

Electronic Supplementary Material 1 (Tables S1–S2) for

Community Patterns and Environmental Associations for the Early Life Stages of Fishes in a Highly Transformed Estuary

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August 30, 2022

Table S1 Early life stages of fishes collected in the Upper San Francisco Estuary during spring and early summer 1995 to 2017. Species' habitat (E: estuarine, F: freshwater, M: marine); migratory behavior (A: anadromous, AM: amphidromous; CA: catadromous; SA: semi-anadromous; OC: oceanodromous; PO: potadromous); fish group (ID: introduced demersal, IP: introduced pelagic, ND: native demersal, NP: native pelagic); fish length (fork length or total length if tail was not forked); catch per unit volume (CPUV), percent of total CPUV; and percent of occurrence.

Fish taxa	Habitat (migratory behavior)	Fish group	Length mean $\pm$ SD (mm)	Length range (mm)	Mean CPUV $\pm$ SD (n per 10 ⁴ m ³)	Percent total CPUV	Percent occurrence
<i>Tridentiger</i> spp.	E, (AM)	ID	10 $\pm$ 3	2–34	311 $\pm$ 2054	31.3	50.2
Longfin smelt <i>Spirinchus thaleichthys</i>	E, F, (A)	NP	19 $\pm$ 7	3–89	260 $\pm$ 1599	26.2	59.9
Striped bass <i>Morone saxatilis</i>	E, F, (A)	IP	12 $\pm$ 7	2–122	115 $\pm$ 371	11.6	65.7
Pacific herring <i>Clupea pallasii</i>	E, M	NP	20 $\pm$ 7	4–73	105 $\pm$ 683	10.6	32.3
Yellowfin goby <i>Acanthogobius flavimanus</i>	E, F, M, (AM)	ID	14 $\pm$ 5	3–89	90.4 $\pm$ 536	9.10	68.5
Threadfin shad <i>Dorosoma petenense</i>	F, E	IP	11 $\pm$ 4	3–49	44.8 $\pm$ 475	4.51	35.6
Northern anchovy <i>Engraulis mordax</i>	M, E	NP	20 $\pm$ 14	2–115	19.1 $\pm$ 102	1.92	30.9
Delta smelt <i>Hypomesus transpacificus</i>	E, F, (SA)	NP	20 $\pm$ 9	4–54	9.50 $\pm$ 30.8	0.96	47.6
Bay goby <i>Lepidogobius lepidus</i>	E, M	ND	20 $\pm$ 10	4–76	7.77 $\pm$ 64.8	0.78	15.5
Prickly sculpin <i>Cottus asper</i>	E, F	ND	8 $\pm$ 3	2–39	7.01 $\pm$ 41.9	0.71	49.6
American shad <i>Alosa sapidissima</i>	E, F, M, (A)	IP	20 $\pm$ 9	5–117	3.84 $\pm$ 23.6	0.39	22.4
White catfish <i>Ameiurus catus</i>	F, (PO)	ID	29 $\pm$ 23	5–122	3.47 $\pm$ 34.0	0.35	22.8
Threespine stickleback <i>Gasterosteus aculeatus</i>	E, F, M, (A)	NP	27 $\pm$ 6	6–54	3.35 $\pm$ 17.5	0.34	30.6
Arrow goby <i>Clevelandia ios</i>	E, M	ND	10 $\pm$ 4	3–28	2.00 $\pm$ 12.4	0.20	14.6
Channel catfish <i>Ictalurus punctatus</i>	F	ID	22 $\pm$ 14	6–122	1.70 $\pm$ 25.9	0.17	8.15
Cheekspot goby <i>Ilypnus gilberti</i>	E, M	ND	14 $\pm$ 6	4–45	0.98 $\pm$ 8.04	0.10	9.50
Splittail <i>Pogonichthys macrolepidotus</i>	E, F	ND	36 $\pm$ 15	7–121	0.86 $\pm$ 4.75	0.09	18.2
Starry flounder <i>Platichthys stellatus</i>	M, E, (CA)	ND	16 $\pm$ 15	6–115	0.79 $\pm$ 5.68	0.08	13.9
Mississippi silverside <i>Menidia audens</i>	E, F	IP	23 $\pm$ 15	4–79	0.79 $\pm$ 13.2	0.08	8.45
Carp <i>Cyprinus carpio</i>	F, (PO)	ID	12 $\pm$ 11	5–111	0.64 $\pm$ 14.4	0.06	9.05
Jacksmelt <i>Atherinopsis californiensis</i>	M	NP	15 $\pm$ 8	5–69	0.62 $\pm$ 3.23	0.06	14.3
Topsmelt <i>Atherinops affinis</i>	E, M	NP	15 $\pm$ 10	4–105	0.57 $\pm$ 7.30	0.06	8.15
Longjaw mudsucker <i>Gillichthys mirabilis</i>	M, E	ND	10 $\pm$ 3	4–38	0.51 $\pm$ 3.77	0.05	6.85
Centrarchids (Unid)	F, E	IP	16 $\pm$ 2	5–20	0.45 $\pm$ 1.89	0.04	17.8
Sacramento sucker <i>Catostomus occidentalis</i>	F	ND	15 $\pm$ 4	9–88	0.36 $\pm$ 2.08	0.04	11.5
Pacific staghorn sculpin <i>Leptocottus armatus</i>	E, M, (AM)	ND	18 $\pm$ 12	6–49	0.26 $\pm$ 2.96	0.03	5.20
Cyprinids (Unid)	–	--	11 $\pm$ 6	4–59	0.25 $\pm$ 2.61	0.03	8.35
White croaker <i>Genyonemus lineatus</i>	M	ND	10 $\pm$ 2	5–23	0.23 $\pm$ 2.58	0.02	3.05

Bigscale logperch <i>Percina macrolepida</i>	F	IP	14 ± 6	4–72	0.19 ± 1.11	0.02	9.75
Chinook salmon <i>Oncorhynchus tshawytscha</i>	E, F, M, (A)	NP	74 ± 20	30–120	0.19 ± 0.94	0.02	9.65
Wakasagi <i>Hypomesus nipponensis</i>	E, F	IP	16 ± 10	4–68	0.18 ± 1.26	0.02	8.20
Smelt (Unid)	–	--	15 ± 10	5–47	0.17 ± 3.84	0.02	1.50
White sturgeon <i>Acipenser transmontanus</i>	E, F, M, (A)	ND	13 ± 7	9–102	0.17 ± 2.51	0.02	2.35
Rainwater killifish <i>Lucania parva</i>	E, F, M, (AM)	IP	17 ± 4	5–24	0.13 ± 3.03	0.01	2.20
Bay pipefish <i>Syngnathus leptorhynchus</i>	E, M	ND	28 ± 12	15–101	0.09 ± 0.66	<0.01	3.95
Unknown	–	--	11 ± 4	3–22	0.09 ± 1.04	<0.01	2.55
Plainfin midshipman <i>Porichthys notatus</i>	M	ND	31 ± 4	21–45	0.04 ± 0.84	<0.01	0.70
Sturgeon (Unid)	–	ND	13 ± 3	7–31	0.03 ± 0.42	<0.01	0.70
English sole <i>Parophrys vetulus</i>	M, E, (OC)	ND	32 ± 12	11–66	0.03 ± 0.82	<0.01	0.60
Largemouth bass <i>Micropterus salmoides</i>	F	IP	25 ± 10	5–55	0.03 ± 0.22	<0.01	2.55
Catfish (Unid)	F	ID	16 ± 2	5–20	0.03 ± 0.91	<0.01	0.35
Gobies (Unid)	–	--	10 ± 6	3–26	0.02 ± 0.34	<0.01	0.80
Bluegill sunfish <i>Lepomis macrochirus</i>	F	IP	36 ± 12	7–62	0.02 ± 0.23	<0.01	0.95
Goldfish <i>Carassius auratus</i>	E, F	IP	39 ± 12	6–64	0.02 ± 0.34	<0.01	0.60
Tule perch <i>Hysterocarpus traski</i>	E, F	NP	39 ± 9	32–65	0.01 ± 0.17	<0.01	1.10
Sacramento blackfish <i>Orthodon microlepidotus</i>	E, F	NP	15 ± 6	7–27	0.01 ± 0.37	<0.01	0.35
Golden shiner <i>Notemigonus crysoleucas</i>	F, E	IP	29 ± 12	6–46	<0.01 ± 0.21	<0.01	0.30
Mosquitofish <i>gambusia affinis</i>	E, F	IP	12 ± 3	9–17	<0.01 ± 0.10	<0.01	0.75
Speckled sanddab <i>Citharichthys stigmaeus</i>	M	ND	39 ± 13	19–60	<0.01 ± 0.16	<0.01	0.25
White crappie <i>Pomoxis annularis</i>	F	IP	47 ± 18	24–97	<0.01 ± 0.21	<0.01	0.30
Black crappie <i>Pomoxis nigromaculatus</i>	F	IP	46 ± 22	20–86	<0.01 ± 0.07	<0.01	0.95
Sculpins (Unid)	–	ND	9 ± 9	5–36	<0.01 ± 0.13	<0.01	0.20
Silversides (Unid)	–	--	28 ± 16	10–46	<0.01 ± 0.14	<0.01	0.20
Lampreys (Unid)	–	NP	75 ± 43	9–120	<0.01 ± 0.05	<0.01	0.45
Brown rockfish <i>Sebastes auriculatus</i>	M	ND	40 ± 3	36–42	<0.01 ± 0.09	<0.01	0.15
Pacific lamprey <i>Lampetra tridentata</i>	E, F, M, (A)	NP	63 ± 55	7–116	<0.01 ± 0.08	<0.01	0.15
River lamprey <i>Lampetra ayresi</i>	E, F, M, (A)	NP	99 ± 33	44–122	<0.01 ± 0.05	<0.01	0.25
Shiner perch <i>Cymatogaster aggregata</i>	E, M	NP	20 ± 8	14–25	<0.01 ± 0.05	<0.01	0.10
Sacramento pikeminnow <i>Ptychocheilus grandis</i>	F	NP	86 ± 51	50–122	<0.01 ± 0.04	<0.01	0.10
California tonguefish <i>Symphurus atricaudus</i>	M	ND	68 ± 18	55–81	<0.01 ± 0.04	<0.01	0.10
Redear sunfish <i>Lepomis microlophus</i>	F	IP	55 ± 0	55–55	<0.01 ± 0.05	<0.01	0.05
Spotted bass <i>Micropterus punctulatus</i>	F	IP	42 ± 0	42–42	<0.01 ± 0.04	<0.01	0.05
Black bullhead <i>Ameiurus melas</i>	F	ID	83 ± 0	83–83	<0.01 ± 0.02	<0.01	0.05
Smallmouth bass <i>Micropterus dolomieu</i>	F	IP	25 ± 0	25–25	<0.01 ± 0.02	<0.01	0.05
Hitch <i>Lavinia exilicauda</i>	F	NP	10 ± 0	10–10	<0.01 ± 0.01	<0.01	0.05

Table S2 Estimated size at first maturity for species of fish caught in the upper San Francisco Estuary

Common name	Scientific name	Length (mm)	Reference
American shad	<i>Alosa sapidissima</i>	380–485	Hart 1973
Arrow goby	<i>Clevelandia ios</i>	29	Prasad 1959
Bay goby	<i>Lepidogobius lepidus</i>	90	Fleming 1999
Bay pipefish	<i>Syngnathus leptorhynchus</i>	152	Fishbase-a
Bigscale logperch	<i>Percina macrolepida</i>	75–102	California Fish Website-a
Black bullhead	<i>Ameiurus melas</i>	160	ADW
Black crappie	<i>Pomoxis nigromaculatus</i>	178–203	Wydoski and Whitney 2003
Bluegill sunfish	<i>Lepomis macrochirus</i>	75–120	Belk 1995
Brown bullhead	<i>Ameiurus nebulosus</i>	140–200	Moyle 2002
Brown rockfish	<i>Sebastes auriculatus</i>	260–380	Echeverria 1987
California tonguefish	<i>Symphurus atricaudus</i>	110	Anderson et al. 2008
Common carp	<i>Cyprinus carpio</i>	250–360	Kailola et al. 1993
Chameleon goby	<i>Tridentiger trigonocephalus</i>	40	Hwang and Baek 2013
Channel catfish	<i>Ictalurus punctatus</i>	254	Starostka and Nelson 1974
Cheekspot goby	<i>Ilypnus gilberti</i>	47	Fishbase-a, b
Chinook salmon	<i>Oncorhynchus tshawytscha</i>	822	Vronsky 2003
Delta smelt	<i>Hypomesus transpacificus</i>	55–70	Moyle 2002
English sole	<i>Parophrys vetulus</i>	300–320	Hart 1973
Golden shiner	<i>Notemigonus crysoleucas</i>	63–89	Coker et al. 2001
Goldfish	<i>Carassius auratus</i>	65–115	Moyle 2002
Hitch	<i>Lavinia exilicauda</i>	170–350	Moyle 2002
Mississippi silverside	<i>Menidia beryllina</i>	80–100	Moyle 2002
Jacksmelt	<i>Atherinopsis californiensis</i>	140	Clark 1929
Largemouth bass	<i>Micropterus salmoides</i>	180–250	Moyle 2002
Longfin smelt	<i>Spirinchus thaleichthys</i>	90	Moyle 2002
Longjaw mudsucker	<i>Gillichthys mirabilis</i>	60–80	Moyle 2002
Mosquitofish	<i>Gambusia affinis</i>	18–36	Krumholz 1948
Northern anchovy	<i>Engraulis mordax</i>	130	Baxter 1966
Pacific herring	<i>Clupea pallasii</i>	214	Gunderson and Dygert 1988
Pacific lamprey	<i>Lampetra tridentata</i>	350–550	Kostow 2002

Pacific staghorn sculpin	<i>Leptocottus armatus</i>	50–70	Tasto 1975
Plainfin midshipman	<i>Porichthys notatus</i>	152–203	Bioweb
Prickly sculpin	<i>Cottus asper</i>	40–70	Moyle 2002
Rainwater killifish	<i>Lucania parva</i>	25	Tomoleoni 2007
Redear sunfish	<i>Lepomis microlophus</i>	151–213	Adams and Kilambi 1979
River lamprey	<i>Lampetra ayresii</i>	162	Coker et al. 2001
Sacramento blackfish	<i>Orthodon microlepidotus</i>	250–370	Moyle 2002
Sacramento pikeminnow	<i>Ptychocheilus grandis</i>	220–250	Moyle 2002
Sacramento sucker	<i>Catostomus occidentalis</i>	200–320	Moyle 2002
Shimofuri goby	<i>Tridentiger bifasciatus</i>	35–60	Moyle 2002
Shiner perch	<i>Cymatogaster aggregata</i>	40–60	Shaw 1971
Shokihaze goby	<i>Tridentiger barbatus</i>	54	Slater 2005
Smallmouth bass	<i>Micropterus dolomieu</i>	280–330	Coble 1975
Speckled sanddab	<i>Citharichthys stigmaeus</i>	70–80	Rackowski and Pikitch 1989
Splittail	<i>Pogonichthys macrolepidotus</i>	170	Moyle 2002
Spotted bass	<i>Micropterus punctulatus</i>	150–325	Moyle 2002
Starry flounder	<i>Platichthys stellatus</i>	280–350	Ralston 2006
Striped bass	<i>Morone saxatilis</i>	250–450	Moyle 2002
Threadfin shad	<i>Dorosoma petenense</i>	50–55	Love et al. 2005
Threespine stickleback	<i>Gasterosteus aculeatus</i>	55	Muus and Nielsen 1999
Topsmelt	<i>Atherinops affinis</i>	112	CDFW 2001
Tule perch	<i>Hysterocarpus traskii</i>	70–80	Moyle 2002
Wakasagi	<i>Hypomesus nipponensis</i>	73	Moyle 2002
White catfish	<i>Ameiurus catus</i>	200–210	Moyle 2002
White crappie	<i>Pomoxis annularis</i>	100–200	Moyle 2002
White croaker	<i>Genyonemus lineatus</i>	1301–50	Eschmeyer et al. 1983
White sturgeon	<i>Acipenser transmontanus</i>	750–1350	California Fish Website-b
Yellowfin goby	<i>Acanthogobius flavimanus</i>	90–100	Moyle 2002

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