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USING DUAL-FREQUENCY IDENTIFICATION SONAR (DIDSON) TO ESTIMATE ADULT STEELHEAD ESCAPEMENT IN THE SAN LORENZO RIVER, CALIFORNIA

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Steelhead, *Oncorhynchus mykiss*, are currently listed under the United States Endangered Species Act (ESA) in central and southern California. In most of this region, steelhead are considered threatened, but the Southern California Distinct Population Segment (DPS), comprising populations in Santa Barbara County and southward is listed as endangered, with only very small numbers of steelhead reported from the Santa Maria River south to the United States-Mexico border (Good et al. 2005). The listings are based mainly on anecdotal information of adult steelhead abundance, with the exception of escapement estimates based on dam counts on the Carmel River (part of the South-Central California Coast DPS), and recently initiated monitoring efforts in two tributaries of the Santa Ynez River system and on the mainstem of the Ventura River (part of the Southern California Coast DPS).

Knowledge of whether a species' abundance is increasing or decreasing is essential to assessing the effectiveness of management and recovery actions under the ESA. Consequently, the need to initiate steelhead monitoring programs in central and southern California is critical. However, the need to monitor abundance of this oftentimes rare species in these regions is beset by a number of technical challenges. First, the low abundance and potentially highly patchy distribution of spawners demand that a higher fraction of available habitats be sampled to achieve a particular level of precision. Additionally, many watersheds in California's coastal region are characterized by highly erodible soil types and extremely dynamic hydrographs, which produce high turbidity and otherwise difficult conditions for conducting conventional spawner, redd, or carcass surveys. These conditions suggest that use of video or other visual monitoring that targets adults in migration corridors downstream of known spawning areas may be more efficient, although such efforts are likewise hindered by the flashiness and turbidity typical of high-order streams in coastal California. The National Marine Fisheries Service (NMFS) has operated a floating resistance panel weir on Scott Creek (Santa Cruz County) to estimate coho salmon, *Oncorhynchus kisutch*, and steelhead escapement since 2004 (Bond et al. 2008). However, this is the only attempt at using such a device in a California coastal stream with a dominant substrate of mudstone and sand, both of which are easily transported during high flow events and can thus render such a weir inoperable during fish migration periods. Additionally, construction of weirs or other structures for the purpose of counting fish is likely to be undesirable, as these structures may impede or hinder the spawning migrations of populations that are close to extinction.

In this paper, we introduce and provide a preliminary evaluation of a sonar-based approach that addresses the difficulties of monitoring rare or endangered salmonids. Dual-frequency identification sonar (DIDSON) uses high-frequency sound waves to produce near video-quality images of underwater objects. Its unique acoustic lens configuration and high-resolution transducer array allow for determination of directional movement and size estimation in a variety of riverine settings, including turbid and low light conditions. DIDSON has been successfully used to estimate large salmon runs in highly productive rivers in Alaska, Idaho and British Columbia (Maxwell and Gove 2004, Galbreath and Barber 2005, Cronkite et al. 2006, Holmes et al. 2006, Kucera and Faurot 2006; Brazil 2008). These studies have very successfully compared DIDSON-derived counts to those obtained using traditional sonar (e.g., single- and split-beam) and other counting methods (e.g., observer towers and video counts). Maxwell and Gove (2004) and Brazil (2008) determined DIDSON was superior to split-beam sonar in its detection capabilities and that it offered other advantages such as greater coverage of the water column, improved image quality, ability to determine directional movement, and ease of operation. Kucera and Faurot (2006) reported that DIDSON successfully captured 99.9% of 914 total salmon passages during validation monitoring using an underwater video counting station. However, applying DIDSON technology to the problem of monitoring small, endangered spawning populations where conventional survey methods are ineffective has not yet been attempted. In addition, no study has compared DIDSON results to those obtained using a stream barrier method such as a weir or fish trap. In this note we describe the use of DIDSON to estimate steelhead escapement at low abundance, rather than the higher abundance situations in which it previously has been used.

We conducted a trial on the San Lorenzo River (Santa Cruz County, California) in 2006, during which we compared DIDSON-derived adult steelhead counts with those obtained at the nearby Felton Diversion Dam fish trap. We deployed the DIDSON for a portion of the spawning season, from 14-17 and 21-24 March 2006 in the San Lorenzo River. The study site was approximately 12 km upstream from the Pacific Ocean and 185 m downstream from the fish trap.

We designed and used a tripod style mount after consulting with and receiving multiple mount design examples from D. Burwen (Alaska Department of Fish and Game, personal communication). The mount was fabricated from heavy gauge steel (heavy wall square tubing) and featured an adjustable arm, three sled-like feet, and a sturdy base made from 3 mm gauge steel (Figure 1). An aluminum box was designed to fit around the DIDSON unit to afford added protection from debris traveling downstream during high flow events. Our goal was to develop a mount that could withstand fluctuating flow patterns in terms of velocity and changes in depth, as well as one that could easily be moved over the substrate because changing flows required positional adjustments. The mount proved useful and effective for this application; mount design and more detailed operational information can be found in Pipal et al. (2010).

Power requirements and site security were major considerations for this study. With all components running (DIDSON, pan and tilt rotator, controller computer, and external hard drives), the system required approximately 130 Amp-hours per day. We utilized AC power (110-V) from a nearby USGS gaging station, which involved running a line from the station, over a bridge and down to our equipment. As the study site was located in a public park with unrestricted access, there were concerns about equipment theft or vandalism. Since this was a pilot study with a short survey window, we did not develop or plan for a permanent infrastructure for securing project equipment. Instead, we staffed the site on a 24-hour basis during deployment.

Figure 1. DIDSON mount design used for our trial on the San Lorenzo River, California in March 2006. Photograph by authors.

Some care had to be taken in situating the DIDSON unit so as to maximize acquisition of useful data. The DIDSON was deployed in the water near one bank and aimed toward the opposite bank to enable determination of directionality of fish passage. The sound beam produced by the DIDSON unit widens with distance from the unit, in both the vertical and horizontal planes, producing a wedge-shaped zone of ensonification. Ideally, a cross-section of channel should be completely ensonified so that no migrating fish can pass undetected. Consequently, we chose a section of channel whose profile resembled a wedge shape, and that started shallow on the near-bank and gradually deepened to allow for the greatest beam spread across the entire channel width. The channel was 20 m wide, with a depth ranging from about 0.5 m at the DIDSON side of the channel to 1.5 m at the opposite side (Figure 2).

Flows during the study period were moderate, averaging 616 cfs with a range from 426 to 1,120 cfs. A single rain event occurred before initial deployment, providing an ideal opportunity to detect fish moving upstream as high flows gradually subsided. During periods of high flow, it may have been possible for fish to swim above the ensonification zone, especially near the DIDSON unit, thus passing through undetected. However, this is unlikely as salmonids generally swim near the river bottom to reduce drag and take advantage of reduced current velocities (Quinn 2005). A small fence that extended to the bank was placed behind the DIDSON to prevent fish from swimming behind the unit. During our sampling periods, the DIDSON was always aimed slightly downward to ensonify the river bottom. We chose a section of channel with sandy substrate, a laminar flow (to reduce the chance of encountering milling fish), and an ensonification zone that was free from any objects (e.g., boulders) that could allow a fish to pass through undetected.

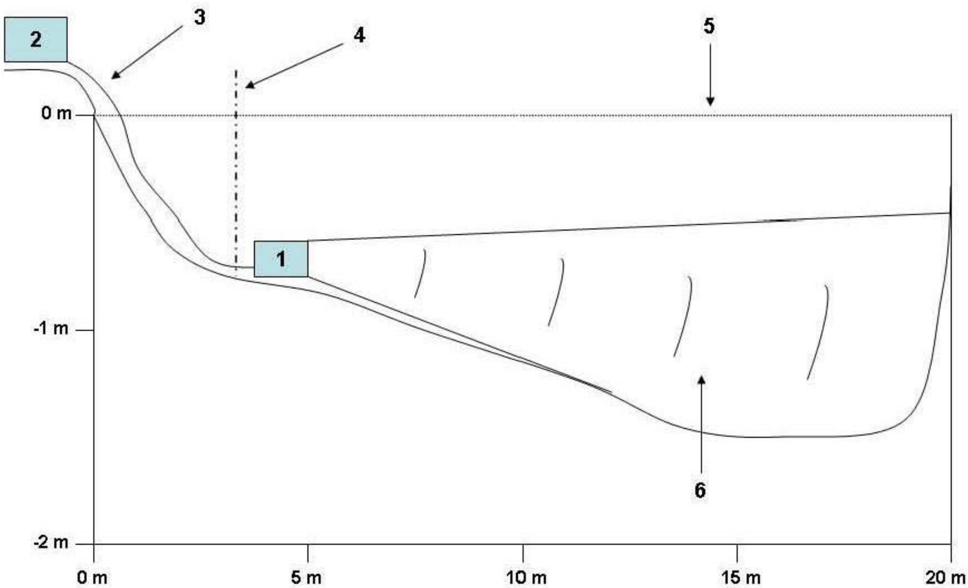

Figure 2. Diagram illustrating a side view of the DIDSON deployment at the San Lorenzo River. Numbers refer to the following: 1) DIDSON unit with pan and tilt rotator mechanism, 2) controller computer and external hard drives housed in a weatherproof storage box, 3) cables connecting DIDSON to controller unit, 4) fencing material, 5) water level, and 6) volume of water ensonified by DIDSON beam. Note that the vertical and horizontal scales differ.

The DIDSON operated for a total of 141 hours. Images from the DIDSON were recorded continuously onto portable, 300 gigabyte external hard drives and later analyzed for species identification and enumeration. External hard drives were housed in a weatherproof storage box on-site, along with the controller computer. Using DIDSON for this application generated large amounts of data, approximately one gigabyte per hour of recording. Files were transferred to and stored on larger external hard drives when returned to our laboratory for processing, and later archived onto back-up tapes stored off-site. We used the Convolved Samples Over Threshold (CSOT) program included in the DIDSON software to analyze data. This program uses an algorithm to select frames where movement is detected utilizing user-selected parameters of sample size (pixel cluster) and threshold (in decibels), thereby shortening review time substantially. This was especially important for our study, which was focused on finding rare events (i.e., steelhead passages) over many hours or days of recorded images.

The fish trap was checked each morning (0700 hours); however, on some days it was checked as many as three times per day, depending on flows. Fish encountered at the trap were identified, measured, sexed, and released upstream. The trap was not operated on 21 March 2006, during which time fish were unable to pass upstream.

Over the period of deployment, the total DIDSON count and fish trap counts were very comparable. The DIDSON unit counted a net total of 41 upstream migrants (46 upstream migrants and 5 downstream migrants), while the trap passed 46 fish upstream (Table 1). The daily counts, however, were very different. It is important to note the differences in the two methods. The DIDSON is observing the fish's natural behavior during upstream migration, while the trap is a barrier to fish during upstream migration. The successful DIDSON studies conducted in Alaska (Maxwell and Gove 2004; Brazil 2008) and Idaho (Kucera and Faurot 2006) did not use barrier systems for comparison. They instead used either traditional sonar or underwater video counts where fish passage was unrestricted, and that resulted in natural fish movement being reflected in both methods included in the comparison. In our study, fish could have held in pools between the DIDSON and the trap due to either natural migratory fish behavior or due to the trap (e.g., reluctance to enter the trap, milling behavior, unattractive flows, etc.). In some instances, fish were observed coming up to the trap and returning downstream. It is also possible that fish encountered at the trap could have passed the DIDSON site before it was deployed or after it was removed.

This trial is the first application of the DIDSON technology to count low numbers of steelhead spawners (c. 9 fish per day) in a central California flow regime. Its use in salmonid escapement estimation has primarily been limited to population sizes which number in the 10's to 100's of thousands of fish that generally pass a fixed location in large numbers over a relatively short period of time (i.e., less than 1 month). The ability of DIDSON to operate consistently over a long time period and over a wide range of flow conditions is ideal for the enumeration of winter steelhead runs in central and southern California where water conditions can be turbid and fish passage may only be occasional during a spawning season that may last 4-5 months. However the operating capacity of DIDSON (e.g., maximum range, optimal site characteristics), power requirements, expected maximum flow and turbidity levels, and site security should be carefully contemplated before considering DIDSON for any particular application. Since DIDSON is a passive device that simply records passage past a fixed location, there is no need to handle fish or impede their movement, both of which can be important when dealing with listed species. DIDSON can be placed near the shore and does not restrict fish movement or alter fish behavior.

Our initial trial suggests it can be very useful for monitoring small runs of steelhead in rivers subject to the flashy, turbid coastal California winter flow regime. Since our study in the San Lorenzo River, we have deployed DIDSON in two other central California streams to further investigate its feasibility in estimating steelhead escapement in systems with low abundance. In 2007, we utilized DIDSON in Big Creek (Big Sur coast, Monterey County) and for the past three steelhead spawning seasons (2008 - 2010), we used DIDSON in Scott Creek (Santa Cruz County). DIDSON operations in Scott Creek provided an opportunity to compare DIDSON results with counts from an existing weir in operation just downstream from our study site. Results from the Scott Creek deployment will be available in a future publication.

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