on depressed salmonid stocks, within the context of the Oregon Plan for Salmon and Watershed.

Science questions - These are the specific science questions addressed by IMST in this report. We have selected the following questions because they address the major uncertainties regarding predation on salmonids and are relevant to the goals of the Oregon Plan:

1. What is the magnitude of predation by pinniped and seabirds on Oregon salmonids, and how is predation distributed among life-history stages and habitats? We address this question separately for pinnipeds and seabirds.

2. How does availability of alternative prey and ocean conditions affect predation on salmonids?
3. What role has habitat modification played in changing salmonid prey-predator relationships?
4. How has management of fisheries and hatcheries affected the predation on wild stocks of salmonids?
5. What is the impact of predation on escapement of adults and recovery of Oregon's wild stocks of salmonids relative to other factors?

Answers to Science Questions

Science Question 1a. What is the magnitude of pinniped predation on Oregon salmonids and how is it affected when passage of adults is restricted?

Pacific harbor seals and California sea lions are opportunistic feeders, foraging on a wide variety of fishes and squids. Their diets vary among regions, seasons and years, but often include salmonids when they are available. Occurrence of sea lions at Willamette Falls (more than 100 miles from the ocean) and harbor seals in coastal freshwater rivers, indicate that predation by these mammals occurs in the ocean, estuaries and rivers.

Magnitude of Predation Evidence of pinniped predation comes both from observation and quantitative data. Most of the evidence relates to predation on adults. Little is known about the extent of predation on salmonid smolts. Smolts migrating to the ocean may attract seals and sea lions, especially in estuaries and near river mouths where these fish occur in high densities during periods of out-migration in the spring and summer. Predation on smolts is more difficult to discern than predation on adult salmon because their otoliths (ear bones) dissolve in the gut and may not be present in fecal samples (scats) and because pinnipeds can consume smolts underwater while adults are often seen being eaten at the surface.

The remains of salmonids are found in pinniped fecal samples, ranging from a few percent to 40% of the fecal samples examined, depending on the season and location (Roffe and Mate 1984; Harvey 1987; R. Brown ODFW unpubl.). Also based on fecal sample analysis, Olesiuk (1993) reported seasonal shifts in the diets of harbor seals in the Strait of Strait of Georgia, British Columbia. Hake and herring predominated in the diet on an annual basis, but increased consumption of salmonids coincided with the return of adult salmon to estuaries in the fall.

There are few reliable quantitative measures or estimates of the magnitude of predation by pinnipeds on Oregon salmonids. Using a bioenergetic model, Harvey (1987) estimated that the 5,034 Pacific harbor seals in Oregon consumed about 600 metric tons of salmonids in 1980, which was about 18% of the salmon landings for that year. NMFS (1997), using similar methods, estimated the biomass (combined weight of all species consumed, not just salmonids) consumed by pinnipeds in Oregon. They estimated the California sea lion consumed about 5,300 metric tons (1994) and the Pacific harbor seal

about 8,500 metric tons (1993). This represents about 12% of the commercial landing of fishes and shellfishes in Oregon for those years. Roffe and Mate (1984) estimated in 1976 through 1979, sea lions and harbor seals consumed less than 1% of the spring chinook and 5-7% of the summer steelhead run into the Rogue River. Pacific lamprey was the most common prey.

Others have also estimated pinniped predation. Using limited data Kaczynski and Palmisano (1992) thought that these predators consumed an equivalent of 85% of the commercial harvest of salmon in 1990. In contrast, Botkin et al. (1995) reviewed the literature and concluded from the data that "sea lions and harbor seals take a small percentage of the salmon caught commercially and by sport fishermen."

Scars believed to be caused by pinnipeds are observed on adult salmonids at fish ladders, hatcheries, and in sport and commercial fish landings. Scarring has been observed in most river systems in Oregon. ODFW reported scarring rates of 6 to 53% for winter steelhead and 11 to 20% for coho salmon (see NMFS 1997). The relationship between scarring and mortality of salmonids has not been established, but it is obvious that encounters between salmonids and pinnipeds are frequent.

The impact of predation depends on the proportion of the run that is affected. For example, Brown and Mate (1983) reported that a larger percentage of the adult chum run to Whiskey Creek (Netarts Bay) was consumed by harbor seals in the fall during years of small than large run size. Thus robust predator populations potentially could suppress the recovery of depleted wild stocks of salmonids.

Most studies recognize the lack of reliable quantitative estimates of pinniped impacts on salmonids. Samples are usually limited in time and space and are not representative of the entire coast for an entire year. Fecal sample analysis does not represent all the prey consumed or killed. Assumptions in the various estimates are usually unverified.

Conclusion about Magnitude of Predation The IMST concludes that although the abundance of seals and sea lions has increased since 1980, and the numbers of salmon have decreased, no data exist to establish a cause and effect relationship. Based on the available evidence, the IMST concludes there is an inadequate basis for estimating the impact of predation on salmonids by pinnipeds in Oregon.

Effects of Restricted Passage Predation by pinnipeds can have significant effects on escapement of depressed stocks during their spawning runs when passage is restricted. This situation is best illustrated by the impact of California sea lions on winter steelhead at Ballard Locks, WA. Scordino and Pfeifer (1993) estimated that California sea lions consumed or killed 42-65% of the total run of returning adult winter steelhead between 1986 and 1992. Predation on salmonids by California sea lions at the restricted passage facilities at Willamette Falls is a similar situation where about 225 salmonids are taken each spring (ODFW 1998a).

During years of drought and low stream flows returning runs of adult salmon and steelhead likely are confined to the mouths of rivers or within estuaries and more vulnerable to pinniped predation; dams have similar effects (NMFS-PSMFC 1997).

Conclusion about Effects of Restricted Passage The IMST concludes that pinniped predation could have serious impacts on depressed salmonid runs that migrate through restricted passages. However there is inadequate quantitative information on which to identify such locations (except at Willamette Falls), and the impact of predation that may be occurring at them.

Science Question 1b. What is the magnitude of seabird predation on Oregon salmonids, and how is predation distributed among stocks, habitats and life history stages?

Birds are effective predators of small fishes in fresh water, estuaries and the open ocean. Wiens and Scott (1975) estimated that four seabird populations along the Oregon coast consumed about 49,000 metric tons of fish, primarily northern anchovy. The diets of seabirds are variable and often change both seasonally and among years (e.g., Ross and Johnson 1995). They can consume a large portion of the juvenile salmonid production in rivers and estuaries (Mace 1983; Kennedy and Greer 1988), but are not believed to have a direct impact on adults.

Cormorants Roby et al. (1998) conjectured that smolt losses to cormorants in spring and early summer of 1997 were "in the millions". They determined that salmonids made up 35% and 16% of the diet of double-crested cormorants near Rice Island and East Sand Island, respectively, in the lower Columbia River. Observations in the Tillamook, Nestucca and Nehalem estuaries suggested feeding activity by large numbers of double-crested cormorants when large numbers of smolts were present in the spring (Oregon Plan, 1997, Measure 17B, Section 4, pg. 30). This has led to a controversial legislatively mandated program to harass cormorants in these three estuaries during the spring out-migration of coho smolts in 1996 through 1999 (Bayer 1989).

Caspian Tern The impact of Caspian terns in the Columbia River estuary is especially noteworthy. Roby et al. (1998) reported that the diet of the Caspian terns on Rice Island during May-July consisted mainly of juvenile salmonids. They estimated that 6-25 million juvenile salmon were consumed during the smolt out-migration period in the summer of 1997 (see also Emmett 1997). This represented 6 to 25% of the estimated 100 million smolts that out-migrate below Bonneville Dam.

Passive Integrated Transponder tags (PIT tags) are used to "mark" a portion of the hatchery and wild smolts in the Columbia River basin. Based on the recovery of PIT tags on Rice Island, they concluded that wild smolts were significantly less likely to be captured by terns than hatchery smolts.

Gulls and Murres Gulls are common predators of juvenile salmonids in the Columbia River. This occurs during smolt out-migration, especially near dams, hatcheries, and barge release points when smolts are near the surface, but reliable estimates of numbers

eaten have not been made. The common murre is an abundant seabird along the Oregon coast, it is usually not a major predator on salmonid smolts except when large numbers of smolts were released in estuaries by private aquaculture (Scott 1973: Matthews 1983; Bayer 1986).

Conclusion about Cormorants, Caspian Terns and Gulls and Murres Based on this limited information, IMST concludes that the Caspian tern in the Columbia River Estuary near Rice Island is an effective predator of salmonid smolts. Although the impact is predominantly on hatchery reared fish; some wild fish are consumed. Predation by other seabirds is known to occur, but the IMST concludes there is not an adequate quantitative basis for estimating the magnitude of this predation or the impact of it on specific stocks.

Science Question 2. How does availability of alternative prey and ocean conditions affect predation on salmonids?

Availability of Alternative Prey Pinnipeds and seabirds are opportunistic feeders and their diet includes many species of fishes. In theory, predators maximize their intake of energy relative to the energy they expend in capturing and consuming their prey (Mittelbach 1981). This means that as the numbers of any individual prey species decrease, it is increasingly likely that a predator will switch to alternative prey species. Similarly, as the numbers of a prey species increases it is increasingly likely that a predator will increase forage on this species, and decrease forage on another species. This is called predator-switching behavior. Holtby (1988) observed an example of this when smolt-to-adult survival of coho salmon increased as the abundance of juvenile herring increased. In this case, increasing numbers of herring presumably reduced predation of smolts (when herring were abundant, predators switch to feeding on herring rather than on coho smolts). This illustrates the effect that the availability of an alternate prey species can have on the predation pressure on salmonids.

Since salmonids are usually only common at any given location during certain seasons of the year, their predators depend on more abundant fishes for their primary nutrition throughout the year. These fishes include anchovy, herring, smelts, lamprey, gadids, flatfishes, etc. In recent years the abundance of anchovy and lamprey has declined. Pacific lamprey, the major prey consumed by sea lions and harbor seals in the Rogue River estuary (Roffe and Mate 1984), has declined precipitously in recent years (Pacificorp 1994; Close et al. 1995). Information on the annual abundance trends of most forage fishes is not available.

Ocean Conditions Ocean conditions influence predation. This is due to predator switching behavior, concentration of salmonids in narrow zones of colder water, increased abundance of competitors and predators and reduced growth and condition of smolts. In addition there are interactions between hatchery practices, ocean conditions and predation on smolts.

Predator Switching - When common forage species are less abundant, such as during periods of low ocean productivity, it is likely that predators switch to salmonids, especially when the salmonids are concentrated along the shore (see previous section).

Concentration of Salmonids and the Influx of Migratory Species - The oceans off Oregon have experienced poor productivity since the late 1970s. There have been several strong (1982-83 and 1997) and many weak (1991-1994) El Niño events. These have caused a deep layer of warm near-surface water, increased stratification, weak or ineffective upwelling and greatly reduced abundance of zooplankton (Roemmich and McGowan 1995; McGowan et al. 1998). We believe these changes among years and over decades have concentrated salmonids near the coast in a restricted upwelling zone where they are more vulnerable to predation by pinnipeds and other predators. Higher survival of some releases of hatchery smolts barged offshore during years of poor coho smolt survival is also circumstantial evidence that near-shore predation is a significant factor in survival (Pearcy 1992**).** Beamish et al. (1992) also reported that dogfish were attracted near-shore to the mouth of an estuary in British Columbia where they ate hatchery smolts. In addition, there are greater influxes of migratory species such as mackerel and hake from southern waters when our coastal waters are warm. These invading species probably compete for food and are possible predators on salmon smolts (Pearcy 1992).

Reduced Condition of Smolts - During unfavorable ocean conditions, growth rates of salmonid smolts may be reduced and they may be less able to avoid predators and more susceptible to predation for a longer period of time. Therefore predation mortality may be elevated compared to conditions favoring rapid growth (Holtby et al. 1990: Healey 1982).

Interactions with Hatchery Practices - Effects of changing ocean conditions influence predation on hatchery salmon. For example, Scott (1973) found no salmonids in the stomachs of murres collected off Yaquina Head in 1969-71. This changed after private salmon hatcheries started operations. Smolt releases by private hatcheries in Yaquina Bay were accompanied by aggregations of common murres, gulls, brown pelicans, and cormorants in the bay. Within hours after a release of smolts, thousands of murres were feeding on them in the bay (Bayer 1986). A similar response was noted in Coos Bay (Matthews 1983). This significant response of murres to the releases in Yaquina Bay was observed in the El Niño year of 1983, but not in the previous intense upwelling year of 1982, presumably because alternative prey were abundant in 1982, but not in 1983. The increased abundance of predators drawn to large concentrations of hatchery smolts may also increase predation on wild fish, but no studies have tested this hypothesis.

Conclusion about Availability of Alternative Prey and Ocean Conditions Predation by marine mammals and seabirds needs to be placed in a broad ecosystem context. Predation by pinnipeds and seabirds is not confined to any one species or group of species, but includes salmonids, non-salmonids, and commercially important fishes. Thus, while pinnipeds do consume salmonids it is not the dominant prey during most of the year. Pinnipeds may prey on species that compete with or prey on salmon smolts, thus pinniped predation on these other species plays a role in the regulation of their

numbers as well, perhaps to the benefit of salmonids. For example, harbor seals in the Georgia Strait feed mainly on hake or whiting, an abundant fish that preys on juvenile salmon; thus predation by harbor seals on hake could be benefiting salmon (Olesiuk 1993).

From this the IMST concludes that ocean conditions and the abundance of alternative prey and their temporal and spatial variability influence the level of predation. Information on all of these factors is needed in taking an ecosystem level approach to the evaluation of predation impacts.

Science Question 3. What role has habitat modification played in changing salmonid predator-prey relationships?

Human activities have caused changes in the habitat of both predators and their prey, contributing to the potential for increased predation on salmonids in Oregon rivers and estuaries. Since 1804, Oregon estuaries, streams and rivers have experienced rapid change (Gregory and Bisson 1997). Tidal sloughs and marshes, large wood, root wads, emergent vegetation and stable banks all have been reduced from historical levels in lowland and estuarine habitats (Hoffnagle and Olson 1974, Thomas 1983; Gonor et al. 1988; Benner 1992, Coulton et al. 1996; Sherwood et al 1990). In addition, hydromodification (diking, ditching, damming and dredging) have blocked or hindered salmonid migration, while altering physical (e.g., temperature, flow, sediment levels, dredge spoil islands) and chemical characteristics (dissolved nitrogen, pesticides, etc.) of streams and rivers (Spence et al. 1996).

Impacts of Habitat Modification In general, as the amount and complexity of habitat is reduced, both predators and their prey are concentrated into smaller areas of suitable habitat. This results in increased concentrations of migrating salmon into fewer channels. Habitat modification has also been reported to change feeding habitats (Gregory and Northcote 1993; Gregory 1994) and the timing of migration (Ginetz and Larkin 1976). Holtby (1988) found that early migration from the streams (related to higher stream temperatures) resulted in lower smolt-to-adult coho salmon survival.

Dams and other man-made structures modify flow regimes, water velocities, water clarity and temperatures. This increases stresses on salmonids, making them more vulnerable to predation by birds, mammals and fishes (Gotceitas and Godin 1993, Gregory 1993, Mesa et al. 1994). These effects are especially obvious in the Columbia River where the size of the spring freshet has been reduced, affecting current velocities, migration rates and water clarity and temperature, all of which may exacerbate predation mortality. Pearcy (1992) postulated that historically a well-developed Columbia River plume transported smolts into offshore waters where predation was less intense.

Habitat modification can also increase population levels of some avian predators. Caspian terns in the lower Columbia River on Rice Island are a good example (Roby et al. 1998). Man-made structures (pilings, buoys, channel markers, etc.) have provided increased nesting and roosting habitats for avian predators in estuaries as well. A

combination of increased nesting and perching habitat, decreased river turbidity and timing of salmon runs have all created conditions favorable to these predators.

Habitat loss can change the behavior of smolts resulting in increased predation (Martel 1996). Walters and Juanes (1993) theorized that with a restricted number of refuges from predators, juvenile fish are subject to higher predation risk especially at high population densities because they must forage in risky areas. Gotceitas and Godin (1991) demonstrated that compared to well-fed Atlantic salmon fry, hungry fry resumed foraging sooner following exposure to a predator, making them more at risk from predation.

Conclusions about Impacts of Habitat Modification Comprehensive studies fully exploring the complex relationship between habitat structure and predation are lacking in Oregon's coastal ecosystems. However, based on the evidence available, the IMST concludes that human-induced habitat modifications likely had a role in changing salmonid prey-predator relationships. In our opinion, such factors as decreased structural complexity of freshwater habitat, decreased water turbidity and flow, and altered salmonid foraging habits, combined with situations that increase the number or density of predators, tend to favor the predators.

Science Question 4. How has management of fisheries and hatcheries affected the predation on wild stocks of salmonids?

Management of Hatcheries The evidence for an effect of hatchery practices on predation of wild fish is indirect, but it is consistent with logic and theory. The theory is that hatchery-reared salmonid smolts are less equipped behaviorally than wild fish to survive in the natural environment (Olla et al. 1994, 1998). The protected environment of hatcheries produces naïve salmon that are easily captured by predators shortly after release. Hatchery reared smolts are usually fed at the surface and aggregate in surface waters after release increasing their vulnerability to avian predators. Stress, disease and inadequate smoltification may also increase the vulnerability of hatchery-produced smolts to predation (Mesa et al. 1994, 1998). The larger than expected proportion of PIT tags from hatchery than wild salmonid smolts recovered on Rice Island illustrates this differential vulnerability of hatchery smolts to predation by Caspian terns (Roby et al. 1998).

The logic is that highly vulnerable prey will lead to attraction of predators and shifts in their diet. This is likely to increase the intensity of predation on wild fish as well. On the other hand, very large releases may saturate predator populations and lead to higher survival (Peterman and Gatto 1978; Fresh et al. 1980; Willette et al. in press).

Large hatchery releases may result in adults that return at smaller than average size (Kaeriyama 1998; Cooney and Brodeur 1998). Although some researchers have reported that marine survival rates of Oregon coho salmon decreased with increased smolt production (McGie 1984; Emlen et al. 1990), others rejected this hypothesis of density-dependent survival (Peterman 1981; Nickelson 1986).

Conclusion about Management of Hatcheries Direct evidence in this area is quite limited. From what is known, the IMST concludes that hatchery releases could have either a positive or a negative effect on the rate of predation on wild stocks. The result likely depends on the magnitude of releases and their timing relative to native stocks, predator species and their motility, and local conditions within an estuary and in coastal waters. Thus we believe hatchery management needs to consider the effects of hatchery release strategies on the survival of wild fish.

Fisheries Management Pinnipeds interact with sports and commercial fishing for salmon. Beeson and Hanan (1996) estimated that sea lions removed about 12% of fish caught during the troll fishery off California in 1995. Reports of pinnipeds removing salmon from fishing gear in coastal waters, estuaries and bays and in-river fisheries have increased in recent years (NMFS 1997). Seals commonly feed on salmon caught in gill nets in the Columbia River. When salmon are removed from fishing gear, they are stressed or wounded and the mortality related to fishing is effectively increased, but is not included in the "catch". This results in the under estimation of total fishing mortality because fish removed by predators are not included as catch.

Conclusion about Fisheries Management The IMST concludes that estimates of the catch of salmonids underestimate the effects of fishing because it does not include the effects of predation on fish "caught". Decisions about initiating sport or commercial fishing for depressed stocks need to take this factor into account. Better estimates of this loss of salmonids are required for this purpose.

Science Question 5. What is the impact of predation on the escapement of adults and recovery of Oregon's wild stocks of salmonids relative to other factors?

This question is critical to evaluation of the importance of predation. Even though predation has been perceived as a problem for decades, we know little about its actual impact. The answer is complex, involving assessment of other factors such as habitat complexity and prey vulnerability that affect recovery. Data are inadequate to prioritize various factors related to recovery. In addition, most factors, including predation, are dynamic and vary among stocks, life-history stages and species, watersheds, and years. The impact of predation also depends on the health and population size of salmonid stocks.

Conclusion A holistic approach is required to evaluate predation in comparison with other causes of population declines and to effectively undertake management actions. The information required for this purpose is not currently available.

Summary of Answers to Science Questions

1. **What is the magnitude of predation by pinnipeds and seabirds on Oregon salmonids, and how is predation distributed among life-history stages, habitats, and seasons?**

The abundance of seals and sea lions has increased since 1972, and the numbers of salmon have decreased, but no data exist to establish a cause and effect relationship. There is an inadequate scientific basis for estimating the impact of predation on salmonids by pinnipeds in Oregon. The Caspian tern in the Columbia River estuary near Rice Island is an effective predator of salmonid smolts, possibly consuming a maximum of 26% of the smolts migrating through this region in 1997. Although the impact is predominantly on hatchery reared fish; it is likely that some enhanced impact occurs on wild fish as well due to the intensity of the feeding in a limited area. Predation by other seabirds (such as cormorants) is known to occur, but there are no data on the magnitude of this predation and or a scientific basis for estimating its impact on specific stocks. Although salmonids are common prey for these predators during some seasons and at certain locations, generally other forage fishes comprise the major portion of their diets on a year-round basis

2. **How does the availability of alternative prey and ocean conditions affect predation on salmonids?**

   Unfavorable ocean conditions are one major reason for the poor survival experienced by many salmonid stocks since the late 1970s. These conditions presumably have had an adverse impact on the survival and production of many species of forage fishes along the Oregon coast that are usually the mainstay in the diet of pinnipeds and seabirds.

3. **What role has habitat modification played in changing salmonid prey-predator relationships?**

   Habitat modifications by humans have contributed to increased predation of salmonids by reducing the quantity and quality of feeding and refuge habitats for salmonids in fresh water and estuaries. This alters salmonid foraging habits and juvenile territorial behavior and concentrates predators and prey into smaller areas of desirable habitat. Human mediated increases in the amount of nesting and roosting habitats for avian predators, and in the Columbia River estuary, changes in water turbidity and stream volume, may be major factors in increased levels of predation by seabirds.

4. **How has management of fisheries and hatcheries affected the predation on wild stocks of salmonids?**

   Hatcheries produce salmonid smolts that are more vulnerable to predation than wild fish. Releases of large numbers of smolts by hatcheries, passage of dams and barging all may attract predators thereby increasing predation on both hatchery and wild smolts. Sport and commercial fishing statistics do not reflect the effects of predation on fish that are removed by pinnipeds from nets or other gear, or the likelihood that the susceptibility to predation is increased in fish that are hooked and released.

5. **What is the impact of predation on the escapement of adults and recovery of Oregon's wild stocks of salmonids relative to other factors?**

   No scientific studies substantiate that predation by pinnipeds and seabirds have caused the recent decline in Oregon's salmonid populations. Although predation has the potential to suppress the recovery of listed or depressed stocks (especially if predation is inversely related to population sizes), the relative importance of predation has not been assessed along with other factors that have caused population declines.

Implications for Policy, Management and the Oregon Plan

This section relates the findings of this project back to the context of the Oregon Plan for Salmon and Watershed and the ODFW Action Plans. Specific actions related to the predation by pinnipeds and seabirds on salmonids are likely to be proposed. In some cases it has already occurred or is underway.

Specifically:

a. NMFS (1997) concluded that pinnipeds could affect the recovery of depressed salmonid stocks in those special cases where passages are restricted, resulting in an unusual vulnerability or density of prey. Feeding by California sea lions at Willamette Falls is an example. It is possible that mitigation for predation by pinnipeds may be sought under the terms of the Marine Mammal Protection Act, or modification of the Act may be sought to allow broader application of mitigation strategies.
b. The Corps of Engineers has embarked on planning to modify the nesting habitat of the Caspian tern on Rice Island in the lower Columbia.
c. The Oregon Legislature has established a program of hazing of cormorants in Tillamook, Nestucca and Nehalem Bays during periods of smolt migration.

In each case the major questions are 1) how much information on pinniped or seabird predation impacts is needed, 2) how precise should it be to provide a basis for proceeding with mitigation or management actions to protect depressed stocks of salmonids, and 3) how will the effectiveness of the actions be measured?

Adequacy of ODFW's Action Plans

ODFW provided draft action plans dated June 17, 1998 for public review. The ODFW Draft Action Plans review information about the nature of the issue and proposes actions based on continuation of current funding levels, and steps that would be taken if funding for their programs were increased. The IMST reviewed these plans to determine if they adequately addressed the issues we felt were most critical, as reflected in the Science Questions focused on in our report.

The ODFW Draft Action Plans (ODFW 1998a,b) include summaries of the state of knowledge concerning pinniped or avian predation on salmonids in Oregon. They are analytical in their approaches and identify many (but not all) of the critical elements embodied within the Science Questions addressed by IMST.

Pinnipeds

In our analysis we conclude that information is inadequate to determine the magnitude and impact of predation on depressed stocks. Actions proposed by ODFW could be part of an effort to provide the information base needed for the development of policy and management programs. The actions proposed under current funding are appropriate. Importantly, they include programs to collect some of the information identified by both ODFW and IMST as needed to improve assessment of the impact of predation on salmonid stocks.

IMST endorses three areas of proposed program expansion:

- increased efforts to document distribution and abundance of pinnipeds in Oregon.
- intensification and expansion of the evaluation of pinniped predation on salmonids at additional coastal areas, and
- expanded studies of pinniped food habits.

If studies of the impact of pinnipeds on depressed stocks indicate mitigation is needed under the terms of the Endangered Species Act or the Marine Mammal Protection Act, then we believe increased efforts to deter, capture and mark California sea lions at Willamette Falls and to capture and mark them in the Columbia River are warranted. Based on current knowledge, increased efforts to deter and/or trap these animals should have a lower priority than other studies to assess impacts on wild salmonid stocks.

We believe the coordination and collaboration with NMFS in this area of work is important, and is appropriately highlighted in the ODFW Draft Action Plan. Coordination with similar agencies in other states and Canadian provinces is also important.

Seabirds

The Avian Draft Action Plan relative to the lower Columbia River and estuary emphasizes the statutory responsibilities of other entities. While we acknowledge this, we encourage ODFW to take a strongly proactive role in addressing issues of relevance to the Oregon Plan with these other entities.

We endorse in particular the elements of the ODFW's Draft Action Plans for Avian Predation that will produce the new information needed to improve policies and management of avian predation on depressed salmonid stocks.

Specifically we feel priority should be given to:

- continue research on diet composition of colonial fish-eating birds on juvenile salmonids, factors influencing levels of avian predation, feasibility of management alternatives to reduce predation, and hatchery and fish transport practices affecting health and survival of salmonid smolts;
- monitor populations of terns, cormorants and gulls to determine location and abundance;
- continue participation in the Interagency Caspian Tern Working Group;
- evaluate the effectiveness of cormorant hazing in Nehalem, Tillamook and Nestucca estuaries on the survival of salmonids.

IMST Summary and Recommendations

The IMST concludes that predation by pinnipeds and seabirds can affect salmonid stocks and their recovery, but compelling evidence for a significant effect on the escapement of wild salmonids is lacking. Further, we conclude that:

a. the current base of information is insufficient to conclude that predation has a significant impact on adult escapement of Oregon salmonids

b. other factors (e.g. habitat modification, ocean conditions, dams) may be equally or more important than predation

c. management actions related to predators should be delayed until sufficient information is obtained to confirm the magnitude of a specific problem, and we know enough about the problem to recommend an effective course of action

d. given this uncertainty, current efforts and resources of the Oregon Plan for Salmon and Watersheds should be focused on other areas that are more effective in achieving recovery of stocks.

IMST Recommendations

In line with our conclusions, we make specific recommendations to improve the information base for future decisions about predation.

We recommend that actions be taken to:

1. **Determine the factors influencing high predation rates of salmonid smolts in the Columbia River estuary.**

   Studies should determine why smolts are so vulnerable to predation by terns and cormorants in the Columbia River estuary. Factors to address include levels of stress, smoltification and disease, speed of migration below Bonneville Dam and habitat modification. Analysis of PIT tags recovered on the nesting locations of terns should be used to evaluate hypotheses that prey selection by terns is influenced by hatchery origin, time, size, health, smoltification, transport, hatcheries practices, and passage conditions in the river.

The mortality of smolts in the upper estuary could be estimated by experimental releases of groups of fish into the lower Columbia River estuary, along with controls released at Bonneville (Solazzi et al. 1991). Radio-or acoustically tagged smolts could be used to study the migration and distribution of smolts relative to the feeding activity of terns and cormorants within the estuary. We also suggest a pilot study to test the feasibility of collecting magnetic coded-wire tags at the nesting sites of cormorants ands terns to obtain data on the identity of the smolts that were consumed (Ross and Johnson 1995).

2. **Improve the estimates of the impact of pinniped predation on salmonid stocks and on the recovery of depressed stocks**.

   Besides continuation of annual statewide surveys of pinnipeds, we recommend expanding site-specific studies of pinniped predation on at-risk salmonid populations. Included in this should be establishing patterns of spatial and temporal pinniped abundance with respect to the timing of out-migration of wild smolts, returns of wild adult salmonids, quantifying predator diets, and estimating their consumption of salmonids. This research should be closely coordinated with ODFW's monitoring of downstream smolt migration and escapement counts. Stream monitoring surveys of escapement should include observations on scarring of fish as an indication of predator interactions.

   We also recommend studies that relate hatchery releases of smolts to pinniped predation to gain knowledge of these impacts on both hatchery and wild stocks. Variables such as month and year of release, magnitude and size of release groups, predator numbers and their food habits, alternative prey availability and other environmental variables should be evaluated during critical periods of ocean entry. The effect of the release of hatchery smolts on the aggregation of predators and their impact on both hatchery and natural smolts should be determined using experimental releases of hatchery fish.

3. **Improve estimates of the impacts of seabird predators on wild salmonids.**

   This should include the monitoring of size and distribution of populations of fish-eating seabirds, the composition of their diets, and their rate of consumption of smolts, especially in regions inhabited by listed stocks of salmonids. These studies should continue for several years to assess interannual variability**.**

4. **Test the feasibility of relocation of Caspian terns to other nesting sites and evaluate the consequences of tern relocation on all salmonids stocks in the area.**

   We endorse experiments to test the feasibility of relocating Caspian terns to East Sand Island (or other sites), but this must be concurrent with evaluation of potential impacts on adjacent salmonid stocks. Simply shifting the location of the birds may only shift the predation pressure to other salmonid stocks. Evaluation of the consequences of a shift in location is needed.

Relocation could include use of decoys, acoustical attraction, and habitat modification. Establishment of several breeding sites could decrease predation on salmonid smolts while stabilizing population size of Caspian terns in the region. We do not endorse harassment of nesting terns**.**

5. **Evaluate the effectiveness of hazing cormorants in Oregon's estuaries.**

   We recommend that the results of previous hazing of cormorants in Tillamook, Nestucca and Nehalem bays be peer reviewed by scientists. If cogent evidence is not found for a significant positive effect on the escapement of wild or hatchery fish, we recommend that hazing either be discontinued or peer reviewed research be designed to estimate the consumption of salmonid smolts by cormorant populations.

6. **Use modeling of pinniped and avian predation in risk assessment.**

   Modeling is recommended to assess the potential impacts and sensitivity of avian and pinniped predation rates at different life history stages and population sizes. This could supplement the modeling of Nickelson and Lawson (1998) to estimate the effects of predation.

7. **Improve coordination with monitoring activities under the Oregon Plan, and coordinate with research projects on pinniped predation along the northwestern coast of North America**.

   This will increase the confidence of estimates of population trends, impacts on salmonids, and the effectiveness of management activities. An annual workshop of the experts in this field to review research results and implications of any proposed management actions can be an important part of this effort.

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