Deterring Harbor seal (*Phoca vitulina*) predation on chum salmon (*Oncorhynchus keta*) with GenusWave Targeted Acoustic Startle Technology (TAST) at Whatcom Creek, Bellingham, WA

Deliverable: Final project report on Oceans Initiative's evaluation of the effectiveness of the GenusWave TAST device as an acoustic deterrent to reduce predation of salmonids by pinnipeds at the Whatcom Creek Hatchery.

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Introduction:

Salmon runs in Washington have declined statewide, with several species such as coho, Chinook, and sockeye listed as threatened under the Endangered Species Act. Predation by pinnipeds on out-migrating juvenile salmon and returning adult salmon, especially at bottlenecks (e.g. dams and fish ladders), represents a significant obstacle in salmon recovery efforts. Some studies suggest harbor seals may consume nearly 6% of their body weight (4-5 kg) in fish each day, with some variability around seal size and season (Aarts et al., 2019). Per capita fish consumption for harbor seals has been estimated at 2.1 kg/day/seal (Howard et al., 2013). In the San Juan Islands, harbor seal diets switch from a primarily non-salmonid diet in the winter and spring to greater than 50% adult salmonid in the summer and fall, coinciding with increases in salmonid abundance during seasonal runs (Lance et al., 2012).

Harbor seal populations have steadily increased since federal protection by the US Marine Mammal Protection Act (MMPA) in 1972 (Chasco et al., 2017), which has resulted in these prolific predators regaining top-down control in coastal ecosystems. A recent study investigating predation on demersal fish in a near-shore habitat estimated that harbor seals were responsible for up to 40% of annual fish mortality (Aarts et al., 2019). Harbor seal aggregation has been found to be directly related to salmonid abundance but the functional response requires more exploration (Middlemas et. al, 2006). However, as salmonid population numbers are historically low and harbor seal populations have recovered, seal aggregation in waterways where fish passage has been restricted by bottlenecks has become a significant contributor to lower stock returns.

Efforts to reduce seal predation over the years have included a variety of lethal and non-lethal methods. In the early 1900's harbor seals were subject to culling as a form of fishery management on both the east and west coasts of the US (Bowen & Lidgard, 2012). Non-lethal deterrents, including harassment devices such as "seal bombs" and acoustic deterrent devices (ADDs) are much more commonly used, and have been employed globally for predator control on fish farms. Seal bombs are hand-thrown pyrotechnic devices that explode underwater with the intended purpose of frightening seals away from a particular area. Neither the efficacy of this method at seal deterrence, nor the unintended effects on other wildlife or the marine environment has been appropriately investigated. However, seal bombs are explosives that are not target-specific, produce sound pressure levels loud enough to be detected up to 9 km from the source (Wiggins et al., 2019), and pose a potential risk of injury (auditory and non-auditory) to nearby wildlife, including fishes.

ADDs have been implemented worldwide with highly variable results. Although a multitude of different conventional devices (with varying signal types, duty cycles, and source levels) have been developed and are currently being used for predation control (Götz, & Janik, 2013), this deterrent method presents its own set of problems. Studies investigating conventional ADDs have identified them as a conservation concern due to noise pollution and long-term impacts on both target and non-target species (Gordon & Northridge, 2002). Long-term efficacy has also been shown to be questionable, especially when they are being used to deter seals from an easy food source (e.g. fish farm) (Götz, & Janik, 2010). There is also the potential for some ADDs to cause hearing damage in seals—for this reason an abundance of caution is necessary when considering utilizing these devices (Götz, & Janik, 2013).

A recent study aimed at reducing the problem of seal habituation to ADDs has shown that eliciting a seal's acoustic startle reflex can produce reliable, lasting avoidance behavior. Götz and Janik (2011) found that repeatedly triggering this startle reflex resulted in a quick and sustained response—seals that were exposed to a signal within the startle threshold exhibited flight behavior and sensitization. In addition, ADDs with signal frequencies that are specific to the target species have been shown to effectively deter grey seals and harbor seals, without adversely affecting other marine mammals (Götz & Janik, 2015). Such research and recent development to improve the effectiveness and specificity of ADDs has resulted in a new technology shown to produce lasting behavioral change. The Targeted Acoustic Startle Technology (TAST) developed by GenusWave represents a new class of ADDs that operates at duty-cycles at least one order of magnitude lower than other devices—rather than pinging every second, as first-generation ADDs do, the TAST can "target" the number of times the signal is emitted over a given period of time to reduce environmental noise pollution and effects on non-target species. TAST also produces a signal specifically designed to avoid inflicting pain or harm on the target species (Götz, & Janik, 2013; Götz, & Janik, 2016). TAST signal frequency bands are chosen based on the hearing sensitivity of the target species. The risk of hearing damage to the target species and other adverse environmental effects such as noise pollution are mitigated by the signal frequency composition, source level, and other signal characteristics. TAST has been tested at salmon farms in the United Kingdom and was successful at deterring grey and harbor seals to reduce predation (Götz & Janik, 2015; Götz & Janik, 2016).

The aim of this project is to evaluate the effectiveness of this new acoustic deterrent technology in reducing harbor seal predation on chum salmon in Whatcom Creek in Bellingham, WA. Historically, Chinook, coho, chum and pink salmon were common to Whatcom Creek. Over the last 5 years, salmon run returns to the creek have been decreasing. The Whatcom Creek salmon runs experienced a drastic decline after a pipeline burst in 1999 and a fire destroyed much of the critical spawning habitat. The numbers recovered slightly in the years following due to a long-term restoration plan but then quickly began to decline again, for reasons likely unrelated to the tragic event (R2 Resource Consultants, 2009). Multiple factors have induced stress on salmon survival and spawning success, even with the Whatcom Hatchery supporting stocks.

The Bellingham Technical College hatchery on Whatcom Creek opened in 1978 in place of a repurposed wastewater treatment plant, and it now supports one of the largest recreational chum fisheries in the Pacific Northwest[1]. Chum salmon are the second most abundant of the five salmon species in the region. Nonetheless, two evolutionarily significant units of chum salmon are listed as threatened federally under the US Endangered Species Act, and have candidate status for listing in Washington state[2]. There is a large population of harbor seals that use Whatcom Creek as a hunting ground during the chum salmon run in early winter. The hatchery on Whatcom Creek is a bottleneck area in which the salmon congregate to swim up the fish ladder for harvest and spawning. This means that pressure on the returning spawning population from pinniped predation is likely high. This site was selected because there is a clear need for some kind of predation mitigation, and there is no record of any previous attempts to use acoustic deterrents with harbor seals hunting chum salmon on Whatcom Creek (i.e., the seals are unlikely to have sustained hearing damage from previous use of seal bombs or firecrackers).

The overarching goal of this project was to deploy the TAST at the Whatcom Creek fish ladder during the 2020 chum salmon run so that harbor seal presence, predation events, and distance to the device could be measured using behavioral observations, and the effectiveness of the device in deterring harbor seals and reducing predation could be assessed.

Field Methods:

The TAST (Figure 1 A, B, C) was deployed at the entrance to the fish ladder at the Whatcom Creek Hatchery in Bellingham, WA on October 26th, 2020. The transducer was lowered into the creek via a pulley system at the end of a 3 m aluminum pole. Ratchet straps secured the pole to the top of the railing adjacent to the fish ladder (Figure 1 D). The pole extended 0.9 m over the

[1] NSEA, https://www.n-sea.org/chum-salmon-1
[2] WDFW, https://wdfw.wa.gov/species-habitats/species/oncorhynchus-keta

edge of the railing in the western-facing direction so the transducer was suspended directly in front of the opening to the fish ladder. On November 7th, 2020 the position of the pole and transducer were shifted less than 1 m south of the opening, due to concerns about blocking fish entry to the ladder. As this adjustment was minimal, the rest of the equipment and observer position remained unchanged. The transducer was deployed in this new position for the remainder of data collection.

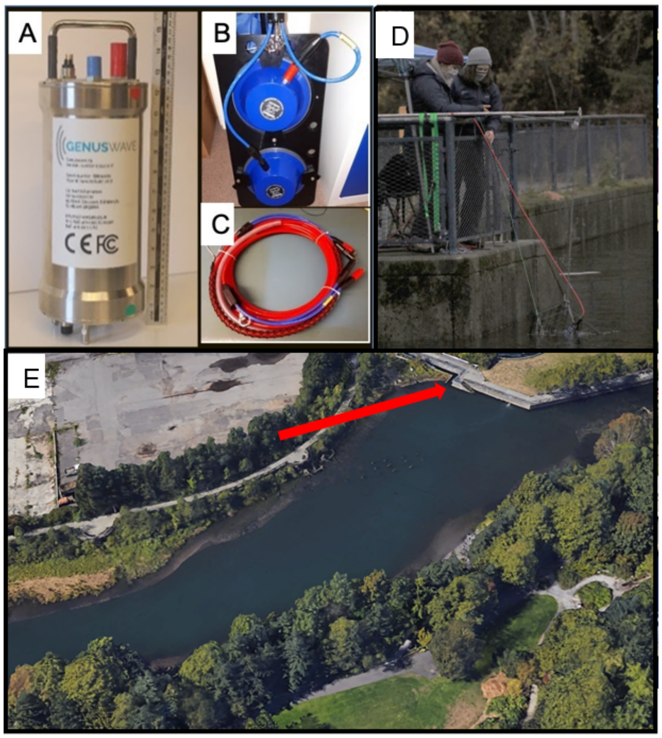

Figure 1. TAST device setup photos: A) Control pod; B) Lubell underwater transducer; C) Power cable; D) Observers deploying the transducer from the observation platform; and E) Aerial view of the study area on Whatcom Creek, red arrow points to the deployment site adjacent to the fish ladder entrance. Photo credit: GenusWave (A, B, C), Oceans Initiative (D), and Google Earth (E).

The transducer was housed in a metal cage to prevent damage by seals and environmental conditions. Orange marking spray was used to mark the 1.5 m water line on the wall adjacent to the observer platform. This was done to ensure that the TAST was never deployed at water levels below the 1.5 m minimum operating depth of the transducer. During experimental set-up each day, the transducer was first lowered to the bottom of the creek, then pulled back up (approximately 18 cm) so it was suspended above the creek bed, and secured into position with a rope attached to the railing on the observation platform.

As TAST deployment was restricted to a minimum operating water depth, observation periods could only be conducted during high tide. Tide measurements were charted each day to identify suitable observation windows. The duration of daily observation periods varied depending on tidal and weather patterns influencing creek depth. Observations were conducted by two observers, during daylight hours, and under most weather conditions except extreme winds.

Operation of the TAST followed a three-day on (experimental condition), one-day off (control condition) schedule. On experimental days, additional 30-minute observation sessions were conducted immediately before and after deployment of the TAST device so that observations could be recorded during these transition periods.

The study area was divided into four blocks (Figure 2), with blocks 1 and 2 extending down the creek approximately 40 m from the TAST, and blocks 3 and 4 extending approximately 130 m from the TAST. During each observation session, both observers continuously scanned the study area looking for seals. Each seal sighting was recorded on a digital GoogleForm as one of four behavioral categories: 1) Foraging (fish visible), 2) Normal surfacing, 3) Surface hunting, and 4) Sub-surface hunting. For each seal sighting, the observers also recorded distance from the TAST using a laser range finder, and angle relative to TAST using an angle board mounted to the observation platform. In addition to surfacing events and location data, observers recorded the total number of individual seals and predation events observed during each session. Weather conditions, as well as any other relevant behavioral observations were recorded in a field notebook following each session. These notes were later grouped into observation periods by tide cycle for analyses. Photos of the seals were opportunistically taken each day using a high-quality camera and telephoto lens, should funding for future photo-ID work become available to identify "nuisance seals," investigate site fidelity of individual seals, or explore effects of the TAST on foraging success of individual seals.

Figure 2. Map of the survey area divided into observation blocks. Green star indicates location of the TAST device and observer. The farthest distance an observer can see is approximately 130 m from the TAST.

Underwater recordings of the TAST signal were collected at the creek so that received levels could be measured and sound propagation within the study area could be characterized. A Cetacean Research Technology (CRT) C75 hydrophone and a Tascam DR-100 MKIII recorder (sampling rate = 44kHz) were used to collect the recordings at 13 locations ranging from approximately 10 – 270 m from the TAST (see Figure 9). Recordings collected within the survey area were taken in approximately 10 m increments, moving downstream from the TAST. Recordings were also collected outside of the survey area to characterize propagation of the signal in other parts of the creek. This was done on the north end of the creek, upstream from the TAST, as well as further downstream, around a bend in the creek. At each location the hydrophone was lowered to 3 m depth from a canoe. A range finder and satellite imagery were used to determine the distance to the TAST from each recording location.

Analysis Methods:

Each tide cycle or period of continuous observation consisting of 30-minute sessions was grouped into observation blocks for analyses. The total number of individual seals in the area (defined as the highest number of seals observed at the surface at one time) was counted for each 30-minute observation session. Seal presence/absence for experimental and control blocks was calculated as the median number of seals (rounded up to the nearest integer) observed across the sessions divided by the number of hours. Seal distance relative to the TAST was analyzed in bins of 10 m increments and a histogram plot was generated to visualize the distribution of distances.

Underwater recordings collected at the creek were analyzed to estimate received levels within the study area. SpectraPlus sound analysis software (Pioneer Hill Software, LLC) was used to calibrate each sound recording (according to a full-system calibration factor provided by CRT) and measure sound pressure levels (SPL) of the TAST pulses in each recording. Received levels (in dB_{RMS} re: 1 µPa) were determined for each of the recording locations. These levels were compared to levels calculated from the transmission loss equation assuming spherical spreading, [$TL = 20 \log_{10}R$] where TL is the transmission loss (dB), and R is the distance (m) from the source. The broadband source level of the device was verified by back-calculating from the received level measured at 10 m.

Preliminary results:

Survey Effort: TAST was first turned on at 15:20 on October 26th, 2020 and followed a 3-day on, 1-day off schedule until November 20th, 2020. The first exception was November 2nd, 2020 when a 4th experimental block was conducted during the first high tide of the day before the control block, which was conducted during the second high tide on the same day. During the final week of TAST deployment the schedule had to be altered slightly, and followed a 1-day on, 1-day off schedule from November 19-21, and a 2-day on, 1-day off schedule from November 22-24.

The TAST was deployed for a total of 22 days with 8 days of control observations resulting in 65 hours with the TAST on and 33.5 hours with the TAST off for a total of 98.5 observational hours.

Presence/Absence: Seal presence was calculated as the median number of seals (rounded up to the nearest integer) in an observation period divided by the number of hours. The average seal presence in the study area decreased by 55% in the experimental (TAST on) condition relative to the control with 0.90 and 1.99 seals per hour in the TAST on and off conditions, respectively.

Distance: Seals occurred at a mean distance of 53 m (median 53 m) from the TAST during the experimental (TAST on) sessions. The mean distance during the control (TAST off) sessions was 43 m (median 34 m). Seal distribution around the device shifted in experimental sessions relative to control.

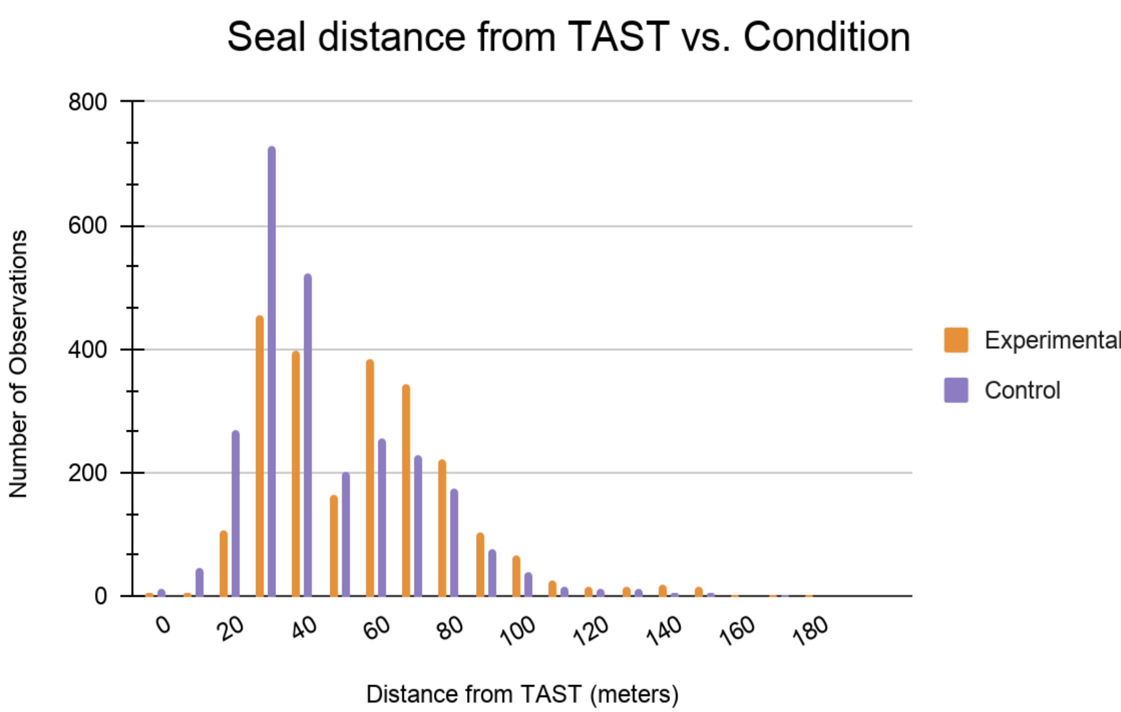

Figure 3. Histogram of seal distances from TAST (m) by TAST on (experimental) and TAST off (control) conditions. Median distance shifted from 53m during experimental sessions to 34m during control sessions. Total sample size was 30 observation blocks.

Predation Rate: Experimental treatment was defined as periods where the TAST device was turned on and control was defined as when the TAST device was turned off; pre-TAST was the 30-minute period before the device was turned on, and the post-TAST was a 30-minute period after the device was turned off. Mean predation rate (number of predation events per hour) was 5.50 when the device was turned off compared to 1.29 when it was on—a 77% decrease (Figure 4). Average pre- and post- TAST predation rates were 9.2 and 7.8, respectively (Figure 5).

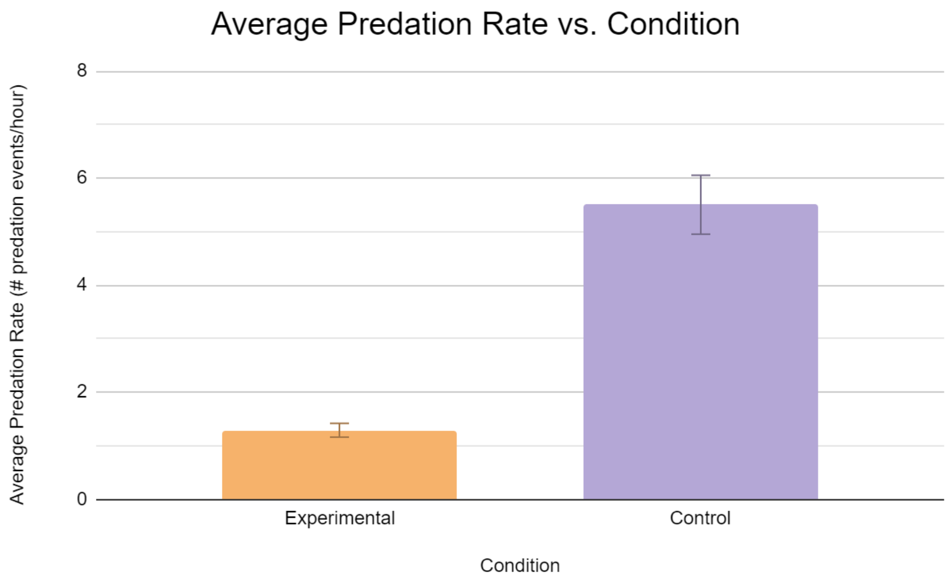

Figure 4. The average predation rates (predation events per hour) are shown by condition over 22 experimental (TAST on) trials and 8 control (TAST off) trials. There was a 77% decrease in predation rate from control to experimental conditions.

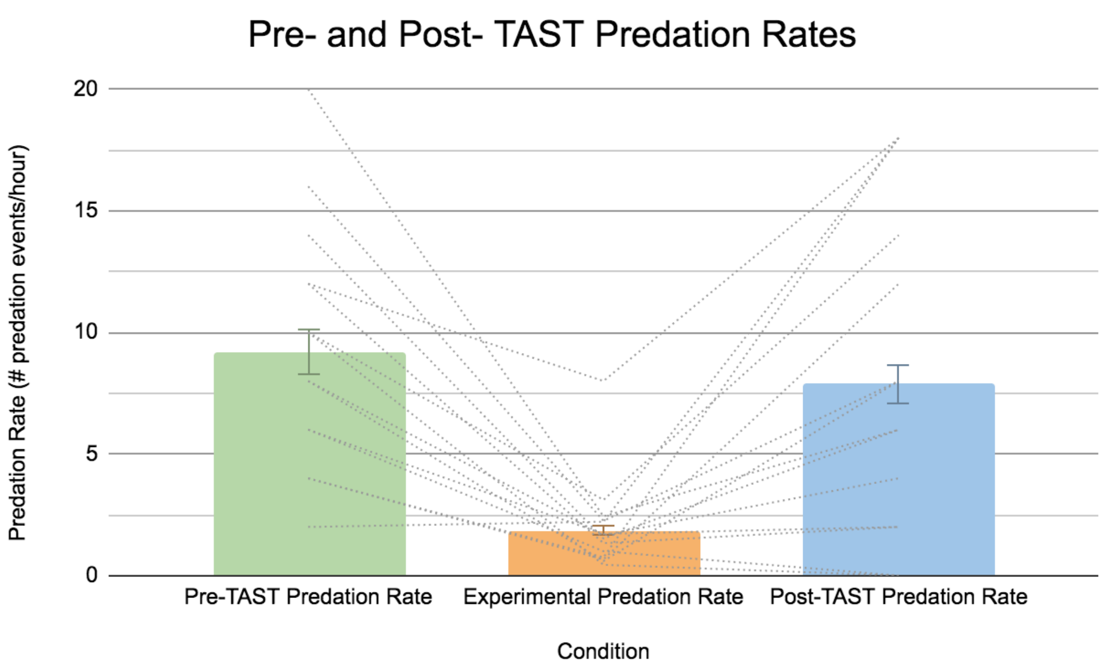

Figure 5. Predation rate (predation events per hour) for TAST-on treatment, the pre-TAST 30-minute period before the device was turned on, and the post-TAST 30-minute period after the device was turned off. Each line represents the observed pre-, during, and post-TAST periods across 15 trials. The bars represent overall average predation rate for each experimental condition.

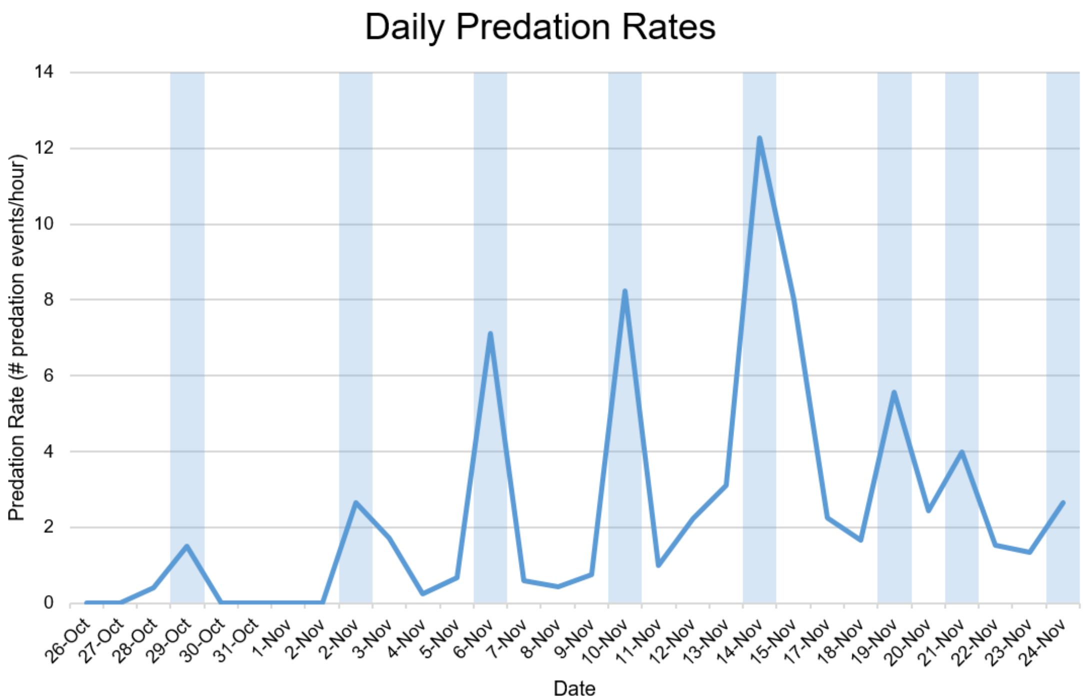

Figure 6. Daily predation rates (number of predation events per hour) are shown as the blue line by TAST on/off condition with blue background bars representing control (TAST off) days. Sample size was 30 observation sessions (8 control and 22 experimental), over 29 days. Two observation sessions were conducted on November 2nd—one experimental and one control shown respectively.

Fish Passage: A total of 1869 fish were counted by the Bellingham Technical college over the course of the season, and 18 counts were done on days during this study, 13 during experimental (TAST on) conditions and 5 during control (TAST off) conditions. The average daily fish counted for experimental and control conditions was 96 fish and 45 fish, respectively. We took the difference of the average experimental and control daily fish counts and multiplied by 13, the number of days with TAST on for which there were fish counts (ie. (95-45)*13 = number of fish saved across TAST on days). We estimated that the TAST saved around 662 fish, a 55% increase in fish passage with TAST deployment (Figure 7).

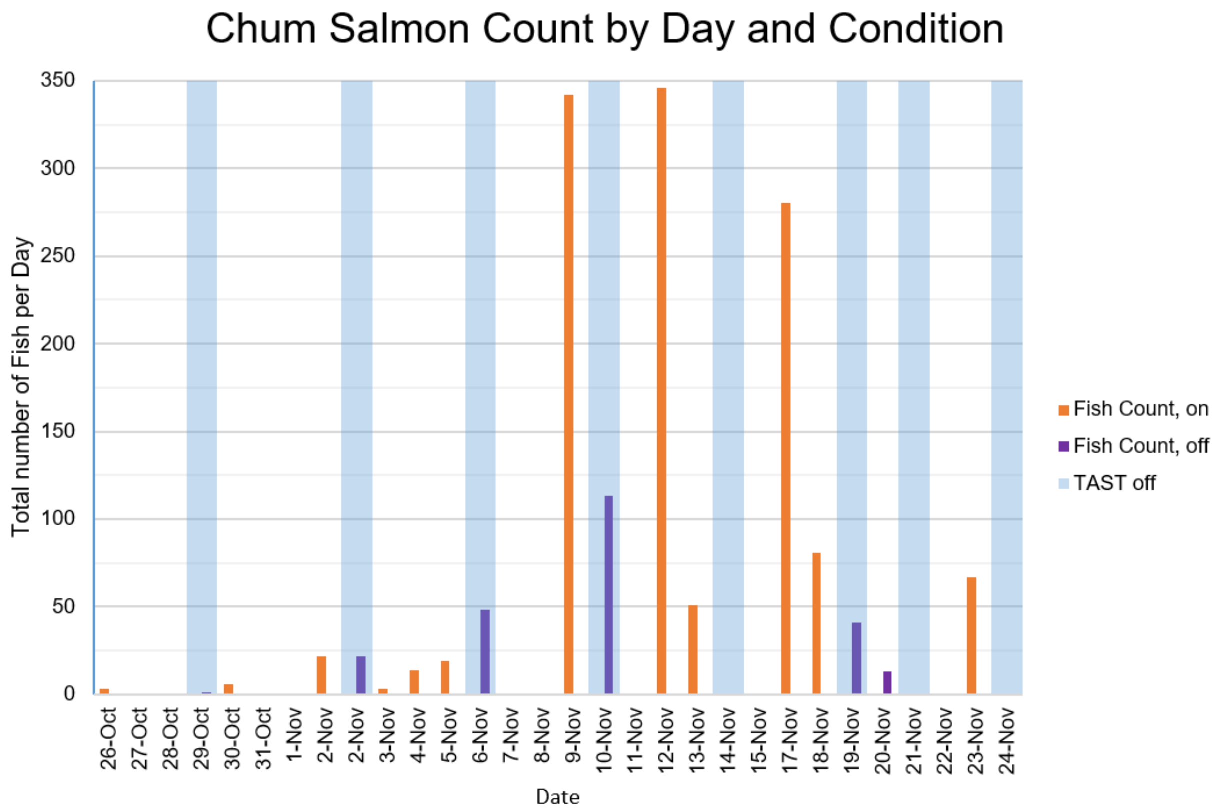

Figure 7. Daily chum salmon counts from October 26 - November 24 with counts for experimental (TAST on) days shown in orange, counts for control (TAST off) days shown in purple, and all control (TAST off) days shaded in blue. The total number of fish counts was 18 days, 13 experimental and 5 control, out of 30 total observation days. Two observations were conducted on November 2nd—one experimental and one control shown respectively. The final cumulative fish count was 1869 individuals. Although the sample size of days with fish counts was too small to allow statistical testing, the data suggest that the days with the highest returns all occurred on days when the TAST was in use.

Acoustic measurements and propagation: Broadband received levels of the TAST signal within the survey area ranged from 142 - 167 dB. Received levels measured upstream from the TAST were 147 dB. Downstream from the survey area (130 - 270 m from TAST) received levels ranged from 124 - 142 dB. As expected, the TAST received levels decreased with increasing distance from the device. In general, the observed transmission loss of the signal followed predicted loss from spherical spreading, with some exceptions. Greater signal loss was observed between 60 - 75 m and at distances greater than 150 m (Figure 9). Increased transmission loss of the signal was also evident at the two recording locations upstream from the TAST (26 - 30 m from the device). The broadband source level was estimated to be 186 dB, which is 4 dB higher than the source level previously taken at a different location (recorded at 1 m distance, in deep water). Further analysis is needed to interpret how received levels and background noise might affect the audibility of the TAST signal to a seal.

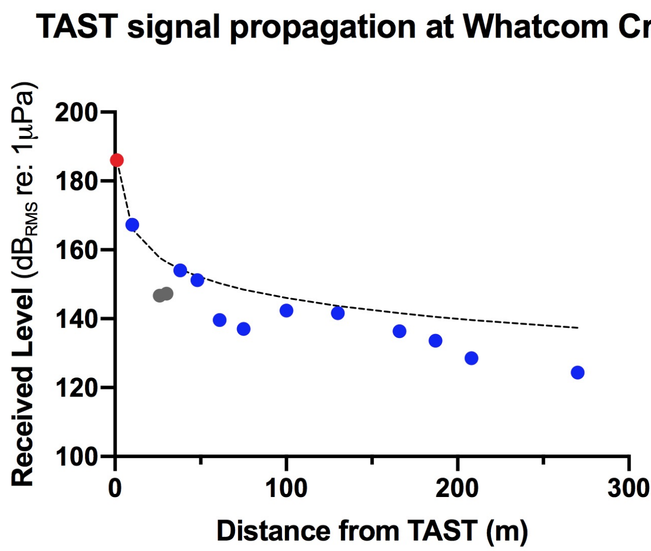

Figure 8. TAST underwater signal levels measured in the Whatcom Creek. Root mean square (RMS) received levels are shown in dB SPL with corresponding distance from the TAST device. Received levels measured downstream from the TAST are shown in blue, and those measured upstream are shown in grey. The TAST source level (back-calculated from a recording at 10 m) is shown in red and provided for comparison. A curve showing sound pressure levels predicted from the transmission loss equation assuming spherical spreading is also shown as a reference.

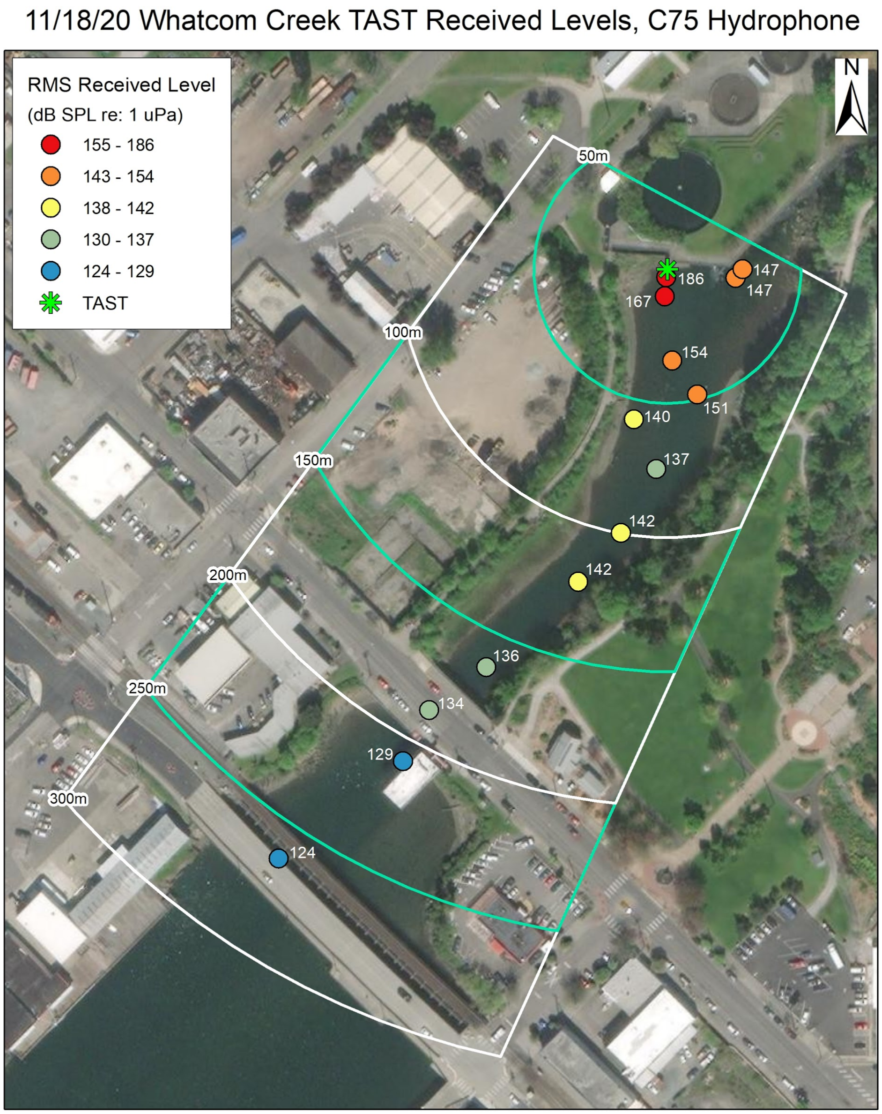

Figure 9. Map of the Whatcom Creek study site showing measured received levels of the TAST signal at each recording location. The location of the TAST device is shown as a green star. The signal source level is shown as the point closest to the TAST (186 dB SPL re: 1 μPa) for reference. There were 6 recording locations within the survey area (Blocks 1-4) and 7 locations outside the survey area— 2 locations upstream from the TAST and 5 locations downstream (>100 m from the TAST).

Discussion:

The analyses revealed that the TAST was effective at reducing the presence of seals in the creek by 55% percent as well as increasing seal distance from the fish ladder by approximately 19m. Overall predation on salmon decreased by 77% (Figure 4), and we estimate the TAST saved around 662 out of the total 1869 fish counted, a 55% increase with TAST deployment (Figure 7).

In the Hatchery and Management plan, Bellingham Technical College proposes an annual broodstock collection level of 1,350 males and 1,350 females to meet the egg take goal of 2.6 million eggs. This year there were 1,248 males and 621 female returns and an 55% increase in fish returns with the TAST on for only 65 hours. There is potential for an even greater increase in return numbers of chum to Whatcom Creek with longer, more continuous TAST deployment, especially if we can figure out how to anchor TASTs in deeper channels to allow the TAST to remain active at low tide.

When the difference in seal presence observed during control and experimental conditions is considered with respect to the received sound levels, there was a greater number of seals observed beyond 60 m from the TAST device when it was on, which corresponds to received signal levels below 140 dB. This means that the ensonified area surrounding the device (0 - 50 m), with corresponding sound levels of 186 - 151 dB, showed a substantial drop in seal presence during experimental sessions. This difference in seal distribution within the study area shows that the TAST device was effective at displacing seals at received levels greater than 151 dB. This signal level is close to the published startle threshold for harbor seals (estimated from harbor seal audiogram and grey seal sensation level startle threshold) of 159 dB (Gotz & Janik, 2011). Received levels exceeded this startle threshold in block 1 only.

The estimated source level of the TAST signal was 4 dB higher than the source level previously measured with the transducers in deep water (> 10 m). This might be explained by the shallow depth of the transducer, and its positioning close to the bottom of the creek. Fluctuations in the tidal cycle, which influenced the depth of the transducer could have influenced propagation of the TAST signal in the creek. The TAST device was turned on for a total of 22 days, during which the maximum high tide coinciding with each observation period ranged from 7.75 ft to 9.52 ft. Received levels were measured on 11/18/20, during a high-tide with a maximum of 9.52 ft, corresponding to the highest end of this range.

During a few experimental days observers noted individual behavior of seals swimming to the fish dense region of the creek near the falls, then speeding away with a fish by the time another pulse occurred. TAST pulses are emitted pseudorandomly with a duty cycle of approximately 1% (Götz & Janik, 2016). However, due to the distance from the outskirts of TAST's effective range to the falls and quiet periods during TAST pulse cycles, individuals could in theory swim to the bottlenecked fish zone to collect a fish without immediate impact from the TAST. In this area, seals could be relatively close to the ladder (20 - 30 m) while avoiding the loudest part of the signal (received levels measured upstream were 147dB— much lower than the rest of blocks 1 and 2, and more similar to received levels in blocks 3 and 4). Seals can swim up to 4.9 meters per second (Williams & Kooyma, 1985). With an approximate distance of 60 meters a harbor seal could swim to the falls from the edge of TAST's effective area in 12.24 seconds, capture a fish, and then swim back out of the area in another 12.24 seconds. The time needed for an individual seal to hunt and catch their prey in Whatcom creek would need to be further studied to truly analyze this behavior and predation success when TAST is deployed.

There were multiple challenges with experimental design related to the depth near the fish ladder, location, and hatchery hours. Time constraints were the most limiting factor because deployment could only occur at high-tide during daylight hours. The restriction of deployment by tide removed the possibility of continuous TAST on and off cycles and weakened experimental design. It appeared that seal presence was higher when the high tide was bigger and also when it was raining. The ability to collect data at all tides would enable exploration into these observations, among others. The chum salmon run started near the end of October at which point it was critical to begin data collection to maximize our window for trials during the run between late October through November. As a result of constraints, we were unable to collect sufficient baseline data for incorporation into the analyses. Nonetheless, there is still an opportunity to compare TAST effects to baseline data collected in previous years by Western Washington University. Another factor to keep in mind is the fact that fishers were not allowed to harvest the chum during the 2020 chum run, therefore comparisons made between years must take this variable into consideration.

The implementation of fishing restrictions may have been a contributing factor to fish counts being higher than previous years. However, it is difficult to analyze fish count data without continuous daily numbers which is a limitation easily remedied by continuing counts on weekends and holidays. The absence of fishers during the 2020 run enabled harbor seals to hunt without competition from humans. The presence of local fishers does not serve as a deterrent to harbor seals, however it is possible that the seals have had experience being hazed elsewhere. Although there have been no official or recorded attempts to haze harbor seals at this site, the use of seal bombs and other deterrents is not uncommon for the population at large, and has been known to occur in other waterways in Western Washington (including at the Ballard Locks in Seattle). When deployed at close range, seal bombs are loud enough to cause hearing damage to harbor seals (Wiggins et al., 2019; Kastak et al., 2005). Photographs were taken for potential future use in a photo-identification study following previously-determined methods (Thompson & Wheeler, 2008) which may help discern what proportion of the population is less affected by the TAST, whether it be a result of hearing damage or otherwise. Photo-ID efforts would allow further exploration into individual variability in the effectiveness of TAST and may even result in an even more pronounced deterrent effect.

In one laboratory experiment, two older male seals exhibited a slight startle response to the TAST, but did not show any flight behavior, and it was hypothesized that raising the sound pressure level could elicit a stronger response (Götz & Janik, 2011). Placement of multiple devices along the creek (including one upstream from the fish ladder, closer to the falls) would raise the overall received levels within the creek, as well as potentially eliminate pockets of water with lower signal levels, essentially mitigating for poor signal transmission due to environmental factors (water depth, size and shape of creek, etc.). This could therefore increase the range of effectiveness, and result in a stronger displacement of seals away from fish-dense areas.

Habituation has been a concern with the use of ADDs but the nature of targeted acoustic startle technology reduces the likelihood (Götz & Janik, 2016). However, Whatcom seals may have been able to expect the presence of TAST during only high tide. If the device is deployed continuously, or around the clock, the possibility for habituation by tide or other circumstance could be easily eliminated in future studies. New equipment that is able to operate in low water levels and remain operable throughout entire tide cycles would reduce potential for habituation related to study design.

At no point during any observations were ESA-listed bull trout (*Salvelinus confluentus*) sighted and thus there are no observations to report.

Conclusion:

Summary statistics suggest that TAST succeeded in achieving three goals: 1) the reduction of seal presence in the area, 2) reduced seal predation on salmon, 3) the displacement of seals from the fish ladder. In addition to these results, it is likely that the TAST was also successful in increasing the number of salmon that passed through the fish ladder. More rigorous statistical analyses are needed to further explore these results.

There are many future applications for TAST to be studied on other wild or captive pinnipeds, such as California sea lions, Steller sea lions, different harbor seal populations, and different management problems (e.g., haulouts, predation on in-migrating adults or out-migrating smolts). Such studies could look at variable amplitude and signal frequencies to target these species and broaden the scope of its effectiveness as a deterrent. There are also possible applications on pinnipeds foraging on out-migrating smolts because higher harbor seal numbers occur in response to higher salmonids upstream in freshwater (Middlemas et. al, 2006). TAST may also be useful on commercial fishing vessels that harvest salmon to prevent bycatch and deter predators. TAST can also expand beyond the scope of protecting fish species and protect pinniped populations from oil spills and natural disasters. Although there were no bull trout sightings during this study, there is potential for TAST to reduce the threat of predation by pinnipeds to this ESA-listed species and increase survival.

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