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Green Sturgeon of the Eel River: 2017 Spring Survey Results

PREPARED FOR

NOAA Fisheries
Office of Protected Resources

PREPARED BY

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Cover photos: Green sturgeon spring survey activities on the mainstem Eel River in June 2017.

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1 INTRODUCTION

1.1 Project Background and Need

Green sturgeon (*Acipenser medirostris*) are found in the coastal waters and rivers of western North America where they feed in coastal marine and estuarine environments and spawn in selected large rivers (Adams et al. 2002, Moyle 2002). Their marine distribution ranges from Ensenada, Mexico to the Bering Sea, Alaska (Scott and Crossman 1973, Moyle 2002), but the only confirmed spawning aggregations were documented in the Rogue River of Southern Oregon (Erickson et al. 2002) and adjacent Klamath River of Northern California (Benson et al. 2007), plus the Sacramento River of California's Central Valley (Kohlhorst 1976, Brown 2007). Genetic studies have led to the classification of two distinct population segments (DPS): the Northern DPS, which includes fish spawning in the Rogue and Klamath rivers, and the Southern DPS, comprising fish spawning in the Sacramento River (Israel et al. 2004). The Southern DPS was listed as threatened under the Endangered Species Act in 2006 (NMFS 2006), largely because only one spawning population is known to occur, while the Northern DPS is listed as a state and federal species of concern due to multiple spawning populations but many of the same general threats. Green sturgeon are a long-lived, late-maturing anadromous fish species, and as such they are vulnerable to freshwater habitat loss and exploitation and population recovery has the potential to be slow (Moyle 2002, Adams et al. 2002, NMFS 2010). Adult green sturgeon generally return to spawn in rivers in late winter through the early summer and spawn every two to six years, with spawning intervals of three to four years being the most common (Moyle 2002, Adams et al. 2002, NMFS 2010, Doukakis 2014).

The Eel River in Northern California is one of the larger rivers in the state and historically had an apparently robust and important spawning run of green sturgeon, although inferences about population size are impossible because of the lack of historical data (Adams et al. 2002). Contemporary fisheries surveys from the Eel River would occasionally record green sturgeon adults or juveniles. The general consensus was that green sturgeon in the Eel River had become exceedingly rare and it was uncertain if these sightings represented a few stray fish from other spawning rivers in the area, or signified an actual persistent and distinct spawning run (Adams et al. 2007). In the late 1960s, anadromous fish outmigration trapping studies conducted by the California Department of Fish and Wildlife (CDFW) documented juvenile green sturgeon approximately 100 km upstream on the mainstem Eel River (Puckett 1976). Similarly, CDFW documented multiple adult green sturgeon during the summer in the mainstem Eel River in the same general areas, a finding consistent with spawning run behavior. Also, sporadic sightings of adult green sturgeon by boaters and fishermen have occurred historically and in recent years, with observations of fish occurring in the lower mainstem as well as over 100 km upstream. In conceiving this project, we hypothesized that contemporary sightings of green sturgeon in the Eel River represented a persistent and distinct, albeit undocumented, spawning run and we predicted that a systematic, multi-year survey would demonstrate this.

Moyle et al. (1992) hypothesized that the green sturgeon spawning run on the Eel River was completely lost after the 1964 flood, which caused severe aggradation and decreased pool depths. The Biological Review Team (BRT) convened by the National Marine Fisheries Service (NMFS) concluded that green sturgeon of the Eel River had certainly suffered severe declines, but some members of the BRT were not convinced that Eel River green sturgeon were fully extirpated (NMFS 2005). In the event that green sturgeon were persisting in the Eel River, there was unresolved debate among the BRT as to whether or not this would constitute a "significant portion of the species' range," with the lack of historical or current spawning data hindering resolution of that debate (NMFS 2005). The most recent status review for Northern DPS green sturgeon showed no evidence for changing their status or new evidence regarding presence of a spawning run in the Eel River (Doukakis 2014).

Although the Eel River was officially designated as part of the Northern DPS (critical habitat for Southern DPS starts south of the Eel River) (NMFS 2010, Doukakis 2014) given its proximity to the Klamath River, there was no direct evidence to verify that any green sturgeon in the Eel River were or actually are of Northern DPS genetics. While the Eel River is indeed proximate to the Klamath River, it is even closer to Humboldt Bay, which is a documented feeding habitat for both Southern and Northern DPS (Lindley et al. 2011). Therefore, it is possible that any green sturgeon in the Eel River could be of Southern DPS origin or a mix of both.

NOAA's recovery planning document for the Southern DPS of green sturgeon (NMFS 2010) states: "*In order to establish a recovery plan for the species, the current status of that species must be understood.*" In order to understand the population status and effectively manage the species, it is necessary to determine whether any green sturgeon that spawn in the Eel River are part of the Northern DPS, as presumed without direct evidence, whether they are part of the Southern DPS, or whether they are a mix. All possible outcomes would be significant: (1) if they are Northern DPS, this would add a third, persistent spawning river/population to that DPS besides the Klamath and Rogue rivers; (2) if they are Southern DPS, this would add a vital second spawning population besides the Sacramento River, which has important implications for population resiliency; and (3) if they are a mix, it would be the first documented mixed spawning run.

In addition to determining the population of origin, it is important to document a spawning run, including the timing and locations, and if possible, spawning success, all of which would allow for a more accurate assessment of the status of green sturgeon in the Eel River, as well as further evaluation of potential threats and recovery actions. Another important question is whether the Eel River estuary, both the riverine and marine portions, is being used as rearing and feeding habitat for one or both DPSs of green sturgeon, similar to nearby Humboldt Bay (mixed), the Umpqua River estuary (Northern DPS only), or the Klamath River (mixed in marine estuary, Northern DPS only in riverine estuary) (Lindley et al. 2008, Israel et al. 2009, Lindley et al. 2011, Doukakis 2014).

1.2 Project Goals and Objectives

The goal of this project is to determine the current status and population of origin of green sturgeon in the Eel River of Northern California. The research activities and findings for study years 2014 to 2016 is reported by Stillwater Sciences and Wiyot Tribe (2017), which also made recommendations for further research that included the continued monitoring of green sturgeon in the Eel River to document the annual run size and detect any returning acoustically tagged fish. This technical memorandum presents the results of monitoring efforts in 2017 for green sturgeon of the Eel River.

The overall objectives of this on-going project are to: (1) determine the presence, timing, and locations of green sturgeon spawning and holding in the mainstem Eel River; (2) evaluate the use of the Eel River estuary (riverine and marine) by adult green sturgeon; and (3) determine the population(s) of origin (Southern DPS vs. Northern DPS) of any sturgeon documented in the Eel River.

1.3 Study Approach

The full study approach to meet the overall project objectives have included the following primary tasks: (1) mobile DIDSON sonar surveys; (2) acoustic bio-telemetry tagging and monitoring; and (3) determination of population of origin through genetic testing.

Specific research activities conducted in 2017 and described in this technical memorandum include: (1) conducting a presence and enumeration survey of adults on the mainstem Eel River over 192 river kilometers using a mobile DIDSON sonar camera; and (2) deploying acoustic receivers to detect river entry by any acoustically-tagged adult green sturgeon, whether from this study or from other studies in different locations.

1.4 Study Area

While the greater study area for this project will ultimately include any areas used by green sturgeon in the Eel River basin, the study area reported herein was the mainstem Eel River from the confluence of the Middle Fork Eel River at river kilometer (rkm) 192 (Dos Rios) to the Pacific Ocean and the nearshore marine portion of the estuary within 2 km of the mouth.

Draining an area of 9,534 km^2, the Eel River is California's third-largest watershed and is located between the Russian, Sacramento, Mad, and Mattole river watersheds. The Eel River basin is divided into the following major sub-basins: Lower Eel River, Van Duzen River, Lower Mainstem Eel River, South Fork Eel River, Middle Main Eel River, North Fork Eel River, Middle Fork Eel River, and Upper Mainstem Eel River (Figure 1-1).

Annual precipitation in the watershed averages 40 inches (102 cm) in the coastal lowlands to 80–100 inches (203–254 cm) at higher elevations. The climate classification of the basin is Coastal Mediterranean, marked by a rainfall pattern of wet winters and dry summers. During the period of record (starting in 1910), discharge in the lower Eel River near Scotia (USGS gage 11477000) averaged 19,900 cubic feet per second (cfs) for January and only 138 cfs for September, with a peak discharge of 752,000 cfs in December of 1964 and a minimum of near zero in August of 2015. Average annual water yield for the watershed at Scotia, which is upstream of the Van Duzen River, is estimated at 5.5 million acre-feet, although annual variation is considerable with wet years having a yield of over 12.5 million acre-feet and dry years of less than 0.5 million acre-feet. Most of the sub-basins in the Eel River are influenced by proximity to the Pacific Coast with winter-rainfall dominated hydrographs, although the Middle Fork Eel River, as well as the North Fork Eel River to some extent, also have a significant spring snowmelt signature in their hydrographs as they drain the sub-alpine Yolly Bolly Mountains.

Under current conditions, however, the spring snowmelt hydrograph is muted in the Upper Mainstem Eel River by Pacific Gas & Electric's (PG&E) Potter Valley Project, which also serves to divert water into the Russian River for consumptive use. An average of approximately 219 cfs is diverted from the Upper Mainstem Eel River and routed south into the Russian River basin, which has amounted to an average of approximately 160,000 acre-feet per year. The Potter Valley Project consists of two dams: the smaller Cape Horn Dam constructed in 1907 forms Van Arsdale Reservoir, which serves as the point of diversion and a fish counting station for salmonids; 17 km upstream, the larger Scott Dam constructed in 1912 forms Pillsbury Reservoir, used for hydroelectric generation. Cape Horn Dam has fish passage for salmonids while Scott Dam is a total barrier to anadromous fish. The Potter Valley Project entered into the Federal Energy Regulatory Commission's license review and renewal process in 2017, which is ongoing.

The historical distribution of green sturgeon in the Eel River basin is not known; however, with the exception of likely barriers to adult upstream migration, the mainstems of the larger river channels should be accessible to adults. Known large and steep rapids expected to limit adult migration of green sturgeon include Goat Rock on the Van Duzen, Split Rock on the North Fork Eel, and Coal Mine Falls on the Middle Fork Eel River. These rapids are similar in magnitude to rapids that are known barriers to upstream migration for adult green sturgeon in the Klamath and Trinity rivers (Dr. Joshua Strange, Sweet River Sciences, pers. obs.). The mainstem Eel River and South Fork Eel River have no notable larger rapids that appear likely to be a barrier to adult green sturgeon migration, but eventually become too small and steep for adult sturgeon. No other tributaries are large enough to be considered as likely green sturgeon habitat. The mainstem Eel River within the study area comprises two sub-basins, the lower and the middle main river, which roughly corresponds to major changes in the character of the river. The lower sub-basin is characterized as being wider with very low gradient, dominated by gravel and fine sediments, with easy access and regular human settlements; in contrast, the middle sub-basin is characterized as being relatively narrower with rapids and higher gradient, dominated by a mix of bedrock and boulders with finer sediments, with minimal access and sparse human settlements. Tide-water influence extends upriver to the vicinity of Fernbridge.

Landscapes in the basin vary from extensive estuarine habitats of the lower Eel River (tidal wetlands, freshwater marshes, sand dunes, grasslands) to redwood and Douglas-fir dominated forests mixed with hardwoods such as madrone in the coastal mountains, grassland and oak woodlands further inland, and sub-alpine mountains in the headwaters of the interior sub-basins. The geology of the watershed is naturally unstable, characterized by unconsolidated Franciscan mélange marine sediments that coupled with the high rate of uplift of the Costal Range results in the Eel River having an exceptionally high sediment load (Brown and Ritter 1971). Land uses in the watershed include ranching and livestock grazing, timber management and milling, light industrial, rural and residential development, recreation, gravel extraction, and agriculture including vineyards and commercial marijuana cultivation. There are no large urban areas in the Eel River watershed, and the largest population centers are Fortuna, Garberville/Redway, and Willits.

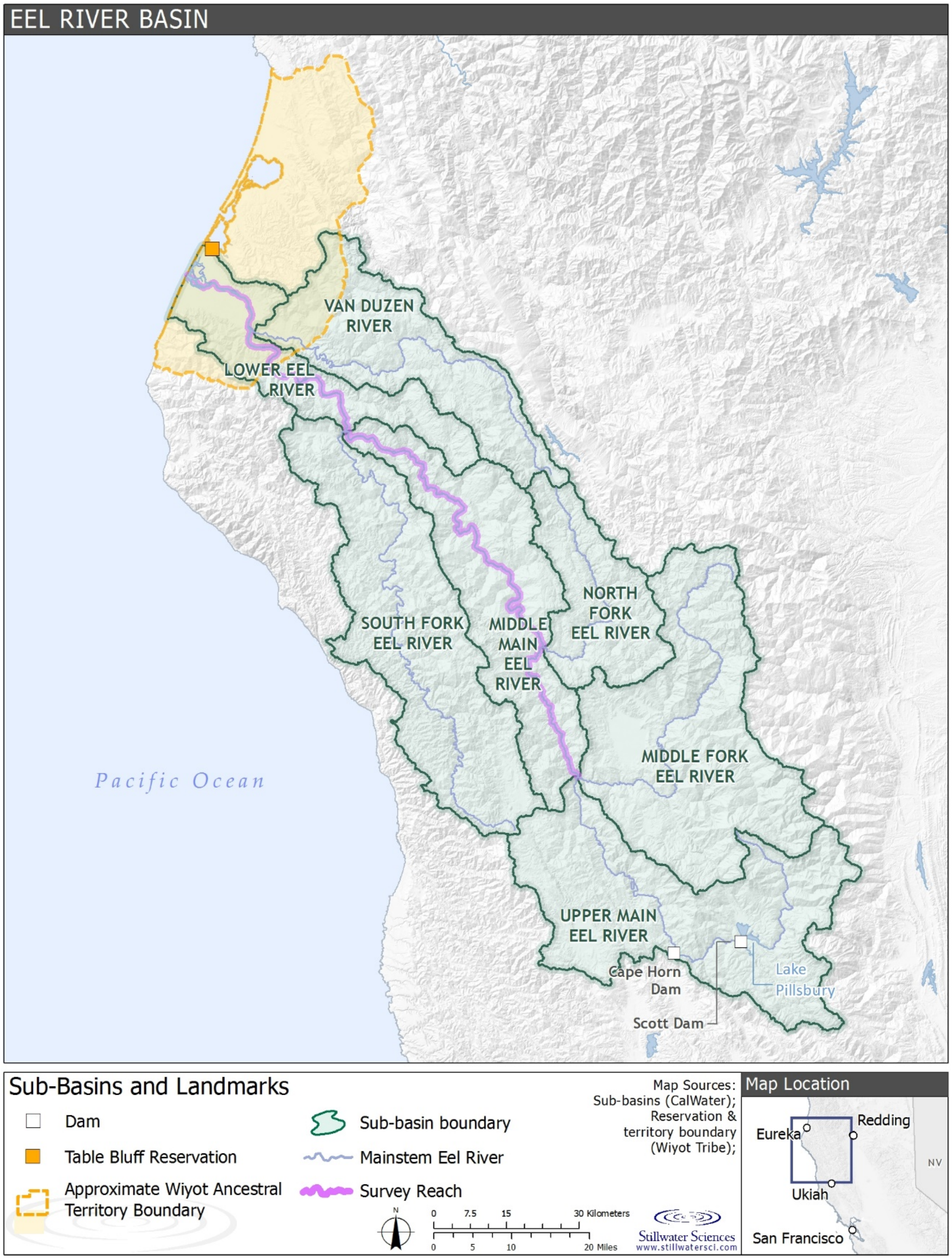

Figure 1-1. Map of the Eel River watershed showing major sub-basins, the 192-km survey reach on the mainstem, and the perimeter of Wiyot Ancestral Territory.

1.5 Green Sturgeon Distribution and Life History

1.5.1 Distribution

North American green sturgeon are a widely distributed anadromous and marine-oriented species found in nearshore waters from Baja California to the Bering Sea (NMFS 2009a, Lindley et al. 2011). There are two distinct population segments of green sturgeon: (1) a Northern DPS consisting of populations originating from coastal watersheds northward of the Eel River in California, with documented spawning populations in the Klamath and Rogue rivers; and (2) a Southern DPS consisting of populations originating from coastal watersheds south of the Eel River, with the only known spawning population being in the Sacramento River Basin (NMFS 2006, Seesholtz et al. 2015). The distributions of both the Northern and Southern DPSs of green sturgeon overlap outside of their natal rivers where they congregate to feed in coastal estuaries and bays (Lindley et al. 2011). Notable feeding areas include Humboldt Bay, Columbia River estuary, Umpqua River estuary, Willapa Bay, and Grays Harbor (Heublein et al. 2009, Lindley et al. 2011).

Heublein et al. (2009) tracked tagged Southern DPS green sturgeon spawning migrations that extended up to Cows Creek (rkm 450) in the Sacramento River. Beamesderfer et al. (2004) and Brown (2007) reported that eggs, larvae, and post-larval green sturgeon are commonly captured during sampling efforts in the Sacramento River. Juveniles have also been observed in the Sacramento River around the Red Bluff Diversion Dam (NMFS 2009b). Northern DPS adult green sturgeon have been observed as far upstream on the Klamath River as Ishi Pishi Falls at rkm 108 (Benson et al. 2007) and upstream on the Rogue River at least as far as Rainie Falls at rkm 107 (Erickson and Webb 2007).

1.5.2 Adult freshwater migration

Adult green sturgeon generally return to spawn in rivers in late winter through early summer and spawn every two to six years, with spawning intervals of three to four years being the most common (Moyle 2002, Adams et al. 2002, NMFS 2010, Doukakis 2014). In the Sacramento River, Heublein et al. (2009) reported that sturgeon lingered at the apex of their riverine migrations for 15–41 days, presumably engaging in spawning behavior and subsequently holding prior to moving back downstream.

Following spawning, during summer and fall months when temperatures were 15–23°C (59–73°F), green sturgeon in the Rogue River were found to generally reside in deep (>5 m) pools with low or no currents (Erickson et al. 2002). Post-spawned adults have also been observed in the Klamath and Trinity rivers, holding in deep pools with areas of low velocity and low to moderate currents (Benson et al. 2007, McCovey 2011, Dr. Joshua Strange, Sweet River Sciences, pers. obs.). Some adult sturgeon move back downstream to the estuary and ocean soon after spawning when river flows are still elevated by snowmelt, but others have been observed to hold in the river until the fall when temperatures decrease and flows increase with precipitation (Heublein et al. 2009, NMFS 2009b). Timing of emigration in the Klamath River is related to increased discharge, particularly with the first fall freshets (Benson et al. 2007, McCovey 2011). In the Sacramento River, some tagged adult green sturgeon remained through February of the year following their spawning run before moving downstream to the ocean with increased winter flows (NMFS 2009b).

1.5.3 Spawning

Green sturgeon are a long-lived, late-maturing anadromous fish species, and as such they are vulnerable to freshwater habitat loss and exploitation, and population recovery has the potential to be slow (Moyle 2002, Adams et al. 2002, NMFS 2010). Conversely, being long-lived and having an extended and variable spawning periodicity of 2–6 years allows sturgeon to be more resilient in the face of variably suitable environmental conditions and periods with poor river conditions.

Spawning adult green sturgeon prefer pools that are >16.4 ft (5 m) deep with complex hydraulic features and upwelling, bedrock shelves, and cobble/boulder substrate (Moyle 2002, Adams et al. 2002, NMFS 2005, Heublein et al. 2009). Substrates suitable for egg deposition and development include bedrock sills and shelves, boulders, or cobbles and gravel with interstices or irregular surfaces to “collect” eggs, to provide protection from predators, and to be free of excessive silt and debris that could smother eggs during incubation (NMFS 2005).

Based on documented spawning locations, spawning behavior, and habitat requirements for green sturgeon embryo development, reproductive females likely select spawning areas with turbulent, high velocities near low velocity resting areas (Israel and Klimley 2008). Eggs are broadcast and externally fertilized in relatively fast water at depths generally greater than 10 ft (3 m) (Moyle 2002). Poytress et al. (2011) conducted underwater videography in three confirmed green sturgeon spawning pools in the Sacramento River and found that these pools generally had highly turbulent flow in the upstream area that flowed over bedrock or hardpan, with downstream areas having lower velocities and substrates composed of cobble, gravel, and sand.

1.5.4 Egg incubation

Female green sturgeon produce 59,000–242,000 eggs that are about 0.17 inches (4.3 millimeters [mm]) in diameter (Van Eenennaam et al. 2004). Eggs hatch 6–8 days after fertilization (Deng et al. 2002). Optimal water temperatures for the development, growth, and survival of green sturgeon eggs and larvae are between 15–19°C (59–66°F) (Mayfield and Cech 2004). Van Eenennaam et al. (2004) reported water temperatures between 17–18°C (63–64°F) to be the upper limit of thermal optima for green sturgeon embryos, with greater temperatures affecting development and hatching success. Similarly, Doroshov et al. (2004) found high survival rates for a temperature range of 16–19°C (61–66°F), but abnormalities increased significantly above 19°C (66°F). Water temperatures greater than 23°C (73°F) have been shown to cause complete mortality before hatch (Van Eenennaam et al. 2004).

1.5.5 Larval development

At hatching, most body systems of green sturgeon larvae are incomplete. Consequently, substantial organogenesis and acquisition of organ functions occur during the larval development stage (Deng et al. 2002). Newly hatched larvae have poor swimming ability and prefer to stay in contact with structure, cover, and dark (very low light) habitat as opposed to open-river bottoms (Kynard et al. 2005, as cited in NMFS 2009b). Larval feeding begins approximately 10 days after hatching when larvae are approximately 1 inch (25 mm) in length (Deng et al. 2002). Larvae begin to display a nocturnal swim-up behavior at 6 days post-hatch, when the rudiments of the pectoral and ventral fins become developed, dorsal and anal fin rays are apparent, yolk of the mid-intestine is depleted, and the mandible begins rhythmic movement (Deng et al. 2002). This swim-up behavior may assist in downstream dispersal to nursery areas (Deng et al. 2002).

Green sturgeon larvae initiate a downstream dispersal migration that begins when they are about 6 to 9 days old and lasts about 12 days (USDI 2008). Trap samples at Red Bluff Diversion Dam and the Glenn-Colusa Irrigation District (GCID) Diversion showed the downstream dispersal of larval green sturgeon in the upper Sacramento River to occur from May through August at sizes ranging from 0.8–2.4 inches (20–60 mm) (Gaines and Martin 2002, CDFG 2002, both as cited in USDI 2008). Larvae occupy bottom habitat with cover during daylight periods, and thus downstream dispersal typically occurs at night (USDI 2008). Poytress et al. (2010) conducted an experimental benthic D-net survey in water that was 8.9–10.8 ft (2.7 to 3.3 m) deep that had a surface velocity of 2.0 feet per second (ft/s), and observed a peak in larval captures between 10 p.m. and 11 p.m. when the water temperature was approximately 15.5°C (60°F).

Larval green sturgeon are regularly captured during the dispersal stage at about two weeks of age at the Red Bluff Diversion Dam (CDFG 2002, as cited in USDI 2008) and are three weeks of age when captured further downstream at the GCID Diversion (USDI 2008). The distance between these two facilities is approximately 34 river miles. Therefore, based on emigration of fish between these two points, the average rate of downstream dispersal by larval green sturgeon during 2002 was approximately 7.9 km (4.9 mi) per day, or more specifically, per night. Assuming that the downstream larval green sturgeon migration reported in USDI (2008) occurs only at night and that there are 9 hours of darkness during the late spring and summer months, then the dispersal rate would be approximately 0.8 ft/s (0.24 m/s).

In a laboratory study of young Kootenai River white sturgeon (*Acipenser transmontanus*), Kynard et al. (2007) found that there is a threshold water velocity needed to trigger larval dispersal; a velocity of 0.2 ft/s (0.07 m/s) was insufficient to trigger downstream dispersal for most larvae, 0.5 ft/s (0.17 m/s) triggered most larvae, and 0.75 ft/s (0.23 m/s) triggered slightly more larvae.

Water temperatures below 11°C (52°F) and above 19°C (66°F) are detrimental for larval green sturgeon development (Doroshov et al. 2004, Van Eenennaam et al. 2004). Doroshov et al. (2004) also determined that water temperatures between 22 and 26°C (72 and 79°F) resulted in notochord deformities in larval green sturgeon. Metamorphosis from the larval to juvenile stage is completed at approximately 45 days post-hatch, when fish range in size from 2.5 to 4.0 inches (6.3–9.9 cm) (Deng et al. 2002).

1.5.6 Juvenile rearing

Juveniles grow rapidly, reaching 12 inches (30 cm) in one year and over 24 inches (60 cm) in 2–3 years (Nakamoto et al. 1995). Very little information is available on the food and nutrient requirements of different life stages of green sturgeon (Klimley et al. 2006). Mayfield and Cech (2004) found that juvenile green sturgeon bioenergetic performance was optimal between water temperatures of 15–19°C (59–66°F) and that swimming performance decreased beyond 19°C (66°F). Allen et al. (2002) reported that river temperatures should not increase beyond 15 to 19°C (59 to 66°F) for optimal juvenile green sturgeon growth rates. Mayfield and Cech (2004) found that juvenile green sturgeon acclimated to temperatures of 11°C (52°F) and 19°C (66°F) did not differ significantly in their thermal preferences (15.9±1.7°C [60.6±3.1°F] and 15.7±2.9°C [60.3±5.2°F], respectively); however, fish acclimated to 24°C (74°F) exhibited a significantly higher preferred temperature (20.4 ±3.1°C [68.7±5.6°F]).

Juveniles migrate downstream (mostly at night) to wintering sites in the fall, ceasing migration at temperatures of 7–8°C (45–46°F) (USDI 2008). Wintering juveniles forage actively at night between dusk and dawn and are inactive during the day, seeking the darkest available habitat

(Kynard et al. 2005, as cited in USDI 2008). Juveniles spend from 1 to 4 years in fresh and estuarine waters of the Sacramento-San Joaquin Delta and disperse into saltwater at lengths of 12–30 inches (30–75 cm) (NMFS 2009a).

1.5.7 Riverine diet

On the Sacramento River, larval sturgeon consume primarily copepods, baetids, chironomids, and simulidae (Liam Zarri, pers. Obs.). Although specific data are lacking for juvenile green sturgeon, nutritional studies on the closely-related white sturgeon within riverine systems showed prey items included amphipods, bivalves, and fly larvae (NMFS 2009b). These food resources are important for juvenile foraging, growth, and development during their downstream migration to the Delta and bays (NMFS 2009b).

NMFS (2009b) noted that adult green sturgeon may not feed during warm summer months based on the reportedly low hook-and-line fishing success rates. This is corroborated by the skinny condition of post-spawn sturgeon observed in the summer and fall in the Klamath River (Dr. Joshua Strange, Sweet River Sciences, pers. obs.). Capture rates increase in the early fall when water temperatures decrease, which may indicate onset of feeding behavior. An adult green sturgeon captured in the Rogue River was found to have an exoskeleton of a crayfish (*Pacifasticus* spp.) and algae in its digestive tract, but there was no indication of when it was taken (Farr and Kern 2005). Digestive tracts from 46 adult green sturgeon commercially caught during 2000–2004 in the Columbia River contained only algae (Farr and Kern 2005).

1.5.8 Sub-adult and adult ocean residency

Recent analysis from archival tags, acoustic tags, and Oregon bottom trawl logbook records indicate that green sturgeon are widely distributed in the nearshore ocean at depths up to 360 ft (110 m), with most use occurring at depths between 130 and 230 ft (40 and 70 m) (Erickson and Hightower 2007). Sub-adults are non-mature fish that have left their natal rivers and entered the marine environment, which may occur around 2 years of age (Allen et al. 2009). Sexual maturity is reached at around 13 years of age (NMFS 2006). Huff et al. (2011) reported that green sturgeon prefer to occupy highly complex seafloor habitats where the substrate contains a large proportion of boulders. This species travels widely up and down the Pacific Northwest coast, as evidenced by tagged individuals reported in the Columbia and Umpqua river estuaries, Humboldt Bay, Willapa Bay, and Grays Harbor in Washington (Heublein et al. 2009, Lindley et al. 2011).

Three acoustic receivers deployed by the Yurok Tribal Fisheries Department in the ocean offshore of the Klamath River reportedly detected 19 tagged green sturgeon in 2007 (McCovey 2008), with 10 of these detections being originally tagged in San Pablo Bay. Of these 10 fish, none entered the Klamath River. The rest of the detections were from fish tagged in Willapa Bay, Grays Harbor, and the Rogue and Klamath rivers. It is believed that green sturgeon reside in bays and estuaries to feed throughout the summer during years in which they are not making spawning migrations (Moser and Lindley 2007, Lindley et al. 2011).

2 METHODS

2.1 Sonar Surveys

2.1.1 Spring surveys

We conducted boat-based mobile sonar surveys to census adult green sturgeon during the spring spawning season, from the confluence of the Middle Fork Eel River and mainstem of the Eel River at Dos Rios (rkm 192) to the estuary (Figure 1-1). Dos Rios is located above all known historical and recent sightings of green sturgeon within the mainstem Eel River, with the majority of those sightings centered from the confluence of the North Fork (rkm 155) to the confluence of the South Fork (rkm 65) as well as in the estuary. Specific dates of the 2017 surveys are reported in the Results section.

We used a waterproof Dual-Frequency Identification Sonar (DIDSON) 300-m sonar camera (Sound Metrics, Bellevue, WA) to detect adult green sturgeon in the mainstem Eel River. The use of a mobile DIDSON to detect and enumerate adult green sturgeon in rivers is a proven technology, including well-developed methods for determining confidence intervals and coefficients of variation (Mora et al. 2015). The advantage of a DIDSON is that it uses dual frequency ultrasonic sonar beams to “see” clearly in highly turbid and/or deep water, conditions where traditional fish detection methods often fail (e.g., divers and underwater video). This ability is especially useful in the Eel River, which is often highly turbid and contains numerous deep pools.

Given that a high percentage of adult green sturgeon over-summer in or near spawning pools, mobile green sturgeon sonar surveys in other rivers (Sacramento, Klamath, and Rogue) have been conducted in the late spring or summer to ensure targeting adults that are not actively migrating. In the Eel River, however, the recession of the wet season hydrograph occurs earlier on average and flows decrease quickly to levels that are non-navigable by the survey vessel due to shallow riffles (< 2,000 cfs at Fort Seward gage), thereby requiring that we conduct our boat-based spring sonar surveys in April or May, which was as late in the season as navigation would allow in past study years. Due to the exceptionally wet winter in 2017, we were able to conduct our spring sonar survey substantially later in the year than other study years.

We conducted our spring sonar surveys using a custom 18-ft (6-m) whitewater cataraft outfitted with rowing oars and 20 HP outboard motor (Figure 2-1). In 2017, we added some support rafts to lighten the amount of gear in the cataraft and in order to make it more nimble, and therefore safer, in the technical rapids, which worked well. This combination allowed safe navigation through Class III+ rapids and also the ability to motor through long stretches of flatwater or upstream to the top of sampled pools to allow multiple survey passes, as would be done using a jet boat in other green sturgeon rivers. The DIDSON unit was mounted to the center bow of the cataraft with a custom mounting arm that allowed for locking it in the water at the proper depth and full movement to pan left or right and adjust the tilt angle up or down. The entire mounting arm apparatus also had the ability to quickly rotate, which facilitated lifting the DIDSON unit out of the water when navigating rapids and flatwater. Electrical power for the DIDSON unit was provided by deep cycle batteries wired in parallel, stowed in a dry box, and charged with an on-board solar panel. The DIDSON was paired to an onboard laptop for real-time viewing of the sonar camera feed. Video of the output was recorded in 2014, but not in 2016 or 2017 due to budget limitations and the low numbers of fish observed. The boat was manned with a three-person crew: DIDSON operator, general assistant, and boat pilot. All provisions needed for the multi-day floats were stowed on-board due to the remote nature of the river. Fort Seward (rkm 101) provided the best mid-way access point to resupply or switch crew members as needed.

Figure 2-1. Custom motorized whitewater cataraft used for mobile sonar survey in the spring. The DIDSON sonar camera and mounting arm (stowed for rapids) is visible to the right of the photo on the left tube of the boat.

As we traveled downstream we recorded the location and depths of all river meso-habitat units greater than 5-m deep, which were almost exclusively pool units with some deep runs. Location of surveyed units were determined using a Trimble Geo Explore GPS unit, in combination with satellite imagery maps containing a rkm overlay. A portable depth sounder was used to determine water depth (Hummingbird 110 fish finder). All locations greater than 5-m deep were considered potential green sturgeon adult holding and spawning habitat and were surveyed for the presence of adults using the DIDSON. Pools were typically formed in association with a scour feature such as large boulders, bedrock, or constriction, often with a wider expansion feature followed by the downstream alluvial tailout. Deep runs were typically much longer relative to their widths and these locations were often not associated with an expansion bar or alluvial tailout at the downstream end.

In pools, we typically performed a minimum three longitudinal transects with the DIDSON to cover the entire unit. In runs, which were narrower than pools thereby allowing full coverage within the viewing window of sonar, we performed a minimum of one transect. We also sampled some pools less than 5-m deep as time allowed, performing one transect. Sampled units were numbered in the order of their occurrence in the mainstem Eel River study area, from upstream to downstream.

Each transect consisted of driving the survey vessel longitudinally downstream along the thalweg of the habitat unit while the DIDSON operator viewed the sonar data in real-time (Figure 2-2). At the top of each unit, prior to beginning each transect, the boat pilot would signal for the DIDSON operator to deploy the DIDSON and start logging the transect path on the GPS unit. The boat pilot would motor or row downstream at a slow pace (about 5 km/h) and the DIDSON operator would pan and tilt the sonar, viewing as much area as possible during each transect. At the end of each transect, the DIDSON operator would log the GPS path in the Trimble, return the DIDSON to its onboard position, while the assistant would record the maximum depth measured during the transect. The second transect would then be conducted in an upstream direction equidistant between the thalweg and the left or right bank, and the third transect in a downstream direction to the other side of the thalweg.

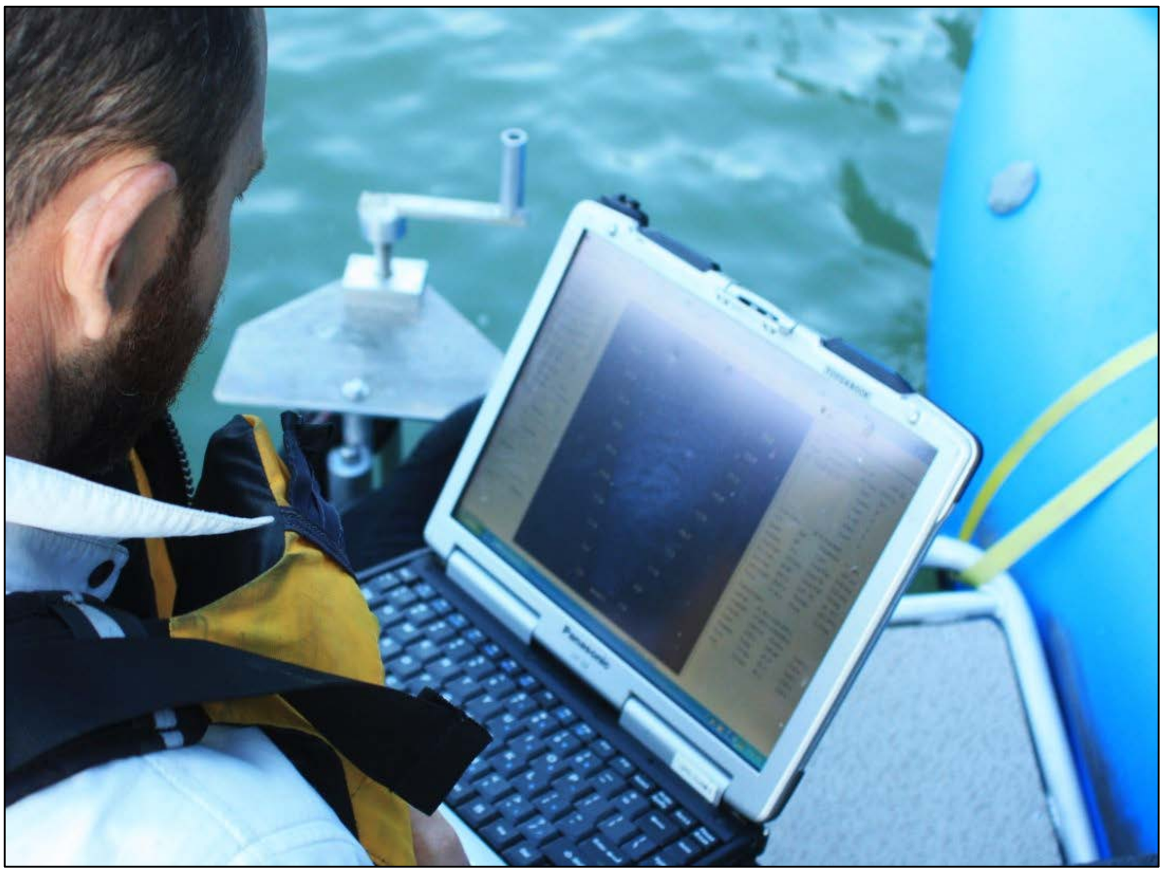

Figure 2-2. Real-time viewing of the DIDSON sonar camera display. The deployed mounting arm attached to the center of the bow of the cataraft frame is visible in the background.

If a potential sturgeon sighting occurred, the DIDSON operator would signal the boat pilot to either hold position or return to the same location while the DIDSON operator sought to confirm the sighting. Sturgeon sightings were generally confirmed by a combination of factors. The most certain sightings are confirmed by a sturgeon-shaped sonar return (pectoral fins and caudal fins visible from a completely perpendicular and oblique viewing angle), the fish changing location with respect to the bottom, a visible tail beat, and the presence of other sturgeon. Sightings of lesser certainty lack any number of these features. Sturgeon lookalikes were typically sunken logs of the right size and general shape, but lacked movement, tailbeats, and expected orientation against flow.

We estimated the number of sturgeon in the Eel River study area during our surveys using a quantitative method developed from occupancy modeling techniques as described by Mackenzie et al. (2006). The specific quanititative method for calculating the abundance of sturgeon in our mobile sonar surveys is described in detail by Mora et al. (2015). Ethan Mora has been one of the DIDSON operators for this study.

We contend that all of the adult sturgeon that we observed during this study were green sturgeon as opposed to white sturgeon based on scute counts and dorsal stripe appearance of the fish we tagged as part of this study and also based on video recordings of adult sturgeon from other researchers and anglers in the Eel River. Based on their biology and habits in the Klamath River, any white sturgeon in the Eel River would be most likely to occur in the estuary or lowermost mainstem river.

2.2 Acoustic Biotelemetry

2.2.1 Receiver array

Adult green sturgeon have been surgically tagged with acoustic transmitters by various researchers over the last decade or so (Lindley et al. 2011). Fish have been captured and tagged in the Sacramento, Klamath, and Rogue rivers while presumably en route to spawning areas and thus can be considered as belonging to their respective DPSs. Adults of both Southern DPS and Northern DPS have also been tagged at marine gathering areas in bays and estuaries such as Grays Harbor and Willapa Bay. All of these fish were tagged with Vemco (Bedford, Nova Scotia) transmitters that have the advantage of being easily detectable with any receiver made by Vemco (VR2Ws with the latest codec at 69 kHz). These receivers are deployed underwater and have a detection range of up to 1 km with the advantages of being inexpensive relative to other types of telemetry receivers, easy to operate, rugged, and possess large data storage capabilities. New generations of Vemco transmitters for larger-bodied fish also have a ten-year battery life, creating the ability to track adult green sturgeon migrations and movements over the long-term.

In 2015, we were able to secure permits and funding to purchase 10 Vemco acoustic tags with 10-year battery life (V16 at 69 kHz). During spring sampling we intercepted migrating adults by placing nets in likely migratory pathways in the lower river below the Van Duzen confluence, whereas during summer sampling we used the results of summer sonar surveys to target specific pools where adults were over-summering below the confluence of the South Fork Eel at rkm 65. Tagging was done by surgically inserting the transmitter into the abdominal cavity while the fish was immobilized upside down in a cradle stretcher, followed by suturing (Figure 2-3). Further details on the tagging procedures we used are describe by Benson et al. (2007).

In order to detect and track any adult green sturgeon tagged in other studies or as part of this study, we deployed a small network of five sonic receivers (Vemco VR2Ws) at strategic locations in the mainstem Eel River, the riverine estuary, and the marine estuary (Table 2-1). In particular, we installed receivers in the main channel adjacent to Cock Robin Island near the upper terminus of the estuary to ensure detection of any tagged green sturgeon entering the river above the estuary, which would be behavior consistent with spawning migration. Receivers in the river and riverine portion of the estuary were anchored with weights and attached to black PVC coated galvanized cable that was secured to rock using a rock hammer drill and bolts or by wrapping the cable around a boulder or tree. We deployed receivers in the late winter to early spring with periodic downloading and retrieval after the first fall freshets but before winter high water. This ensures detection of outmigrating sturgeon as results from the Klamath River have consistently shown that tagged adult green sturgeon often outmigrate during the first fall freshets but are not likely to be migrating in the river during the winter (McCovey 2011, Dr. Joshua Strange, Fish Biologist, Sweet River Sciences). Further, the high turbidity associated with winter flow events tends to greatly decrease the detection range of sonic receivers and exposes them to mechanical damage from debris and abrasion.

Table 2-1. Location and years of deployment of sonic receivers to detect adult green sturgeon tagged with acoustic tracking tags.

Year(s)	Location	Coordinates	rkm
2014–2017	Cock Robin Island Bridge, southern	40.63609, -124.28168	2.0
2015–2017	Mainstem above South Fork Eel	40.35445, -123.91419	65.0

3 RESULTS

3.1 Sonar Surveys

3.1.1 Spring Survey 2017

In 2017, we conducted a boat-based mobile sonar survey from May 31st to June 6th during the descending limb of the wet season hydrograph and at the end of the window for navigation of the mainstem Eel River (Figure 3-1). Drought conditions abated in 2017 and the water year was generally extremely wet. While flows during the winter and spring of 2017 were exceptionally high, stream flows during the survey were moderate to low, ranging from approximately 1,400 to 2,000 cfs at the Scotia USGS gauge.

During the spring 2017 mobile sonar survey, we inspected 73 of 93 meso-habitat units for the presence of green sturgeon over the 192 km from Dos Rios to the estuary. Multiple survey units from 2016 appeared to have filled in with sediment during winter floods, and in 2017 many such units were no longer over our depth threshold for surveying (≥ 4 m). In addition, equipment failure resulted in a loss of power to the DIDSON sonar camera and inability to survey 20 units in the mid-reaches of the survey area.

Pool and deep-run meso-habitat units in 2017 ranged from 12 ft (4 m) deep to 45 ft (14 m) deep, but the majority of units were ≥ 5 m in depth Appendix A). Overall, 25 units were ≥ 6 m in depth, 11 units were ≥ 7.5 m in depth, 7 units were ≥ 9 m in depth, and 2 units were ≥ 12 m in depth.

During the 2017 spring survey, one adult sturgeon was observed with the DIDSON sonar camera near Fortuna. One adult green sturgeon was observed visually near Fort Seward in a localized area of elevated turbidity. No other adult sturgeon were observed during the 2017 survey. No adult sturgeon were observed in notable large, deep pools where they had been observed during the 2016 survey.

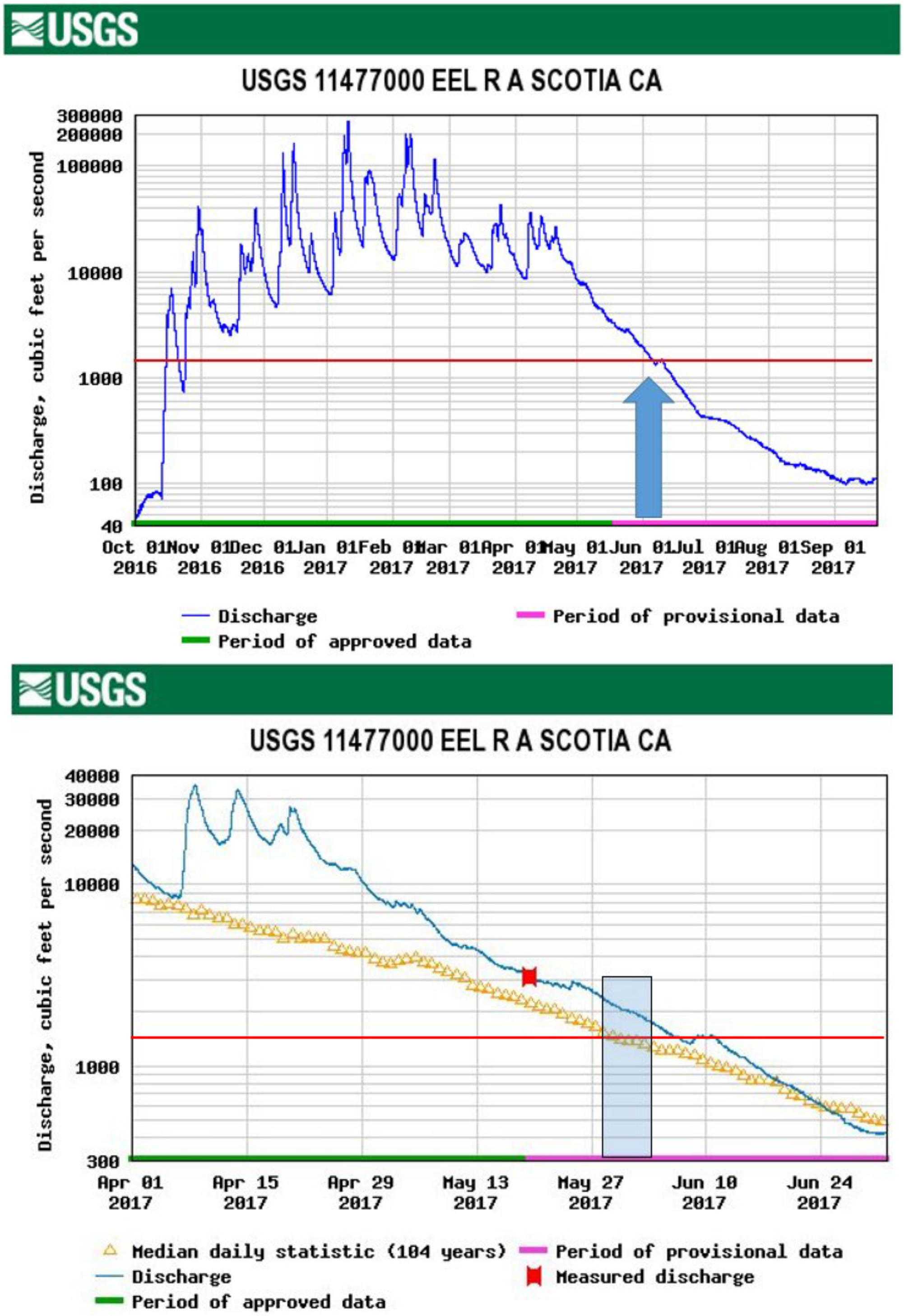

Figure 3-1. Flows on the lower mainstem Eel River at Scotia (rkm 36) during the very wet water year of 2017 (top) and during the spring of 2017 (bottom). The blue arrow and blue box indicate the timing of the spring survey and the red line indicates flows below which navigation of the survey reach becomes impossible and upstream migration of adult sturgeon to spawning grounds may become problematic.

3.2 Acoustic Biotelemetry

3.2.1 Receiver array

The locations and periods of deployment of acoustic VR2W receivers are summarized in Table 2-1. The acoustic receivers were deployed in the early spring and retrieved after the first freshets of the fall or winter. During the period that acoustic receivers were deployed, no sturgeon tagged in other river basins and locations were detected entering into the Eel River or its estuary above rkm 2. We are confident that the 1 km detection range and duration of deployment was sufficient to have detected any tagged sturgeon that entered the Eel River above rkm 2.

In 2015, we successfully tagged five adult green sturgeon in the Eel River and none of these fish were detected in our acoustic receiver array in 2017, which is expected given the 3 to 4 year spawning periodicity of green sturgeon. We anticipate that these tagged fish will return starting in 2018 and beyond.

4 SUMMARY OF MAJOR FINDINGS

- The exceptionally wet winter allowed conducting the 2017 spring survey in early June, substantially later than in other study years.
- We surveyed the mainstem of the Eel River from Dos Rios (rkm 192) to Fortuna (rkm 17). During the survey, one sturgeon was observed in Fortuna with the DIDSON and one sturgeon was observed (visually) in the vicinity of Fort Seward in association with an area of turbidity (potentially being used for cover).
- The majority of adult sturgeon in the Eel, Klamath, and Rouge rivers have been observed over-summering in deep pools after spawning. However, as is well-documented in the Klamath River, in wet water years the majority of fish are able to migrate, spawn, and return to the ocean in the spring without over-summering. Also, wetter years appear to have larger returns of adults. Therefore we hypothesize the lack of green sturgeon observations in the Eel River during the 2017 spring survey was due to fish migrating in and out of the river prior to our survey in early July, as allowed by the wet water year and higher spring flows. Alternatively, and considered less likely, the lack of sturgeon observed in 2017 could have been due to extremely low run size of adult sturgeon in the Eel River.
- We recommend continued monitoring to determine annual run size through use of mobile or stationary DIDSON methods.

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Appendices

Appendix A

Meso-habitat Units Measured During Boat-based Sonar Surveys - Spring 2017

(*Due to sensitivity regarding holding locations of adult green sturgeon, appendix available upon request)*