Appendix Q

Tenera Addendum

Empirical Transport Modeling of Potential Effects on Ichthyoplankton Due to Entrainment at the Proposed Samoa Peninsula Bay Water Intakes

Addendum 1: Longfin Smelt

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Introduction

This report is provided as an addendum to a report (Intake Assessment - version dated May 13, 2021) submitted to the Humboldt Bay Harbor Recreation and Conservation District (the District) on a modeling study that assesses the potential for impacts to marine organisms that could occur due to the operation of two seawater intakes in Humboldt Bay that will support aquaculture and a variety of other uses. The two intakes will be constructed, owned, and operated by the District. The two planned intakes will be located at the Redwood Marine Terminal II Dock (RMT II) and the Red Tank Dock (RTD) which are located on the eastern shore of the Samoa Peninsula approximately 3.8 mi (6 km) from the entrance to the bay (Intake Assessment - Figure 1-1). The Samoa Peninsula is west of the City of Eureka in Humboldt County, California and east of the Pacific Ocean. The two intakes are located at the north end of the Main Channel where it starts to bifurcate around Tuluwat Island before merging into Arcata Bay (Intake Assessment - Figure 1-2).

This report presents information on Longfin Smelt (*Spirinchus thaleichthys*) (LFS) which is listed as threatened under the California Endangered Species Act (CESA) and provides an assessment of the potential effects on the species due to the operation of the intakes. As a result of its status as a listed species, additional information was requested on LFS and the potential for the proposed intakes to affect the population in Humboldt Bay.

DRAFT

Life History and Distribution

LFS is one of the seven recognized species of the family Osmeridae that occur in California (Moyle 2002). They are a euryhaline, planktivorous silver fish with a pinkish or olive iridescent hue with distinctive long pectoral fins hence their common name. Adult LFS, occur in freshwater, brackish waters and seawater from Alaska to Monterey Bay (Moyle 2002). The San Francisco Bay and Sacramento-San Joaquin Delta (SF Bay Estuary) is currently the southernmost spawning location for this species and supports the largest population of LFS in California. LFS are pelagic and anadromous; although some subpopulations live their entire lifecycle in freshwater lakes and streams. Although populations are present in Humboldt Bay nearly all information available on longfin smelt comes from either the SF Bay Estuary or Lake Washington populations (Baxter et. al. 1999, Bennett et al. 2002, Chigbu and Sibley 1994, Moulton 1974, Nobriga and Rosenfield 2016, Stevens and Miller 1983, USFWS 2012).

LFS typically live two years and reach 3.5–4.3 in. (6–7 cm) SL, although they have been reported in some cases as living to age three and a length of 4.7–5.9 in. (12–15 cm) SL (Moyle 2002). Adults have been found in a range of saline concentrations from pure freshwater to pure seawater (Moyle 2002); a range of 0–35 practical salinity units (psu). However, during their juvenile stage they are found more commonly in brackish water with salinities ranging from 14 to 28 psu (Baxter 1999). Adult LFS prefer temperatures ranging from 16 to 20° Celsius (C) and will travel into deeper areas with cooler water temperatures during summer months as they are thought to be restricted by water temperatures exceeding 22°C (Baxter et. al. 2010). The species has a wide geographic distribution in the SF Bay Estuary (Merz et al. 2013), which reflects the wide salinity and temperature tolerances of the species and its ability to occupy different habitats during different life stages and times of the year (Moyle 2002). Following the major growth period from April–October, the mature fish begin their migration into low salinity and freshwater habitats in November–December (Merz et al. 2013, Moyle 2002), where spawning occurs in water with temperatures from 5.6 to 14.5°C (Baxter 2009).

Freshwater deltas and bays provide important habitat for LFS spawning. Although, specific locations of spawning events vary with a multitude of conditions including substrate type, flow, temperature, and salinity (Rosenfield 2010)), shallow brackish tidal marshes and sloughs are identified as important spawning and recruitment areas (Lewis et al. 2020). Spawning occurs from November through May peaking around March (CDFW 2009). Most fish die after spawning but some females have been found to live another year. Females lay 1,900 to 18,000 adhesive eggs on sandy or grassy substrate that will hatch after ~40 days (CDFW 2009). The newly hatched larvae have a salinity tolerance of 2–6 psu and move downstream into more saline water and after a few weeks can tolerate salinities around 8 psu (Baxter et al. 2010). This is consistent with sampling in the SF Bay Estuary that showed the density of LFS larvae was negatively affected in areas with salinities less than 2 psu and greater than 12 psu (Grimaldo et al. 2017). More recent laboratory studies on salinity tolerances of early LFS larvae showed highest survival and growth at salinities of 5 and 10 psu, while salinities of 20 psu presented osmoregulatory problems for the larvae and levels of 32 psu resulted in almost 100% mortality (Yanagitsuru et al. 2021). After around 90 days the larvae mature into the juvenile stage and can tolerate normal ocean salinities.

Late larval and juvenile LFS mainly feed on copepod larvae, and other insect larvae and plankton. As adults, they primarily feed on small crustaceans, cumaceans, and euphausiids (CDFW 2009). Adult LFS are considered an important part of the food web and can act as a buffer prey species for a variety of salmonids (Chigbu 2000).

The LFS is listed as threatened under the California Endangered Species Act (CESA) largely based on the well documented decline in the population in the SF Bay Estuary (Kimmerer 2002, Rosenfield and Baxter 2007, Baxter et al. 2010). The decline of LFS and other pelagic fish species in the SF Bay Estuary since the early 2000s has been the object of considerable research and is known as the Pelagic Organism Decline (Sommer et al. 2007, Merz et al. 2013).

Distribution in Humboldt Bay

There is less information on the current status of LFS in Humboldt Bay, which is 260 mi (418 km) north of San Francisco Bay, but larval (Eldridge and Bryan 1972) and adult surveys (Sopher 1974) of fishes from the late 1960s and 1970s showed that it was one of the most abundant fishes in the Humboldt Bay (Moyle 2002). A fish study by California Department of Fish and Wildlife showed that Longfin Smelt have been collected in Humboldt Bay or associated tributaries every year between 2003 and 2009, with the exception of 2004 (CDFW 2009). However, an extensive study in 2000–2001 collected very few LFS (Gleason et al. 2007), which is consistent with declines seen in the SF Bay Estuary. A survey on the historic and contemporary distribution of LFS along the California Coast showed an overall decline of the LFS in fish surveys along the coast and in the vicinity of Humboldt Bay when comparing the period of 1931–1999 with the more recent period of 2000–2016 (Garwood 2017) (**Figure 1**).

Figure 1. Locations of all life stages of Longfin Smelt collections in Humboldt Bay, its tributaries, the Eel River, and offshore waters from 1931 to 2016 (from Garwood 2017).

A more recent study on the distribution of LFS in areas north of SF Bay Estuary included larval sampling of 16 sites from Tomales Bay north to the Smith River (Brennan 2021). Sampling was conducted during the winter months of 2019 (five surveys from January through April) and 2020 (six surveys from January through May) in areas that had salinities of 2–12 psu. Due to heavy rainfall in 2019, freshwater flows into estuarine areas including Humboldt Bay were much higher in 2019 than in 2020. As a result, LFS larval abundances across all of the sampling sites were much higher in 2020, which was likely due to high flows in 2019 flushing many of the larvae out of the sampling areas. In Humboldt Bay, slightly more LFS larvae were collected during 2020 than in 2019 (61 vs. 65), but the sampling in 2020 collected LFS larvae at many more sites, including sites further upstream. During both years, the only locations where LFS larvae were collected in Humboldt Bay was in Eureka Slough. No LFS larvae were collected in the Mad River Slough or South Bay. The data from an earlier study on ichthyoplankton in Humboldt Bay (Eldridge and Bryan 1972) also indicated that LFS larvae were most abundant at their sampling location in the area of the Eureka Slough. The data from the Eldridge and Bryan (1972) station closest to the intake location had the lowest numbers of larvae of anywhere in the bay. Brennan (2021) also sampled locations in the Mad and Eel rivers to the north and south of Humboldt Bay, respectively. LFS larvae were only collected at one location in the Mad River in 2020 near the mouth of the river, and LFS larvae were collected at several sampling locations in the Eel River with most of the larvae being collected in 2020.

Potential Intake Effects

The potential for the two seawater intakes proposed for Humboldt Bay, California at the RMT II and the RTD to impact LFS larvae was investigated by analyzing historic salinity data from Humboldt Bay. This assessment focuses only on LFS larvae since the early larval stages of LFS are most likely to be exposed to potential entrainment from the intakes. There is information indicating that at later larval stages, LFS exhibit swimming abilities (Bennett et al. 2002). This may allow these later stage larvae to avoid entrainment, especially at intakes similar to the systems proposed for Humboldt Bay that have been designed with very low approach velocities. Larger juvenile and adult LFS would not be subject to entrainment or impingement at the intakes due to the low approach velocities and the small 1.75 mm openings used for the screens.

As previously discussed, LFS spawn in freshwater areas of coastal estuaries similar to Humboldt Bay. As the larvae mature, they migrate into areas with increasing salinities, but the newly hatched larvae are limited to a relatively narrow range of salinities (Yanagitsuru et al. 2021). Therefore, salinity data from instruments at two locations in Humboldt Bay were analyzed to estimate the probability of survival of LFS larvae at the intake locations.

Salinity (psu) data were downloaded from the Central and Northern California Ocean Observing System (CenCOOS) website for two stations maintained by Humboldt State University (HSU). A long-term data set on salinity (February 2013 to present) was available from an HSU station (40.7775N,-124.1965W) located on a pier on the east side of the Main Channel approximately 1.8 mi (2.9 km) south of the RMT II intake location (HSU pier station). The other data set used was from the HSU Burke-o-lator station (40.7940N,-124.1930W) that is located inside the Hog Island Oyster Company shellfish hatchery on the west side of the Main Channel approximately 0.7 mi (1.12 km) south of the RMT II intake. Since the Burke-o-lator instrument uses feed water to the hatchery it is reliant on the operation of that intake. Therefore, large fluctuations in instrument readings for psu and temperature are indicators that the intake may not be operating. The data for the Burke-o-lator were available for the period from September 2018 to present. After consulting with CenCOOS staff regarding problematic Burke-o-lator data readings, data records with psu values <= 5 and > 38 and with temperatures <=5°C and > 20°C were deleted. Also, readings in both data sets that did not have passing quality control (QC) values of 1 were deleted. The Burke-o-lator takes readings four times a minute. The readings for the HSU station are collected every 15 minutes. The four readings from the Burke-o-lator from the minutes corresponding to the 15-minute readings at the HSU station were averaged to provide data for comparing the psu data from the two stations after converting all of the times for the data from UTC to PST. Only the data with matching times at the two stations were analyzed (n=67,399).

The results show very little difference between the psu readings at the HSU station and the Burke-o-lator with an average difference of 0.3 psu (**Table 1**). The frequency distribution shows that 99% of the readings for the two stations are within 2.5 psu of each other (**Figure 2**). To provide an estimate of the salinity at the two intakes located further in the Samoa Channel we used the data from the HSU station for seven years from 2014 to 2020 to identify the times that the readings dropped below psu readings of 10 (+2.5), 15 (+2.5), and 20 (+2.5) psu. Those values were selected based on recent laboratory studies on LFS larvae that showed that the optimum salinity for larval health and survival was 5 to 10 psu, and at 20 psu the larvae could survive but were not able to properly osmoregulate (Yanagitsuru et al. 2021). The value of 15 psu is cited as the highest salinity level tolerated by LFS larvae (Grimaldo et al. 2017) but this was likely based on field observations of salinity levels during field sampling which may not accurately reflect salinity tolerances for the larvae. The 2.5 added to the values will help account for potential differences between psu levels at the HSU station and the intakes that generally range within 2.5 psu of each other.

Table 1. Summary statistics for salinity data (psu) from HSU pier station, HSU Burke-o-lator station, and the differences in the readings for the two stations from September 5, 2018 to July 2, 2021.

Variable	N	Mean	Std Dev	Minimum	Maximum
Difference	67,399	0.2911	2.4737	-12.5668	33.9433
HSU Pier	67,399	32.4350	1.9588	8.7600	36.6500
HSU Burke-o-lator	67,399	32.1439	3.0110	0.0453	34.3578

The psu data from only the months from January through April were summarized to determine the salinity levels during the peak spawning period for LFS based on sampling data from Brennan (2021). The data summary shows that the lowest average salinity during those months occurred in 2017, but the lowest salinity levels evidenced by the 1st and 5th percentile level occurred in 2019, the high flow year when Brennan (2019) conducted his study (**Table 2**). The percentage of data readings exceeding psu readings of 10 (+2.5), 15 (+2.5), and 20 (+2.5), show that on average, the percentage of time when salinity levels are within tolerances levels of LFS larvae is expected to be very low (**Table 3**). The percentage frequency distribution of the values for the seven years shows that salinity levels rarely drop below 20 psu with the exception of 2019 (**Figure 3**). Levels from laboratory studies of 10 psu (+2.5) that have been shown to be within the tolerance of LFS larvae occur on average less than 0.005% of the time with an upper limit of 0.014%.

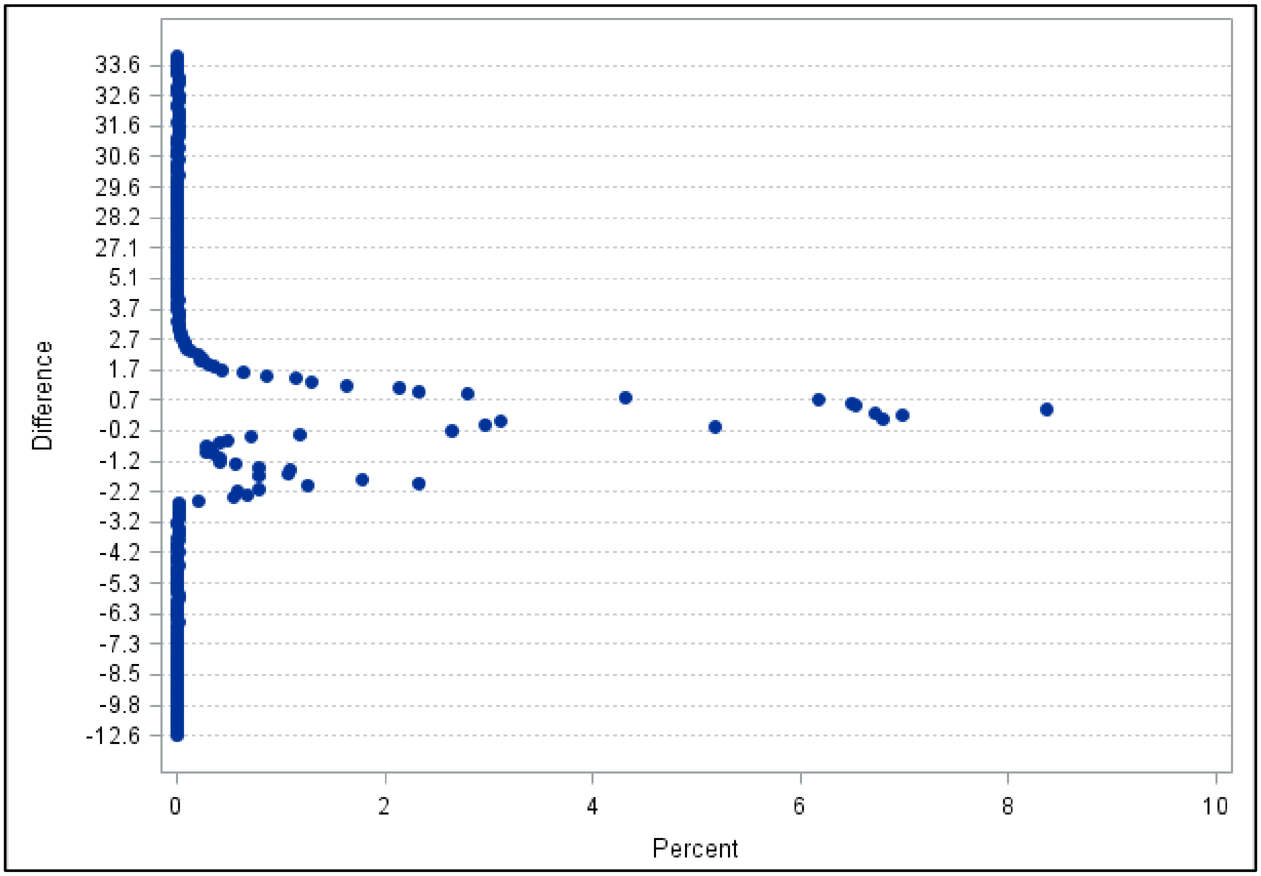

Figure 2. Percent frequency distribution of differences in psu values between data points from HSU pier station and HSU Burke-o-lator station for 67,399 readings from September 5, 2018 to July 2, 2021.

Table 2. Annual statistical summary of salinity (psu) data from CeNCOOS in situ water quality monitoring station at Humboldt Bay Pier maintained by Humboldt State University located at 40.7775N and -124.19652E. The difference in N size among years was due to a change in the sampling frequency of the instrument from hourly to four times an hour.

						Std.	Percentile Values			
Year	**N**	**Mean**	**Min**	**Max**	**Median**	**Dev.**	**1st**	**5th**	**95th**	**99th**
All Years	43,836	31.00	8.76	36.76	31.67	2.50	21.84	26.14	33.72	34.19
2014	2,860	31.89	24.46	33.57	32.32	1.24	28.00	29.56	33.17	33.35
2015	2,784	31.29	22.70	33.34	31.69	1.44	25.64	28.24	32.79	33.08
2016	2,640	29.80	21.75	33.12	30.30	2.13	23.75	25.54	32.44	32.82
2017	2,777	28.60	16.70	33.24	28.90	2.39	21.99	24.33	32.09	32.93
2018	10,292	31.48	15.91	36.76	31.92	1.99	25.06	27.77	33.97	34.22
2019	10,992	30.04	8.76	34.00	31.07	3.23	17.92	23.04	33.01	33.36
2020	11,491	32.04	24.86	34.36	32.50	1.72	26.70	28.27	34.07	34.25

Table 3. Summary of salinity (psu) values from CeNCOOS in situ water quality monitoring station at Humboldt Bay Pier maintained by Humboldt State University located at 40.7775N and -124.19652E that exceed salinity values of 10, 12.5, 15, 17.5, 20, and 22.5 psu for the months of January through April for seven years. An upper limit of 2.5 psu was added to the values of 10, 15, and 20 psu to account for potential differences in salinity between the Humboldt Bay Pier station and the area along the Samoa Peninsula closer to the proposed intake location.

Year	N	Percentage of values exceeding target psu values					
		<= 10 psu	<= 12.5 psu	<= 15 psu	<= 17.5 psu	<= 20 psu	<= 22.5 psu
All Years	43,836	0.009%	0.025%	0.089%	0.251%	0.538%	1.273%
2014	2,860	-	-	-	-	-	-
2015	2,784	-	-	-	-	-	-
2016	2,640	-	-	-	-	-	0.189%
2017	2,777	-	-	-	0.144%	0.180%	1.368%
2018	10,292	-	-	-	0.097%	0.185%	0.214%
2019	10,992	0.036%	0.100%	0.355%	0.873%	1.929%	4.485%
2020	11,491	-	-	-	-	-	-
Averages		0.005%	0.014%	0.051%	0.159%	0.328%	0.894%

Summary

The results from the analyses presented in this addendum for salinity tolerances of LFS larvae need to be combined with the results from the Empirical Transport Model (ETM) results in the Impact Assessment to determine the joint probability of mortality for early stage LFS larvae subject to entrainment. As presented here, early stage LFS larvae have limited tolerance of salinity levels above 10–12 psu, that on average are estimated to occur 0.014% of the time at the proposed intake locations (**Table 3**). During the periods of time that salinity values are within the tolerances of LFS larvae, the probability of entrainment for those larvae would be dependent on the period of time that the larvae are susceptible to entrainment. Even using the worst case from the ETM modeling, the probability of entrainment would be less than 1.0% (Impact Assessment – Table 4-1). Combining the two estimates results in a value of 0.00014%, which indicates a very low potential for any impacts on LFS larvae due to entrainment.

As previously stated, this assessment only focuses on potential impacts to early stage LFS larvae. At a length of approximately 12 mm TL Longfin Smelt larvae develop air bladders and swimming abilities that allow them to manipulate their vertical position in the water column to retain position near favorable prey (Bennett et al. 2002). These swimming abilities and the increased size of the larvae at 12 mm may allow them to avoid entrainment at the intakes due to the low approach velocities and small slot openings. Larger juveniles and adult LFS would not be impacted by the intakes due to the small 1.75 mm openings and low approach velocities of the proposed screens, which should eliminate any impacts due to entrainment or impingement.

Although there are limited data on the abundances of LFS larvae available for Humboldt Bay, information presented in this addendum indicates very low probabilities of entrainment and low potential for significant effects on LFS populations in Humboldt Bay.

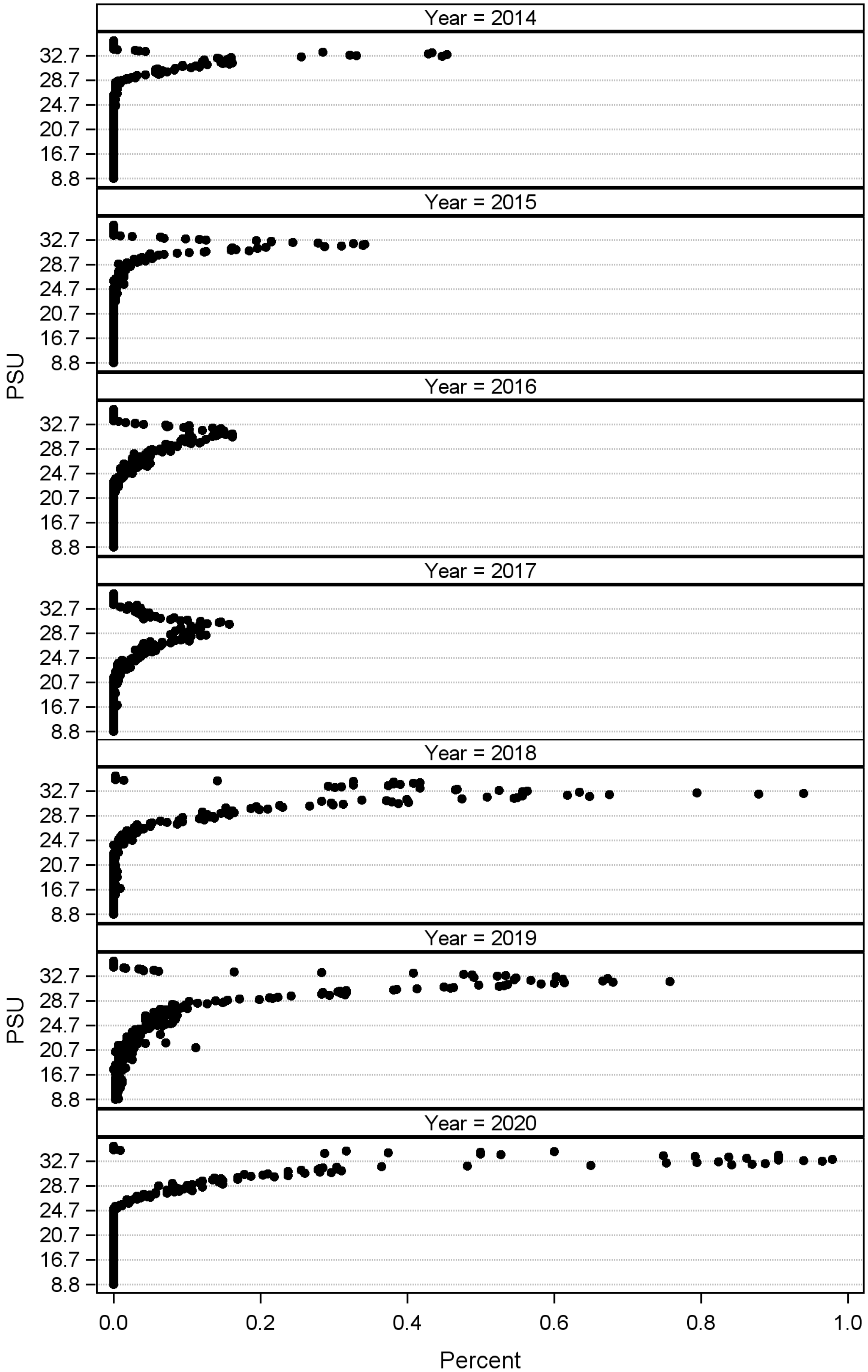

Figure 3. Percent frequency distribution of psu values for the years from 2014 through 2020 for the months from January through April for the HSU pier station.

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