NOAA-NWFSC Tech Memo-28: Impact of sea lions and seals on Pacific Coast salmonids

DISCUSSION OF MITIGATION MEASURES FOR PINNIPED CONFLICTS

Most information on the effectiveness of mitigating measures for pinniped/fisheries interactions is the result of NMFS and state efforts to control California sea lion predation on depressed salmonid runs (i.e., at the Ballard Locks), and have been undertaken under the authority of section 109(h)(1)(C) of the MMPA which authorizes nonlethal removal of nuisance animals. Up until 1995, commercial fishers were permitted to injure or kill a marine mammal that was causing immediate damage to their catch or gear so long as other nonlethal efforts had been attempted without success. Since the reauthorization of the MMPA in 1994, fishers and members of the public are permitted to use only nonlethal deterrence methods to prevent pinnipeds from damaging property.

Measures that have been tried or considered for reducing or eliminating pinniped predation on salmonids or minimizing interactions with fisheries are harassment, aversive conditioning, exclusion from selected areas, removal of offending pinnipeds, and pinniped population control.

Harassment Methods

Methods to directly deter pinnipeds from fish predation or fishing gear include noise stimuli and tactile and vessel harassment. Deterrence efforts involving noise stimuli (underwater firecrackers, cracker shells, acoustic devices, and predator sounds) are based on the assumption that noise can be used to startle, warn, scare, or cause physical distress to pinnipeds, moving them out of areas where fish are vulnerable to predation or away from fishing gear. Vessel chase and tactile harassment have also been attempted as a means of deterrence.

Firecrackers

Underwater firecrackers (called "seal bombs") have been used to disperse pinnipeds. Underwater firecrackers have been effective on a short-term basis in many situations, but over the long-term with repeated use, sea lions and seals learn to ignore or avoid the noise (Gearin et al. 1986, Pfeifer et al. 1989, Geiger and Jeffries 1986). At the Ballard Locks, although firecrackers were effective in reducing predation rates of California sea lions in the first season of use, they became relatively ineffective in subsequent years because the animals appeared to have learned to ignore or tolerate the noise (Pfeifer et al. 1989). They also learned to evade close exposure to firecrackers by diving and surfacing in unpredictable patterns (NMFS 1995b). Similar tolerance/avoidance of firecrackers has been observed in fisheries interaction situations with harbor seals (Geiger and Jeffries 1986).

Cracker Shells

Cracker shells are shotgun shells containing an explosive projectile designed to explode about 50-75 yards from the point of discharge. Although the noise may startle pinnipeds and cause them to temporarily flee, there is usually no physical discomfort to the animals involved since the explosion is in the air or on the water surface. Cracker shells have been used in fishery interaction situations with harbor seals with limited effectiveness because the seals have learned to avoid or ignore the noise (Beach et al. 1985).

Acoustic Harassment Devices (AHDs)

The AHD produces a high-amplitude, pulsed but irregular "white noise" under water in the 12-17 kHz range that is intended to cause physical discomfort and to irritate pinnipeds, thereby repelling them from the area of the sound (Mate and Greenlaw 1981). A complete description of the AHD and the areas that it has been used is presented in a workshop report, "Acoustical Deterrents in Marine Mammal Conflicts with Fisheries" (Mate and Harvey 1987). AHDs have been shown to be initially effective in some situations, but their effectiveness diminishes quickly as pinnipeds learn to tolerate the noise. AHDs were used on harbor seals in the Klamath River in an attempt to deter seals from preying on salmon released from seines, but were not effective in reducing harbor seal predation. The AHD also was used on California sea lions at the Ballard Locks facility, but was ineffective in deterring most sea lions (NMFS 1995b). Several researchers have reported that the use of AHDs on commercial fishing gear resulted in the devices appearing to act as a "dinner bell," thereby attracting pinnipeds to fishing gear (Geiger and Jeffries 1986, Jefferson and Curry 1994).

Acoustic Deterrent Devices (ADDs)

The ADDs are a modification of the AHDs, developed for use in deterring seals and sea lions from commercial salmonid net-pen and salmonid ranch facilities. The ADDs have omni-directional and unidirectional arrays which produce periodic sound emissions centered at 10 kHz and at higher decibel levels than the AHDs (Norberg and Bain 1994). At the Ballard Locks, an acoustic ensonified zone has been established under water in the area below the spillway dam and fish ladder to control the presence of California sea lions and reduce their predation on returning winter steelhead. The ADDs appear to be effective in deterring new sea lions from the Ballard Locks area, but have limited effectiveness on California sea lions that repeatedly forage at this site (NMFS 1996a).

Predator Sounds

The effectiveness of predator vocalizations to frighten sea lions has not been consistent (Shaughnessy et al. 1981, Fish and Vania 1971). Pinnipeds sometimes have shown immediate avoidance responses to the projection of killer whale sound recordings, but generally they have habituated quickly (Anderson and Hawkins 1978, Shaughnessy et al. 1981). In one study, sea lions were actually attracted to a researcher's broadcast of predator vocalizations in the Baja California area (NMFS 1995b).

Vessel Chase

Chasing or hazing California sea lions with a vessel proved to be ineffective at the Ballard Locks, as animals learned to avoid the vessel or swim under it (Pfeifer et al. 1989). Both commercial and sport fishermen have also used their vessels in an attempt to chase seals and sea lions from their operation, but such efforts are usually unsuccessful.

Tactile Harassment

Tactile harassment involves shooting pinnipeds with nonlethal projectiles such as rubber bullets or blunttipped arrows. Tactile harassment has been used successfully by instilling an avoidance reaction in other wildlife species (e.g., grizzly bears and polar bears) in some situations. Blunttipped arrows were tested by WDFW on California sea lions at the Ballard Locks with no significant change in predation rates (Pfeifer et al. 1989). Rubber projectiles discharged from a shotgun were tested by ODFW on California sea lions at Willamette Falls with limited success.

Aversive Conditioning

Aversive conditioning is the application of an unpleasant or painful stimulus to train animals to avoid a specific behavior. This technique has been used with coyotes to condition them not to eat sheep (ForthmanQuick et al. 1985).

Taste Aversion

Taste aversion is a form of aversive conditioning that involves putting an emetic agent (e.g., lithium chloride) into a prey species to induce vomiting when the prey is consumed. This technique has been used successfully on a prey-specific basis with captive California sea lions. Using lithium chloride-treated fish, Kuljis (1986) conditioned captive sea lions to avoid one of three prey species without affecting the sea lions' desire to eat the other two species. Taste aversion using lithium chloride was attempted on California sea lions at the Ballard Locks, but the effort was not successful (Gearin et al. 1988a). A variation on this method is to dart (inject) lithium chloride directly into a pinniped when it consumes a fish or enters an area. The same theory applies: if the pinniped associates becoming sick with entering an area or consuming fish in that area, it would develop an aversion. This approach has not been field tested.

Exclusion from Selected Areas

Efforts to exclude pinnipeds from certain areas have included installation of physical barriers. Other approaches that have been considered, but not implemented, to prevent access to specific areas or haul-outs near "problem areas," are the use of scarecrow or alarm devices on haul-outs, or use of predator models (e.g., killer whale model). The assumption is that if pinnipeds are excluded from a haul-out site, they will leave the area to haul-out elsewhere.

Physical Barriers

Physical barriers have been used to prevent sea lion access to a prime forage area in front of the entrance of the fish ladder at the Ballard Locks, and have been used to prevent harbor seals from entering a channel in the Dosewallips River where harbor seal presence was causing high coliform counts in shellfish beds. The barrier at the Ballard Locks (a large-mesh net strung under water) was ineffective because fish passage may have been hampered by the barrier, and sea lions were observed foraging on steelhead at the face of the barrier. The barrier at the Dosewallips River was effective in excluding harbor seals from a haul-out site and resulted in lowered coliform counts at the shellfish beds. Fences also have been used successfully to prevent sea lions from hauling-out on marine buoys and docks in Shilshole Bay. At the Willamette Falls fishway, a metal barrier consisting of vertical metal bars was placed in the opening of the fish ladder to prevent sea lions from entering but still allow salmon to pass.

Predator Models

Although media reports on the use of a killer whale model indicated that it was effective in repelling seals from net-pens in Scotland, use of the same predator model at net-pens in Maine had no effect in repelling harbor or gray seals (NMFS 1995b). Observations of pinniped behavior in the presence of predators and during field testing has shown that these methods are very short term or ineffective. Sea lions have been shown in varying experimental regimes to quickly become nonresponsive to activities that do not result in infliction of pain (NMFS 1995b).

Scarecrows/Alarms on Haul-outs

Harassing seals from haul-out areas in rivers/estuaries during salmonid runs might be accomplished by placing scarecrow or harassment devices (sirens or loud noise/explosions that dispense noise periodically) on haul-outs. This method has not been tested. It would be effective only if the pinnipeds relocated to areas far away from the river mouth or estuary. Unfortunately, California sea lions and harbor seals do not necessarily have to haul-out at any particular time or place, and may remain in the water during the salmonid run.

Nonlethal Removal of Offending Individual Pinnipeds

Capture and Relocation

Capture and relocation efforts with California sea lions at the Ballard Locks indicate that transporting captured sea lions relatively short distances (from Ballard to the outer Washington coast) are not effective, as the sea lions quickly return. Longer distance relocation from Ballard to the southern California breeding area was a possible, albeit costly, means of delaying sea lion return to Puget Sound for at least 30 days, thereby providing a window of safe passage for migrating salmonids that season (NMFS 1995b). Unfortunately, not all predatory animals can be easily captured, especially those of greatest concern that had been captured/removed previously and had returned to forage at the Ballard Locks (NMFS 1996a). Harbor seals also have been captured and relocated relatively short distances (Ballard Locks to Hood Canal), but the seals also soon returned to the problem area.

Capture and Placement in Captivity

California sea lions have been captured at the Ballard Locks, placed in temporary captivity, and released after the steelhead run. Temporary holding was found to be ineffective in the long term because the sea lion returned the following season and could not be recaptured before it had preyed on salmonids (NMFS 1996a). Sea lions from the Ballard Locks also have been captured and placed in captivity permanently. Although permanent captivity does eliminate the "problem" sea lions without having to kill them, the method is limited by costs and the availability of facilities that can hold sea lions permanently.

Effectiveness of Nonlethal Measures

Past efforts by NMFS and WDFW at the Ballard Locks have been unsuccessful in finding an effective, longterm, nonlethal approach to eliminating or reducing pinniped predation on salmonids (NMFS 1996a). Some nonlethal deterrence measures appear to be effective initially or effective on "new" animals, but become ineffective over time or when used on "new" animals in the presence of "repeat" animals that do not react to deterrence. In situations where nonlethal measures are successful on "new" pinnipeds, lethal removal of the experienced/habitual predators combined with nonlethal deterrence of "new" animals may be an effective means of controlling pinniped predation on salmonids (NMFS 1996a). Further research on the development of new technologies and techniques is needed.

Lethal Removal of Offending Individual Pinnipeds

Lethally removing individual "problem" pinnipeds has been considered in many areas as a solution to problems that involve small numbers of pinnipeds. The lethal removal of all problem animals may not be necessary if limited shooting serves as a deterrent to other animals (NMFS and WDW 1989). The seal control technique used by the Fish Commission of Oregon from 1959 to 1970 involved working downstream in the Columbia River from a boat, shooting at every seal encountered. According to the seal hunter and many gillnetters, the seals became conditioned to the sound of his boat and would flee downstream (NMFS and WDW 1989). Beach et al. (1985) concluded that if this reaction could be replicated, the scaring of seals could prove to be more important for reducing fisheries interactions than killing the seals.

Lethal removal of selected, known individual California sea lions by State authorities was authorized at the Ballard Locks in 1995 under the authority of Section 120 of the MMPA. A number of conditions were placed on the authorization to ensure that only the "problem" animals would be lethally removed and only as a last resort (NMFS 1995b).

For example, the lethal authorization required that nonlethal deterrence efforts be in place (use of ADDs) and, in the first year of the authorization, lethal removal could be used only if temporary holding facilities were unavailable or temporary holding was not feasible or practical. To date, no sea lions have been lethally removed. In 1996, three sea lions that were candidates for lethal removal were instead captured and placed in captivity permanently.

Pinniped Population Control

Several programs were instituted in the past to control the population of pinnipeds, but only a few have been monitored to document the effects. A culling program was instituted in 1977 with the goal of reducing the gray seal population of Orkney and Outer Hebrides from 50,000 to 35,000 by 1982 (Harwood and Greenwood 1985). Originally, the plan was to kill pups annually and adult females in alternate years, but because of public concern, only pups were hunted. The cull had little apparent effect as the gray seal population had increased to 65,000 by 1987 (Harwood et al. 1991). Between 1956 and 1968, at least 300,000 northern fur seal adult females were culled from the Pribilof Islands population. The purpose of the culling was to reduce density and thereby lower the age of first reproduction in an attempt to increase pup production. The expected result was to maintain a constant number of subadult males available for the commercial harvest, with lower total population numbers. While the culling was unsuccessful in increasing pup production, it did reduce population numbers (York and Hartley 1981). Beginning in the 1920s and 1930s, state-financed bounty programs in Washington and Oregon selectively killed large numbers of seals and sea lions to reduce the number of predators on commercially important fish species (Newby 1973, Pearson and Verts 1970). Exact numbers of seals and sea lions killed are unknown, but the programs were apparently successful in controlling pinniped populations in both states. The programs ended by 1960 in Washington and by 1970 in Oregon.

A contention of those in favor of pinniped population control is that reducing the number of seals and sea lions will increase the number of fish available to commercial fishers. Butterworth (1992) states that there is no scientific evidence that this contention is true. In fact, he suggests that reduction of pinniped numbers may increase the population of other predators of commercial fish, thus reducing the population of the commercial fish because predatory fish are greater consumers of fish than marine mammals or sea birds. For example, South African Cape fur seals feed on both anchovy and squid, and if the fur seal population were reduced, the squid population which also consumes anchovies would increase and cause a reduction in anchovies available to the fishery (Butterworth et al. 1988). In another example, because Pacific harbor seals and California sea lions are predators of lamprey, decreasing the seal and sea lion population could increase the lamprey population. Lampreys are parasites which can affect both growth and survival of salmonids; consequently, pinnipeds may benefit certain salmonid populations by limiting the lamprey population (Jameson and Kenyon 1977). DeMaster and Sisson (1992) note that the recruitment rate of most fish stocks is quite variable and that this has a much greater effect on determining stock abundance than predation.

CONCLUSIONS

The California sea lion and Pacific harbor seal populations in Washington, Oregon, and California are healthy, robust, and increasing. In contrast, most salmonid populations on the West Coast have declined significantly or are currently declining at significant rates. The Working Group found that concerns over the negative impacts of predation, particularly by pinniped populations that cooccur with depressed salmonid populations, are justified based on intense studies in some situations, such as California sea lion predation on winter steelhead at the Ballard Locks where California sea lions have had a significant negative impact on the recovery of a small salmonid population. However, for most sites of cooccurrence of pinniped and salmonid populations, the Working Group found there is insufficient information to determine whether the pinnipeds are currently having a significant impact on the salmonid populations. Of particular concern are areas where pinnipeds may be impacting salmonid populations that are listed or proposed for listing under the ESA. In spite of the lack of much directed research on pinniped impacts on salmonids, the Working Group found that existing information is sufficient to determine that pinnipeds can affect the recovery of depressed salmonid populations in areas of co-occurrence.

The Working Group found that much of the information from past studies on pinniped-salmonid interactions was inadequate to estimate consumption and impacts on most salmonid populations. Studies of food habits of seals and sea lions show that the occurrence of salmonids varies among food habits samples, depending on when and where the studies were conducted, what kind of samples were taken, and how the samples were analyzed. One of the major problems with interpreting the existing food habits data is that few of the studies were designed to directly assess impacts of predation on specific salmonid populations. It is clear, however, that where salmonid populations are at low levels, and particularly where salmonid passage is restricted by man-made structures, such as at the Ballard Locks, pinniped predation can affect salmonid stocks. Even in areas without man-made passage constrictions, pinniped predation on small salmon runs can be substantial, such as harbor seal predation on 46% of the fall chinook run in the Puntledge River estuary in British Columbia. The predation issue that has received the most attention concerns adult salmonids returning to spawn. Nonetheless, reducing predation on juvenile salmonids, which is more difficult to observe and quantify, may be just as important a factor in reversing declining trends in some salmonid stocks. The Working Group concluded that additional research is needed to fully address the issue of impacts of pinnipeds on salmonid populations.

The Working Group identified three categories of concern for pinniped-salmonid interactions on the West Coast.

1. Areas where there are known impacts from pinniped predation on one or more salmonid populations.

The Ballard Locks is the only area where adequate research has been conducted to determine that pinniped predation has had a significant impact on the recovery of a salmonid population. There has been insufficient research to place any other specific rivers, creeks, or estuary systems in this category.

2. Areas where there is potential for impacts on salmonids and where studies are needed to quantify the level of impact on one or more salmonid populations.

Various rivers in Puget Sound, Lower Columbia River, Willamette River, Nehalem River, Tillamook Bay, Siletz Bay, Alsea Bay, Umpqua River, Rogue River, Klamath River, Russian River, San Lorenzo River, and Scott Creek fall under this category.

3. Areas with depressed or significantly declining salmonid stocks where there is insufficient information to determine whether there could be impacts on salmonid populations.

Hood Canal, Strait of Juan de Fuca, Eastern Bays in Washington, coastal rivers/bays in Oregon, Smith River, Mad River, Eel River, Noyo River, Pajaro River, Carmel River, Salinas River, Big Sur River, Little Sur River, Santa Ynez River, and San Francisco Bay/Central Valley in California fall under this category.

The Working Group could not determine to what degree the increased presence of pinnipeds and increased biomass consumption affects ecosystems because of the complexity of ecosystems and the limited knowledge of how they function. However, it is reasonable to assume that increasing numbers of pinnipeds are consuming an increasing number of prey composed of a variety of species. The Working Group estimated total biomass consumption along the coasts of Washington, Oregon, and California (minimum of about 217,400 t) and found that it amounted to almost half of what is harvested in commercial fisheries. The Working Group found no direct evidence of pinniped-related declines in non-salmonid fish stocks, but there is concern about pinniped removal of significant amounts of fishery resources. For example, Pacific whiting in Puget Sound, eulachon in the Columbia River, and anchovy in southern California are non-salmonid populations that also have declined and are the principal prey of pinnipeds in the area, raising concerns that pinniped predation may impact recovery of these fish stocks.

The Working Group concluded that the increased number of pinnipeds coastwide has brought new problems and issues that must be addressed. The Working Group found that California sea lions and Pacific harbor seals are interacting with many commercial and recreational fisheries on the West Coast. There are also numerous instances of conflicts, primarily with California sea lions, at docks and marinas that raise human safety concerns. In all three states, reports of pinnipeds removing salmonids and other fish from fishing gear and damaging gear have increased. There are no recent, comprehensive assessments of the full degree of human interactions with pinnipeds on the West Coast nor coastwide estimates of economic losses due to pinniped conflicts with commercial and recreational fisheries. Mitigation measures that have been used to reduce or eliminate pinniped predation on salmonids or minimize interactions with fisheries have limited or short-term effectiveness. Development of new technologies and techniques is needed to effectively deter pinnipeds from fishery conflicts and from marinas where human safety issues arise. In particular, resource managers and the public must find solutions that conserve all species in the ecosystems, especially those that are severely depressed or listed under the ESA, while allowing optimum yield for healthy living marine resources.

RESEARCH NEEDS

Conservation of salmonid populations is a critical issue on the West Coast. To assess impacts of California sea lions and harbor seals on depressed salmonid stocks and other fish stocks and take appropriate action with pinnipeds where necessary to conserve salmonids, an extensive field research and management program must be designed to specifically address this problem. Research programs should include the following elements:

1. Conduct coastwide survey efforts to determine seasonal distribution and abundance of California sea lions and harbor seals in areas where salmonids are present. The surveys must cover the periods of both smolt and adult migration in each area and should also determine what proportion of the pinniped population present is involved in salmonid predation. This information would identify all areas where there is potential for substantial predation and focus future research on those areas.
2. Conduct pinniped food habits and mitigation studies in areas identified as having a significant level of co-occurrence of salmonids and pinnipeds. Food habits studies should occur during the salmonid runs. Sampling methods and methods of prey identification must ensure that salmonid remains are identified and consumption levels can be quantified. Studies may involve collection of pinnipeds to quantify salmonid consumption levels. Research should focus on sites where the effects of predation can be determined.
3. Develop methods to identify salmonid hard parts according to species. At present, vertebrae can be used to easily distinguish salmonids from other fish, and some preliminary work has been done to separate steelhead smolt from other salmonids. Further research needs to be done to identify diagnostic characteristics of hard parts for each salmonid species for both adults and juveniles.
4. Determine adult salmonid mortality due to wounds inflicted by pinnipeds during spawning migration. The correlation between scarring and predation is unknown, nor is it known if wounded salmonids have a higher mortality rate or a lower reproductive capacity than non-wounded salmonids.
5. Develop a working model for pinniped consumption estimates. The model should take into account annual and seasonal changes in abundance of predators (fish and marine birds as well as marine mammals) and prey, and annual and seasonal changes in caloric density of prey species. Other sources of natural mortality on prey should be included in the model.
6. Conduct foraging behavior studies of subadult and adult male California sea lions with instrumented animals to document migratory rates, time spent foraging or on land, and foraging areas (geographically and in the water column). This

information can be used to estimate consumption of salmonids and other prey species by California sea lions throughout the migration area.

7. Determine if pinniped predation is affecting the recovery of non-salmonid fish stocks (e.g., Pacific whiting in Puget Sound and eulachon in the Columbia River).

Table of Contents