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A previously undocumented life history behavior in juvenile coho salmon (*Oncorhynchus kisutch*) from the Klamath River, California

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During the fall of 2012 juvenile coho salmon (*Oncorhynchus kisutch*) were sampled by Yurok Tribe employees in two tributaries of the Lower Klamath River: McGarvey Creek (41°29'03.09"N, 124°00'48.09"W) and Hunter Creek (41°35'44.28"N, 124°02'12.02"W). Fish were captured by either seining or electrofishing and if the FL was greater than 65 mm then a full duplex Passive Integrated Transponder (PIT) tag was inserted into the body cavity. A hand-held device was used to scan each PIT tag before it was implanted. The code was manually recorded and later proofed against the electronic download from the scanner. All fish were released in the immediate vicinity of each sampling site. A total of 32 coho was implanted with PIT tags in McGarvey Creek on 5 September 2012 and 70 in Hunter Creek on 15 October 2012.

Three Streamwidth Passive Interrogation (SPI) monitoring stations (41°29'9.74"N, 124° 0'41.33"W; 41°29'30.48"N, 124° 0'20.67"W; 41°29'58.00"N, 123°59'56.91"W) for detection of PIT tags were operated by the Yurok Tribe in McGarvey Creek during the fall and winter of 2012–2013.The SPI monitoring stations were equipped with multiplexing transceivers capable of reading full duplex PIT tags. Hunter Creek was not monitored with a SPI monitoring station. Both the initial PIT tagging event information from McGarvey and Hunter Creeks and subsequent detections at SPI monitoring stations in McGarvey Creek were uploaded into the Klamath River Basin (KRB) PIT tag database maintained by the United States Geological Survey (USGS) Western Fisheries Research Center located in Klamath Falls, Oregon.

Redwood Creek (41°17'33" N; 124°05"31" W) enters the Pacific Ocean 17 miles south of the Klamath River and Prairie Creek (41° 17'57.73"N, 124°03'02.15"W) is a tributary to Redwood Creek. Although Prairie Creek was equipped with a SPI monitoring system, operated by California Department of Fish and Wildlife (CDFW), it was not capable of detecting full duplex tags. All PIT tagged juvenile coho salmon in the Klamath River were implanted with full duplex PIT tags. Therefore, no SPI data were available for detecting the presence of Klamath River coho salmon in Prairie Creek.

In the spring of 2013 a rotary screw trap (RST) was operated in lower Prairie Creek, located just upstream from the confluence with Redwood Creek (river mile 3.2). The trap was operated for monitoring purposes in the Prairie Creek system unrelated to Klamath River studies (Sparkman et al. 2014). The RST was operated continually (24 hrs/day, 7 days a week) except during high discharge events during the smolt migration period (10 March 2013 to 13 August 2013). Captured juvenile coho salmon were measured for fork length (mm) and weighed (g). All fish of a size that potentially held a PIT tag were scanned with a hand-held device. If the device detected a PIT tag code it was manually recorded and later proofed against the electronic download from the scanner. The locations of the initial PIT tagging events in McGarvey and Hunter Creeks, the McGarvey Creek SPI monitoring stations, and the Prairie Creek RST are displayed in Figure 1.

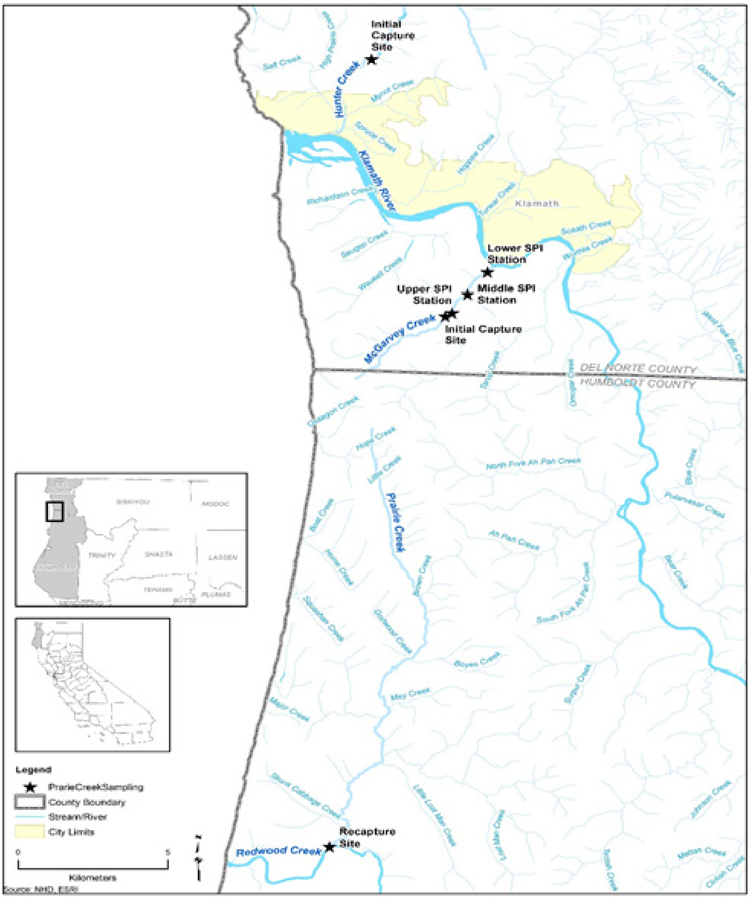

Figure 1.—Map of the study area showing tagging locations, SPI monitoring stations, and recapture site of juvenile coho salmon from three streams in coastal northern California. The tagging sites were in the Lower Klamath River watershed and the recapture site was located in a tributary to Redwood Creek.

During analysis of the PIT tag data collected from the Prairie Creek RST, it was determined two of the captured coho were not tagged in either Prairie Creek or Redwood Creek. To obtain information on where these fish were initially tagged the two PIT tag codes were entered into the KRB PIT tagging database. The query revealed that the initial tagging events for PIT# 985121025924963 and PIT# 985121025905793 were in McGarvey Creek and Hunter Creek respectively (Table 1). The query also displayed detections of PIT# 985121025924963 on two of the three McGarvey Creek SPI stations during 6 December 2012. The initial marking location was above all three SPI monitoring stations and the fish was detected at Upper SPI station at 19:00:51 hrs and at the Middle SPI station at 19:39:47 hrs indicating the fish was moving downstream. Data for Klamath River discharge were retrieved from the USGS gaging station (KNK) near Klamath, California, through the California Data Exchange Center (http://cdec.water.ca.gov). The flow data indicated the fish was moving downstream during a major freshet that occurred in early December 2012. Although the fish was not detected at the lower-most SPI station this is not surprising since the entire lower portion of the McGarvey Creek Valley becomes inundated during high flow events from the Klamath River and the monitoring station only covers a small fraction of the channel width during high water. The flows on 2 December and 5 December 2012 are the two highest December flows for the Klamath River over a 10 year record spanning 2006 to 2015. Discharge from the Klamath River during December 2012 and date of detections for the fish are displayed in Figure 2.

Table 1.—Tagging and subsequent recapture events for two juvenile coho salmon. Both of the coho were initially tagged in Lower Klamath River tributaries and recaptured in a tributary of Redwood Creek.

	Initial Tagging				**Recapture**			
PIT Tag #	Location	Date	Fork Length (mm)	Wet Weight (g)	Location	Date	Fork Length (mm)	Wet Weight (g)
985121025924963	McGarvey Creek	09/05/12	99	13.0	Prairie Creek	04/29/13	120	17.0
985121025905793	Hunter Creek	10/15/12	97	11.0	Prairie Creek	04/28/13	123	18.5

In response to high flow events juvenile coho salmon may redistribute in search of better overwintering habitat (Giannico and Healey 1998; Bell et al. 2001). Based on the detections of the McGarvey Creek fish leaving during a major freshet, we hypothesize that this fish entered the mainstem of the Klamath River in search of better overwintering habitat. No data are available to indicate when the Hunter Creek fish emigrated, but it is likely this fish moved into the mainstem Klamath River during the same general period due to the protracted freshet that was occurring. During the same freshet (1-7 December 2012) 5 fish PIT tagged in McGarvey Creek and 9 from Hunter Creek were detected entering non-natal tributaries in the Lower Klamath River estuary. It is possible the two coho recaptured in Prairie Creek were swept out to sea by high flows. However, since other fish were capable of locating new overwintering sites during the freshet it seems probable the movement was volitional rather than passive. Once in the Klamath River, we hypothesize that these fish continued downstream until they encountered the ocean. The lower river as

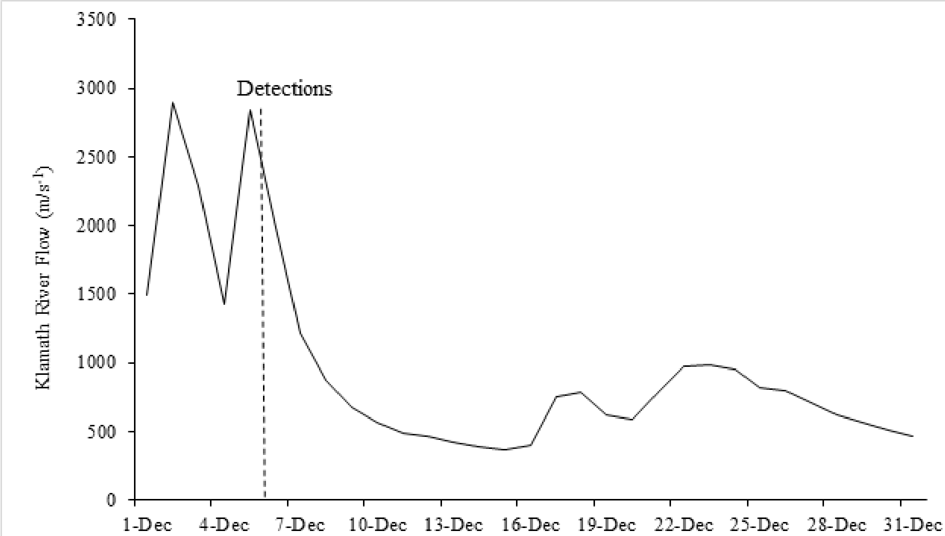

FIGURE 2.—The SPI monitoring station detections of a PIT tagged juvenile coho salmon in McGarvey Creek on 6 December 2012 in relation to Klamath River stream flow (m/s^{-1}). Data for Klamath River discharge were retrieved from the U.S. Geological Survey gaging station (KNK) near Klamath, California through the California Data Exchange Center (cdec.water.ca.gov).

it enters the ocean flows swiftly during high flow events, and the freshwater plume would have extended some distance out into the ocean. Upon ocean entry juvenile salmon typically follow the direction of ocean currents (Royce 1968; Brodeur et al. 2003; Azumaya and Ishida 2004). The current direction at the surface of the ocean is largely driven by the direction of prevailing winds (Nelson 1977) and the surface current in the coastal zone of Northern California is highly variable during the fall and winter months based on current direction images accessed from the Cooperative Ocean Prediction System website (west.rssoffice.com). Ocean current images revealed sustained southward current from the Klamath River to Redwood Creek from 6-11 December 2012 (J. Farrara, Remote Sensing Solutions, Inc., personal communication; Figure 3). During the remainder of December current direction was northward. Therefore, we conclude the period of 6−11 December 2012 was the likely time these two fish immigrated to Redwood Creek. It is probable the two fish moved into Prairie Creek soon after entering Redwood Creek since it contains higher quality over-wintering habitat. However, there is no data available to determine for certain when these two fish entered Redwood or Prairie Creek. If the coho were either implanted with half duplex PIT tags or the SPI station in Prairie Creek was capable of detecting full duplex tags more information might be available. Furthermore, since a SPI station is more efficient at detecting recaptures than a RST, the likelihood of encountering this coho movement pattern in the future would be enhanced by compatible PIT tag technology.

Spring and early summer is the typical period for juvenile coho salmon parr-smolt transformation and entry into the ocean (Sandercock 1991). Although juvenile coho are capable of surviving saltwater before parr-smolt transformation it generally results in poor growth (Folmar et al. 1982; Mahnken et al. 1982). Furthermore, ocean entry typically coincides with seasonal peaks in marine productivity and good feeding opportunities (Spence and Hall 2010). Since

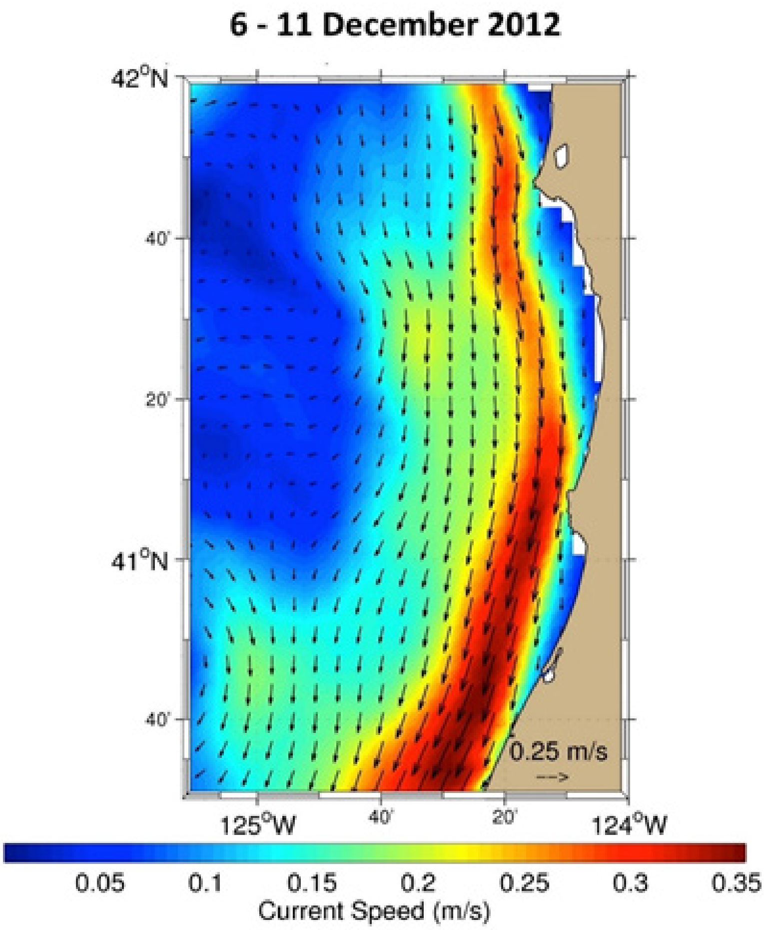

Figure 3.—Prevailing current direction off the coast of northern California adjacent to the Klamath River (41°32’37” N; 124°04’53” W) and Redwood Creek (41°17’33” N; 124°05”31” W).

December is not a typical month for coho entry into the ocean or a period of high marine productivity we conclude these two fish reentered freshwater to enhance their chances of survival.

Migrations through saltwater to find suitable freshwater rearing habitat have been previously documented in age-1$^+$ coho salmon from Alaska that out-migrate in the spring, rear and travel significant distances in saltwater (upwards to 113 km), then enter another river system to overwinter in the fall and out-migrate to the ocean as age-2$^+$ smolts the following spring (Shaul et al. 2011; Shaul et al. 2013). Our finding documents behavior different than observations in Alaska since the two coho from the Klamath River entered saltwater at age-0$^+$ during late fall and most likely returned to freshwater shortly thereafter.

It is well established that juvenile coho salmon utilize rearing habitat in areas other than their natal streams (Tschaplinski and Hartmann 1983; Peterson and Reid 1984; Bramblett et al. 2002; Roegner et al. 2010; Sutton and Soto 2012). Peterson (1982) suggested that potential rearing habitat is not confined to a natal stream and can include other areas within a river system beyond natal areas, particularly those located downstream. Our findings demonstrates that juvenile coho salmon from the Klamath River can migrate through the ocean and rear in another river system, thereby expanding available rearing habitat beyond their river of origin.

Our findings would not have been possible without the existence of the KRB PIT tag database especially since the recapture events took place in sampling outside the Klamath River watershed and by different organizations. Therefore, it provides a good example of the importance for funding and maintaining databases which cover large geographic areas and contain tag information from the multiple agencies involved in studies that include PIT tagging and recapture events. A template for creating a PIT tag database could be the Regional Mark Information System coded wire tag database maintained by the Pacific States Marine Fisheries Commission. We suspect as the use of PIT tag technology increases in the Pacific Northwest and California, and access to data from different organizations is expanded, the extent and significance of coho salmon movement patterns will become better understood.

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