Supplementary Appendix to State of the California Current Ecosystem 2021: Winter is Coming?

The State of the California Current Report (SOCCR) has been reporting physical and biological conditions throughout the California Current Ecosystem since 1993. Until 2020 (Weber et al. 2021), the SOCCR was published in the now defunct CalCOFI Reports journal and was essentially a collection of vignettes describing various components of the CCE as written by a contributor's area of expertise. In 2020, when the SOCCR transitioned to Frontiers in Marine Science, we began to transition the format of the report into a more streamlined format. The 2021 SOCCR (renamed State of California Current Ecosystem Report (SOCCER) further continued the streamlining process and attempted to report data that was more common among sampling regions. As such, we cut from the main manuscript data that did not integrate smoothly with the main body main that examined conditions in 2021 relative to previous La Niña years. However, this additional data is still important to gain a fuller understanding of CCE conditions in 2021, and we present in this Supplemental Appendix additional data streams and vignettes that were not presented in the main paper. Here, we follow the same flow of presentation by first providing additional data at large scales and then regional results from north to south.

Weber, E.D., Auth, T.D., Baumann-Pickering, S., Baumgartner, T.R., Bjorkstedt, E.P., Bograd, S.J., Burke, B.J., Cadena-Ramírez, J.L., Daly, E.A., De La Cruz, M., Dewar, H., Field, J.C., Fisher, J.L., Giddings, A., Goericke, R., Gomez-Ocampo, E., Gomez-Valdes, J., Hazen, E.L., Hildebrand, J., Horton, C.A., Jacobson, K.C., Jacox, M.G., Jahncke, J., Kahru, M., Kudela, R.M., Lavaniegos, B.E., Leising, A., Melin, S.R., Miranda-Bojorquez, L.E., Morgan, C.A., Nickels, C.F., Orben, R.A., Porquez, J.M., Portner, E.J., Robertson, R.R., Rudnick, D.L., Sakuma, K.M., Santora, J.A., Schroeder, I.D., Snodgrass, O.E., Sydeman, W.J., Thompson, A.R., Thompson, S.A., Trickey, J.S., Villegas-Mendoza, J., Warzybok, P., Watson, W., and Zeman, S.M. (2021). State of the California Current 2019–2020: Back to the Future With Marine Heatwaves? Frontiers in Marine Science 8.

Broad Scale. North Pacific High (NPH)

The North Pacific High serves as an index of productivity in the CCE (Schroeder et al. 2013). High values of the NPH are indicative of turbulent ocean conditions that elevates nutrients towards the surface, fuels primary productivity, providing food for zooplankton such as krill and copepods (Feinberg and Peterson 2003) By contrast, low values of the NPH are associated with a calm, stratified ocean and low primary production. Six-hourly data used to find the area of the NPH is located https://coastwatch.pfeg.noaa.gov/erddap/griddap/erdlasFnPres6.

The NPH is typically high during La Niñas but it was actually low in January and February 2021 due to episodic low pressure events. However, the NPH increased greatly in March, reaching levels not seen since the 1970s.

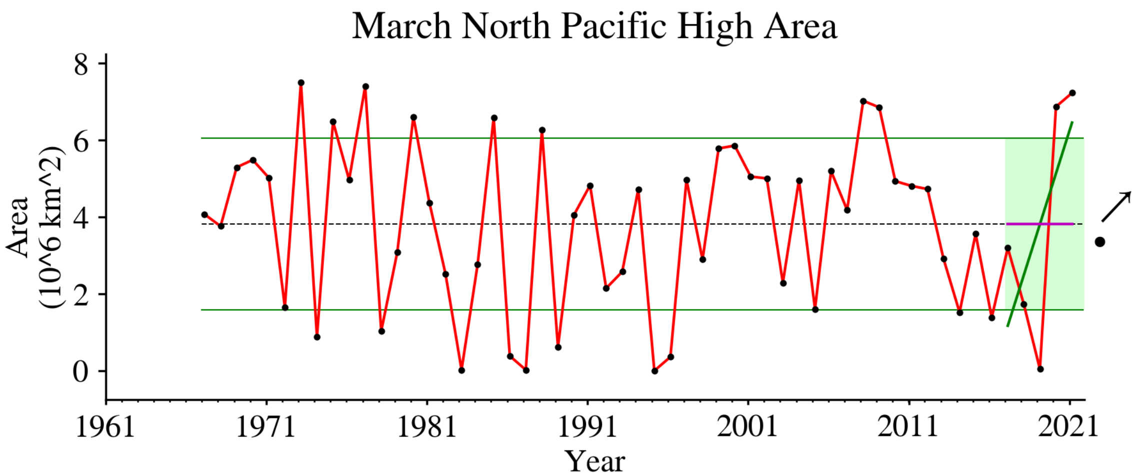
Feinberg, L.R., and Peterson, W.T. (2003). Variability in duration and intensity of euphausiid spawning off central Oregon, 1996–2001. Progress in Oceanography 57, 363-379.

Schroeder, I.D., Black, B.A., Sydeman, W.J., Bograd, S.J., Hazen, E.L., Santora, J.A., and Wells, B.K. (2013). The North Pacific High and wintertime pre-conditioning of California current productivity. Geophysical Research Letters 40, 541-546.

NPH Figure Caption.

NPH Figure 1. Area of high atmospheric pressure of the North Pacific High in March of each year. The area is the areal extent of the 1021 hPa isobar located in the eastern North Pacific.

NPH Figure 1


March North Pacific High Area
Area
(10^6 km^2)
8
6
4
2
0
1961
1971
1981
1991
2001
2011
2021
Year

Broad Scale. Coastal Upwelling Transport Index (CUTI)

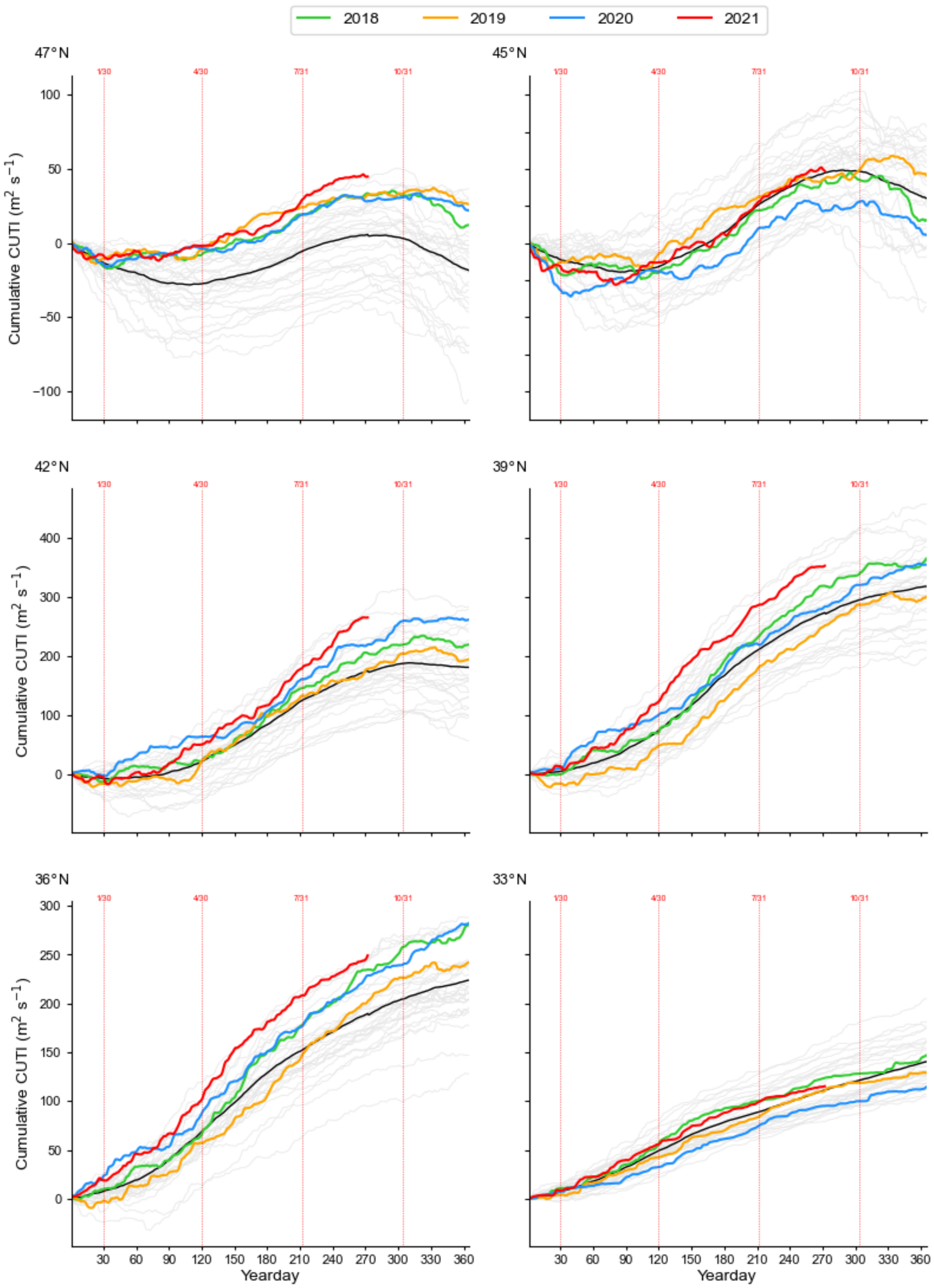
The cumulative Coastal Upwelling Transport Index (CUTI) is calculated from assimilative regional ocean model data (Neveu et al. 2016) and is available at https://oceanview.pfeg.noaa.gov/upwelling/. Upwelling is typically high in La Niña years. In 2021, CUTI was close to long-term averages for the first two months of the year. Off Washington (47°N), southern Oregon (42°N), northern California (39°N) and central California (33°N), CUTI rapidly increased in March and was at record or close to record highs by late summer. CUTI patterns were somewhat geographically varied, however, as upwelling was at near average levels throughout the year off central Oregon (45°N) and southern California (33°N).

Neveu, E., Moore, A.M., Edwards, C.A., Fiechter, J., Drake, P., Crawford, W.J., Jacox, M.G., and Nuss, E. (2016). An historical analysis of the California Current circulation using ROMS 4D-Var: System configuration and diagnostics. Ocean Modelling 99, 133-151.

CUTI Figure Caption.

CUTI Figure 1. Yearly curves of the cumulative Coastal Upwelling Transport Index (CUTI) starting on January 1 calculated from daily CUTI at locations along the west coast of North America. Grey lines are all yearly CUTI for the years 1988-2018; colored curves are for recent years of 2018-21. The black line is the climatological mean. The red dashed vertical lines mark the end of January, April, July, and October.

CUTI Figure 1



Broad Scale. West Coast, USA. Highly Migratory Species (HMS) Diets

Characterizing trophic links is key to understanding food webs and ecosystem dynamics. Monitoring HMS diets can help link estimates of forage availability from trawl surveys to forage use by the predators as well as reveal links to prey that are commercially important species. Juvenile Albacore Tuna (*Thunnus alalunga*) and Broadbill Swordfish (*Xiphias gladius*) are both highly migratory predators that migrate to the CCLME to forage seasonally, taking advantage of the high regional productivity. Diet studies for both species have been ongoing for over a decade. Albacore were collected off Northern California, Oregon, and Washington by commercial and recreational fishers during the summer and fall and processed following Glaser *et al*. (2015). Swordfish were collected off Southern and Central California during the commercial drift gillnet season (August 15th through January 31st, classified by the year the fishing season began), and were processed following Preti *et al*. (2012). For both Albacore and Swordfish, prey were identified from whole or hard part remains and are reported as a mean percent abundance.

Both Swordfish and Albacore opportunistically consume a wide variety of prey taxa including fish, squid, and crustaceans across a range of depths and habitats. Swordfish are larger on average and generally fed on larger prey than Albacore. (The large interquartile range for Market Squid in Albacore stomachs was driven by the consumption of a 24cm individual in 2012 and a 33cm individual in 2013.) A subset of prey species are presented here focusing on those that are either management unit species or important ecosystem components. For both species, significant shifts in diet composition are observed over relatively short time periods. Of the prey species included in management units, North Pacific Hake (*Merluccius productus*) and Market Squid (*Doryteuthis opalescens*) were the most frequently important for Swordfish throughout the time-series. The most important contributors to the "other" category (HMS Figure 1) were squids including Humboldt (*Dosidicus gigas*), *Gonatopsis borealis*, and *Gonatus* spp.. Swordfish consumption of Anchovy (*Engraulis mordax*) was greater in 2019-2020 than any year previously, and was accompanied by a relative increase in the consumption of Market Squid. For Albacore, Anchovy, Pacific Saury (*Cololabis saira*), and rockfishes (*Sebastes* spp.) are relatively important prey throughout the time-series. The most important contributors to the "other" category for Albacore are the squid *Onychoteuthis borealijaponica*, Hyperiid amphipods (Suborder: *Hyperiidea*), and Slender Barracudina (*Lestidiops ringens*). After a low in 2018-2019, Anchovy consumption by Albacore increased in 2020, coincident with decreases in the importance of Pacific Saury and rockfishes. While Anchovy were dominant in the diets of Albacore throughout the time series, 2020 was the first year on record when Anchovy were present in relatively high numbers in both species. The diets of HMS are highly variable reflecting the high variability in mid-trophic levels species composition and oceanography in the CCLME.

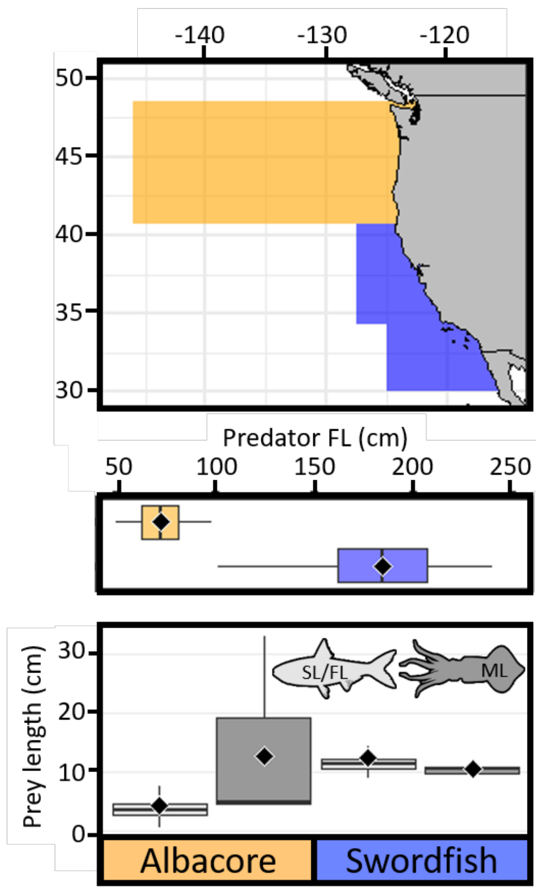
Glaser, S.M., Waechter, K.E., and Bransome, N.C. (2015). Through the stomach of a predator: Regional patterns of forage in the diet of albacore tuna in the California Current System and metrics needed for ecosystem-based management. *Journal of Marine Systems* 146, 38-49.

Preti, A., Soykan, C.U., Dewar, H., Wells, R.J., Spear, N. and S. Kohin (2012). Comparative feeding ecology of shortfin mako, blue and thresher sharks in the California Current. *Environmental Biology of Fishes*, 95(1), 127-146.

HMS Figure Caption.

HMS Figure 1. Summary of the diet monitoring programs for Juvenile Albacore Tuna (*Thunnus alalunga*) and Broadbill Swordfish (*Xiphias gladius*). Upper left plot shows collection regions for Albacore (orange) and Swordfish (blue). Middle left plot shows fork lengths (cm) of predators included in the diet analyses. Mean lengths (black diamond) and boxplots of length distributions for forage fishes (light grey) and Market Squid (dark grey) are depicted on the lower left. The right panel shows the annual mean proportional abundance of prey as a heat map, where the color saturates at 30%.

HMS Figure 1



predator	prey	mean	sd	'07	'08	'09	'10	'11	'12	'13	'14	'15	'16	'17	'18	'19	20
Albacore	anchovy	0.23	0.23			0.11	0.15	0.8	0.14	0.29	0.2	0.16		0.51	0.01	0.02	0.16
Albacore	hake	0.01	0.02				0.06										
Albacore	jack mack.	0.01	0.01							0		0.05			0		0.02
Albacore	Pac. mack	<0.01	<0.01									0				0.01	0
Albacore	Pac. saury	0.06	0.09				0.03	0	0.11	0.08	0.02	0.05		0.01	0.03	0.31	0.01
Albacore	rockfishes	0.07	0.06			0	0.01	0.03	0.06	0.12	0.02	0.04		0.05	0.11	0.19	0.1
Albacore	sardine	0.02	0.03											0.07	0.06		0.08
Albacore	mkt. squid	<0.01	0.01				0		0.03	0							
Albacore	other	0.61	0.21			0.89	0.76	0.17	0.66	0.51	0.75	0.7		0.36	0.79	0.47	0.62
Swordfish	anchovy	0.04	0.09	0	0											0.28	0.13
Swordfish	hake	0.07	0.07	0				0.19	0.14	0.07	0.14					0.09	0.08
Swordfish	jack mack.	0.01	0.01	0.01	0.01	0.01	0.02	0.04	0.03	0	0						0
Swordfish	Pac. mack	0.01	0.02		0	0	0.05	0.04	0.01	0	0					0.01	0.01
Swordfish	Pac. saury	0.01	0.01	0.01	0.01		0.02	0.01	0.01	0.02	0.02						
Swordfish	rockfishes	<0.01	<0.01			0.01			0	0						0	0
Swordfish	sardine	0.01	0.01		0.01	0	0.04	0.02	0.02	0.01						0.01	0
Swordfish	mkt. squid	0.09	0.07	0.01	0.03	0.09	0.23	0.09	0.06	0.08	0.06					0.17	0.12
Swordfish	other	0.75	0.13	0.97	0.94	0.88	0.64	0.6	0.75	0.81	0.78					0.44	0.65

Mean proportional abundance

0.30+
0.25
0.20
0.15
0.10
0.05
0.00

Broad Scale. California. Harmful Algal Blooms (HABs)

It has been suggested that HABs will increase as oceans warm and we thus predicted that particulate domoic acid (pDA) would decrease during cool La Niña conditions (Gobler et al. 2022). We evaluated the modeled probability of the concentration of the toxin domoic acid being greater than 500 ng/L based on a combination of ocean circulation models, satellite remote-sensing data of ocean color and chlorophyll patterns, and statistical models (Kudela et al. 2015). pDA concentrations were similar to those in 2020 and higher than most recent years dating back to 2015 (HABS Figure 1). Geographically, predicted pDA was consistently high south of Cape Mendocino but relatively low between the Cape Mendocino and Oregon border.

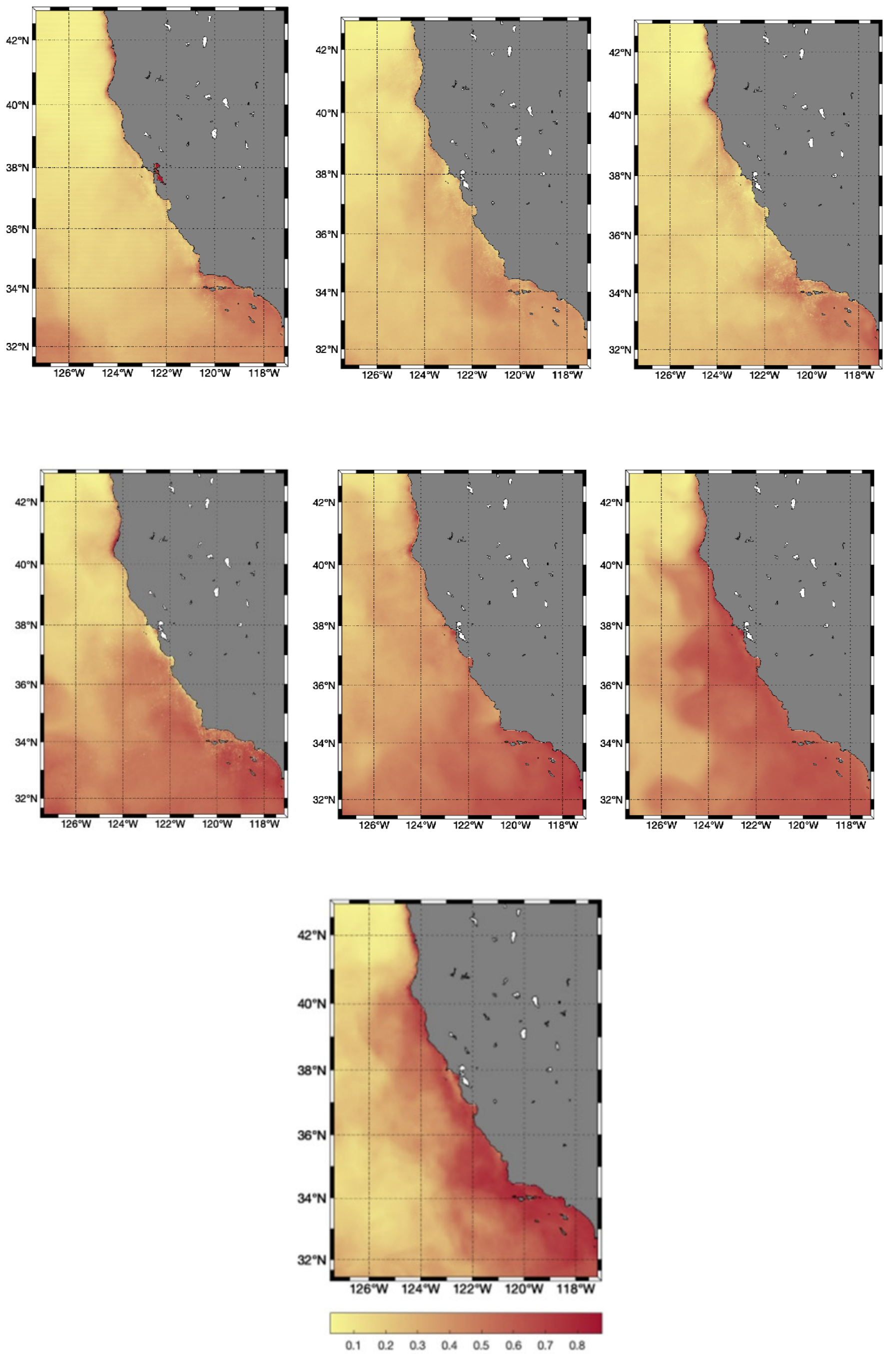
Gobler, C.J. (2020). Climate Change and Harmful Algal Blooms: Insights and perspective. Harmful Algae 91, 101731.

Kudela, R.M., Bickel, A., Carter, M.L., Howard, M.D.A., and Rosenfeld, L. (2015). "Chapter 5 - The Monitoring of Harmful Algal Blooms through Ocean Observing: The Development of the California Harmful Algal Bloom Monitoring and Alert Program," in Coastal Ocean Observing Systems, eds. Y. Liu, H. Kerkering & R.H. Weisberg. (Boston: Academic Press), 58-75.

HABS Figure Caption.

HABS Figure 1. Predicted probability of domoic acid >500 ng/L based on the California Harmful Algae Risk Mapping model in spring 2015-2021. Each panel is a year beginning with 2015 in the upper left hand corner.

HABS Figure 1



Broad Scale. Central and Southern California. Coastal Pelagic Survey. CUFES

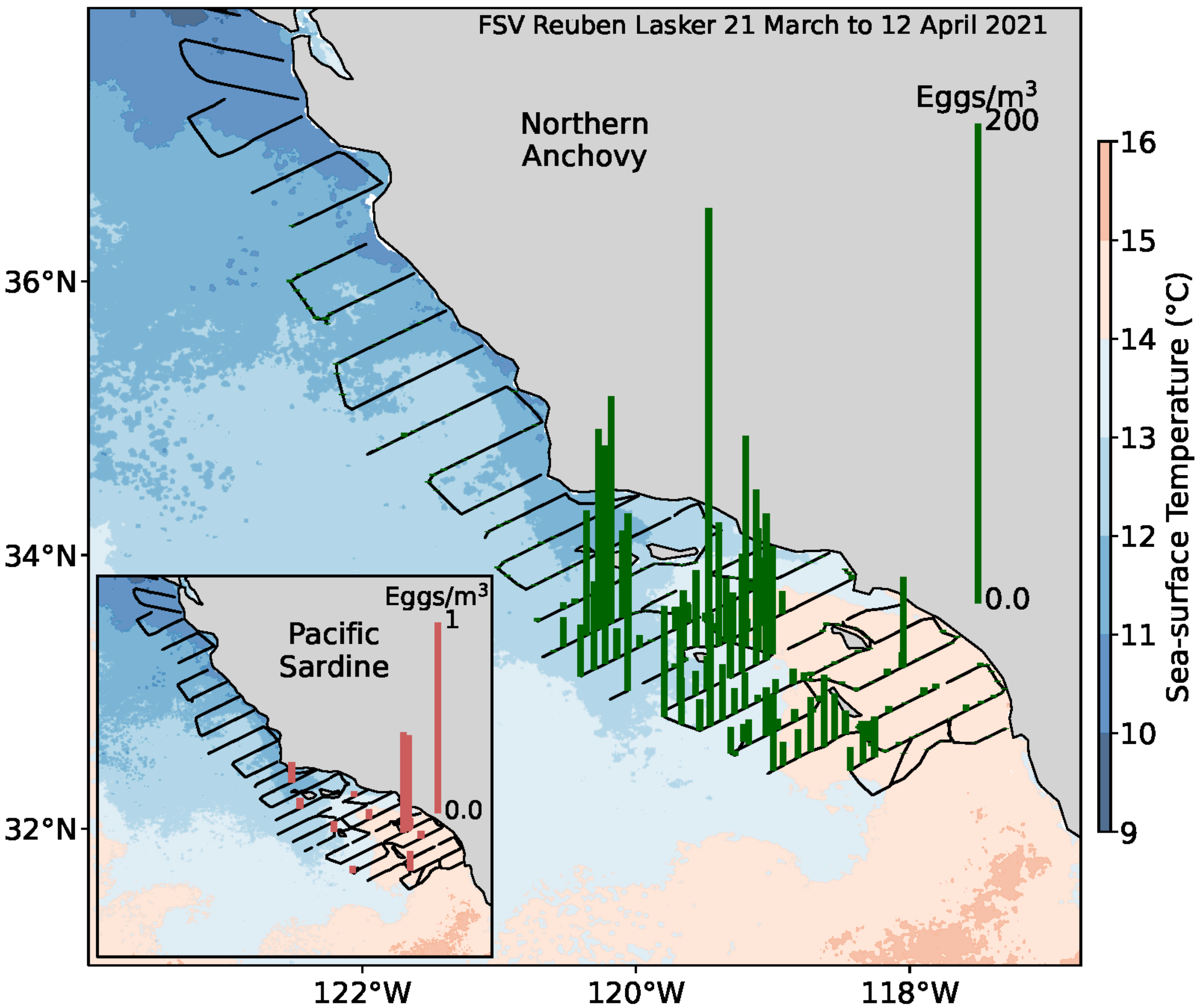
Fish eggs were collected using a continuous underway fish egg sampler (CUFES; Checkely Jr. et al. 1997) during the spring, 2021 coastal pelagic fish survey. Anchovy eggs were captured at relatively high densities, many greater than 100 eggs/m^3, in the SCB about 50-150 km offshore (CUFES Figure 1). Anchovy egg densities have remained relatively high since 2017. A few sardine eggs were captured throughout the SCB but densities were very low, never exceeding 1 egg/m^3. No Jack Mackerel eggs were captured in spring 2021.

Checkley Jr, D. M., P. B. Ortner, L. R. Settle, and S. R. Cummings. 1997. A continuous, underway fish egg sampler. Fisheries Oceanography 6:58-73.

CUFES Figure Caption.

CUFES Figure 1. Density of anchovy and sardine (inset) underlaid by temperature during the spring 2021 acoustic trawl cruise. Note the greatly different scales between anchovy and sardine egg density.

CUFES Figure 1



Regional Scale. Southern California. CalCOFI. Gliders along CalCOFI line 90

The California Underwater Glider Network has been collecting physical data along CalCOFI line 90 since 2007 as described in Ren and Rudnick (2021). There has been persistent anomalous warmth since 2014 at about 1°C. The La Niña of this past winter caused local temperature to dip back toward normal (where the baseline is 2007-2013). Right now the anomaly is closer to 1°C but may be dropping, especially if another El Niña sets in this winter, as is forecast (Glider Figure 1). The anomalously strong upwelling of the past winter is apparent based on the depth anomaly of 26 kg/m^3 isospycnal (Glider Figure 2)l. This shoaling is the first sustained period like this since 2013. In addition, a persistent positive salinity anomaly has been present starting in 2018 (Glider Figure 3). This suggests that the water in the southern CCS has a different origin than in previous years. The strongest anomaly in 2015-2016 was associated with the El Niño when southern influence in the California Undercurrent is often most apparent. Further offshore the recent salty anomaly was likely due to a source for the California Current from further south in the subtropical gyre than usual.

Ren, A.S., and Rudnick, D.L. (2021). Temperature and salinity extremes from 2014-2019 in the California Current System and its source waters. *Communications Earth & Environment* 2**,** 62.

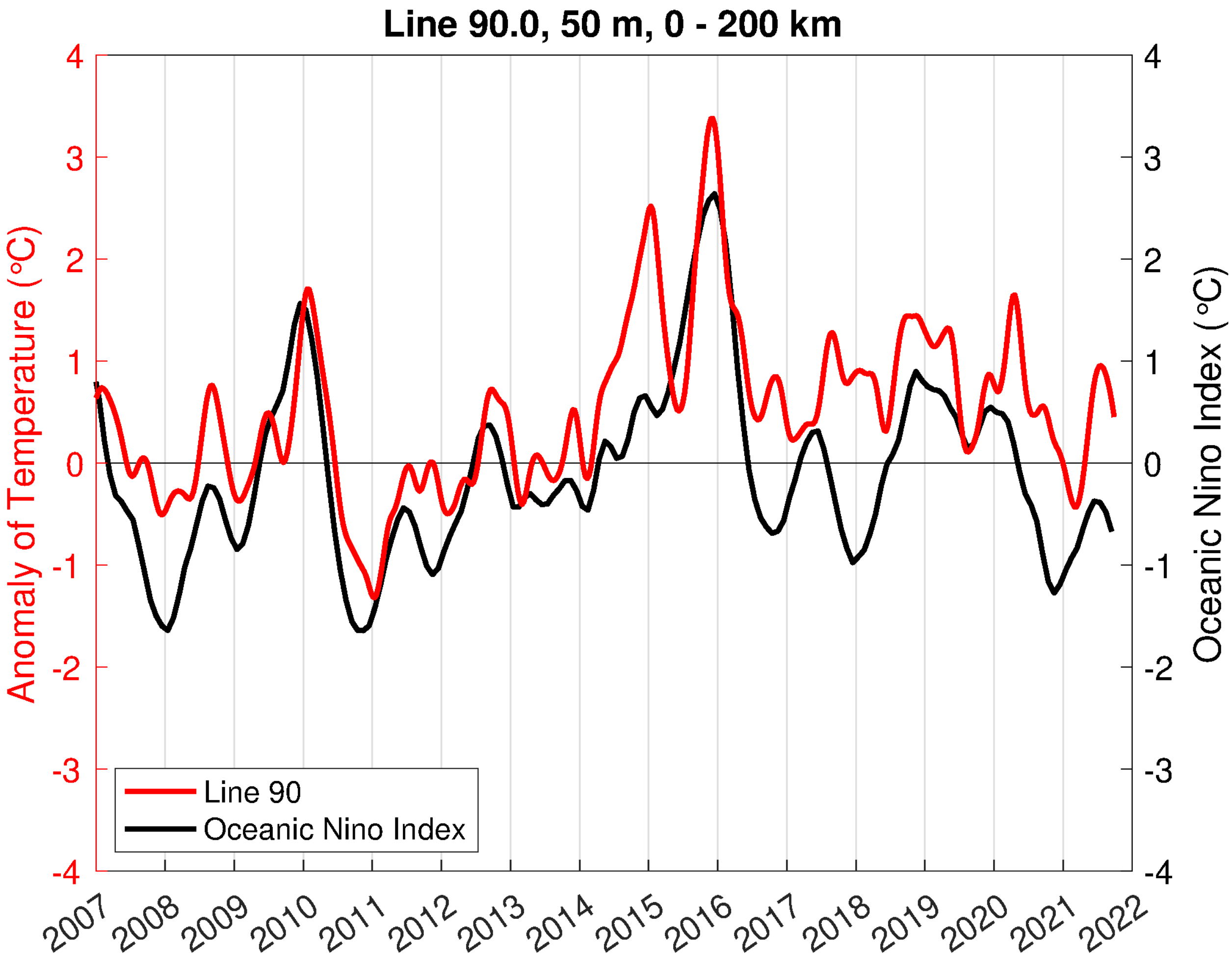
Glider Figure Captions.

Glider Figure 1. On line 90, temperature anomaly at 50 m averaged over the inshore 200 km (red), a metric we have called the SoCal Temperature Index, and the Oceanic Niño Index (black).

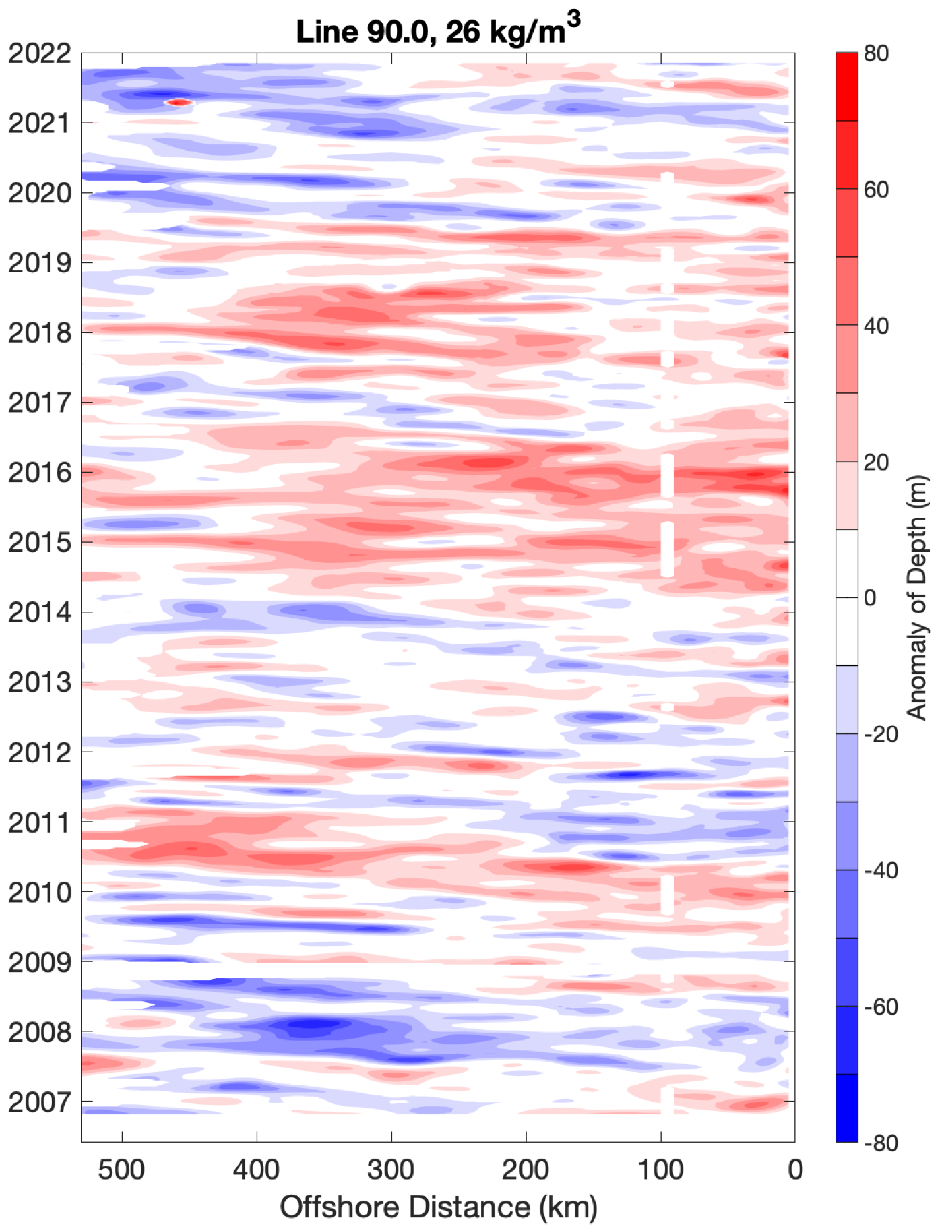
Glider Figure 2. On line 90, depth anomaly of the 26 kg/m^3 isospycnal as a function of distance offshore and time. Positive (red) is deeper than normal, and negative (blue) is shallower than normal.

Glider Figure 3. On line 90, salinity anomaly on the 26 kg/m^3 isopycnal as a function of distance offshore and time.

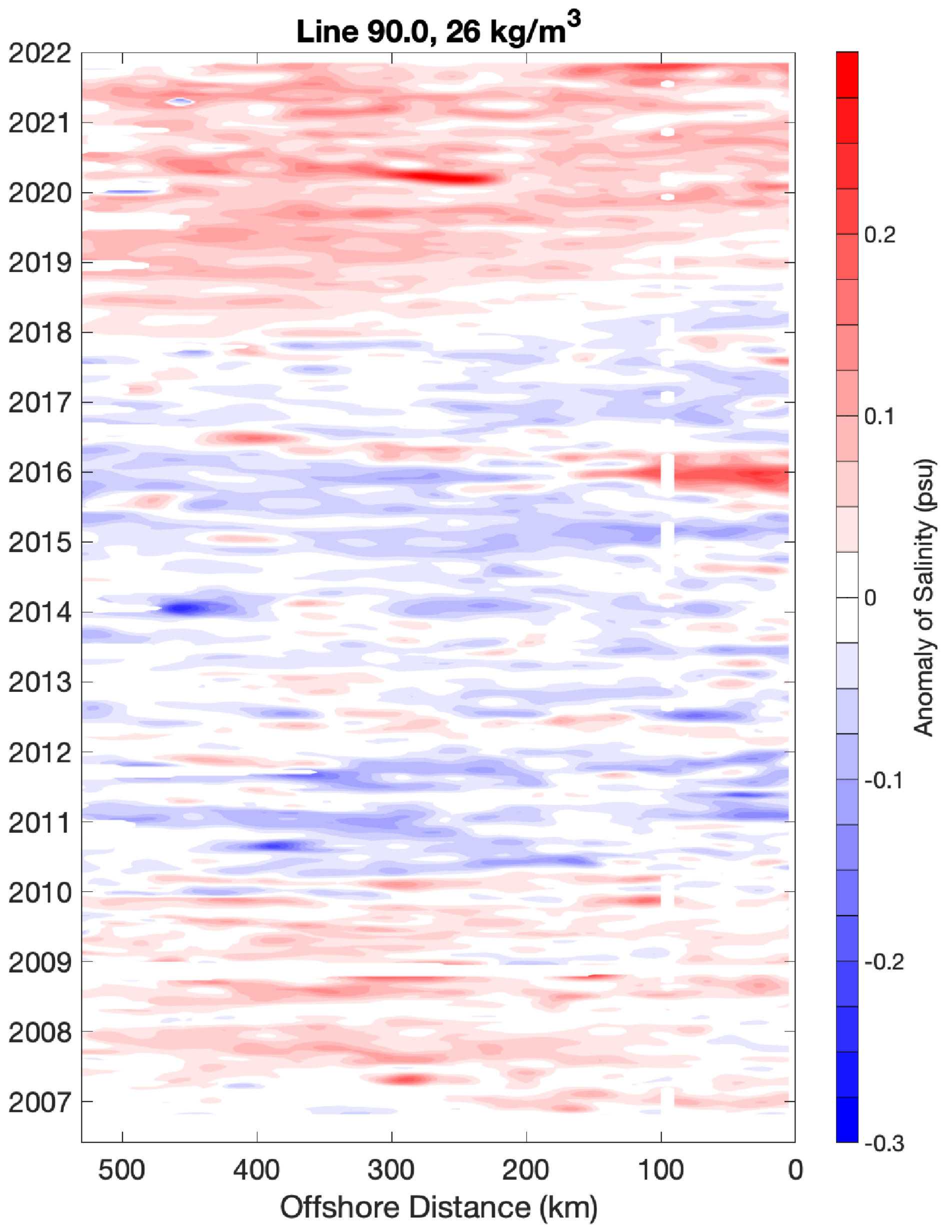
Glider Figure 1



Glider Figure 2



Glider Figure 3



Regional. Northern CCE. Juvenile Salmon and Ocean Ecosystem Survey (JSOES)

Beginning in 2015, the jellyfish community off Washington and Oregon transitioned from the large, cool-water scyphozoan species, sea nettle (*Chrysaora fuscescens*), which had been numerically dominant, to the more offshore-oriented water jellyfish (*Aequorea* spp.) (JSOES Figure 1). By 2019, both sea nettle and water jellyfish returned to average densities. In 2021, the sea nettle remained near average densities while the water jellyfish densities were the third highest for the 23 years that we have quantitative jellyfish data.

Yearling Chinook salmon (*Oncorhynchus tshawytscha*) abundance during June surveys correlate positively with returning spring Chinook jack and adult salmon counts at the Bonneville Dam (with 1 and 2 year lags, respectively), as did the abundance of yearling coho salmon (*O. kisutch*) to subsequent coho salmon smolt to adult survival (Morgan et al. 2019). Catch-per-unit effort of both yearling Chinook and coho salmon during the June 2021 survey was near average (JSOES Figure 2). Based solely on the correlations observed in previous years, this suggests that adult returns of spring Chinook salmon in 2023 and coho salmon returns in 2022 will be close to average, though other ecological factors will influence this relationship.

California market squid (*Doryteuthis opalescens*) and Pacific pompano (*Peprilus simillimus*) were observed at higher than average densities since the beginning of the marine heat wave. In 2021, the density of market squid was average and no Pacific pompano were captured in June (JSOES Figure 3). However, pompano were still captured during our May survey, indicating that they were likely still present in the area in low numbers.

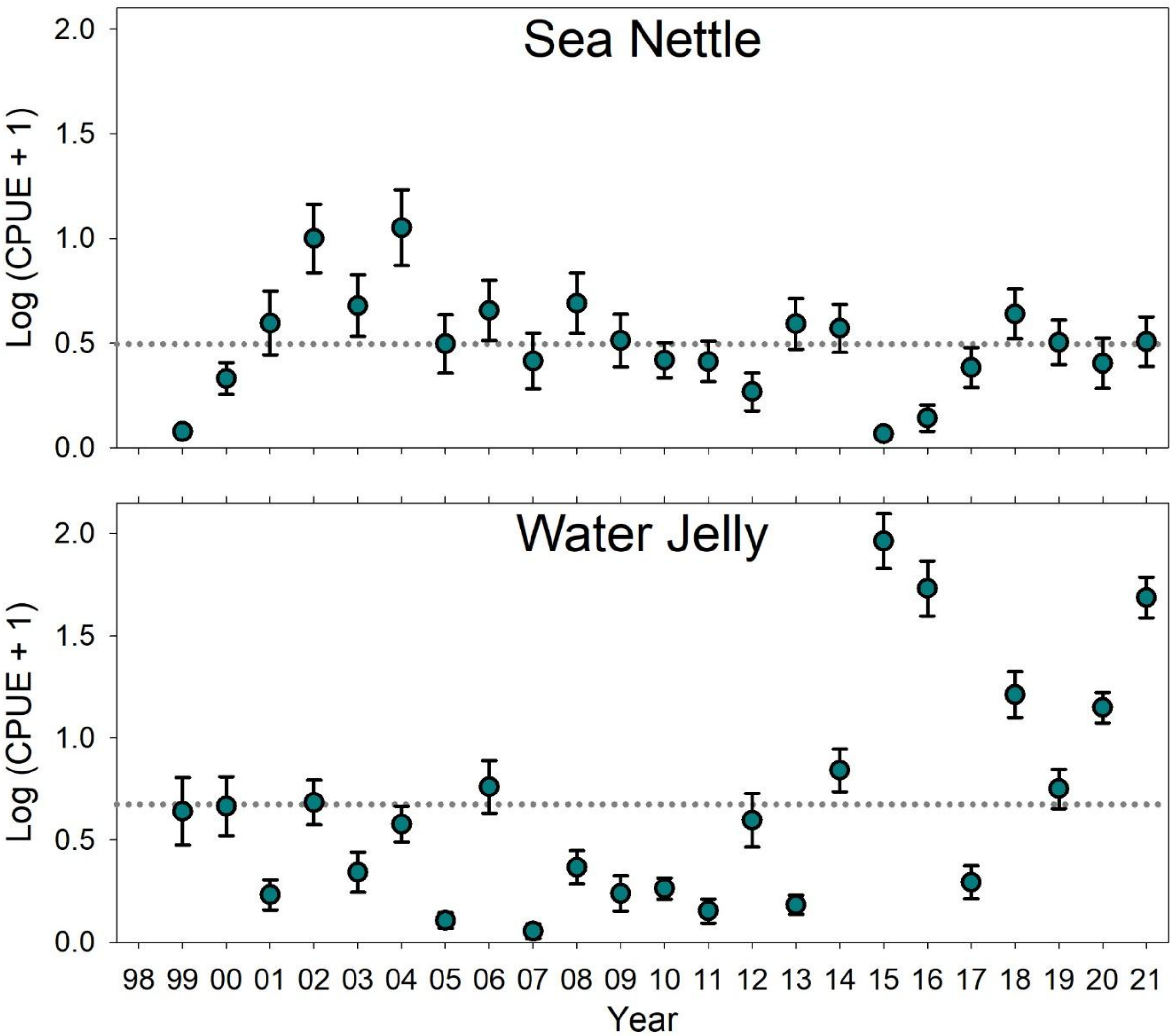
JSOES Figure Captions.

JSOES Figure 1. Catch per unit effort Mean(Log10((Number per km trawled +1))) of sea nettle and water jellyfish off Washington and Oregon from 1999-2021. The gray dotted line is the time-series mean catch.

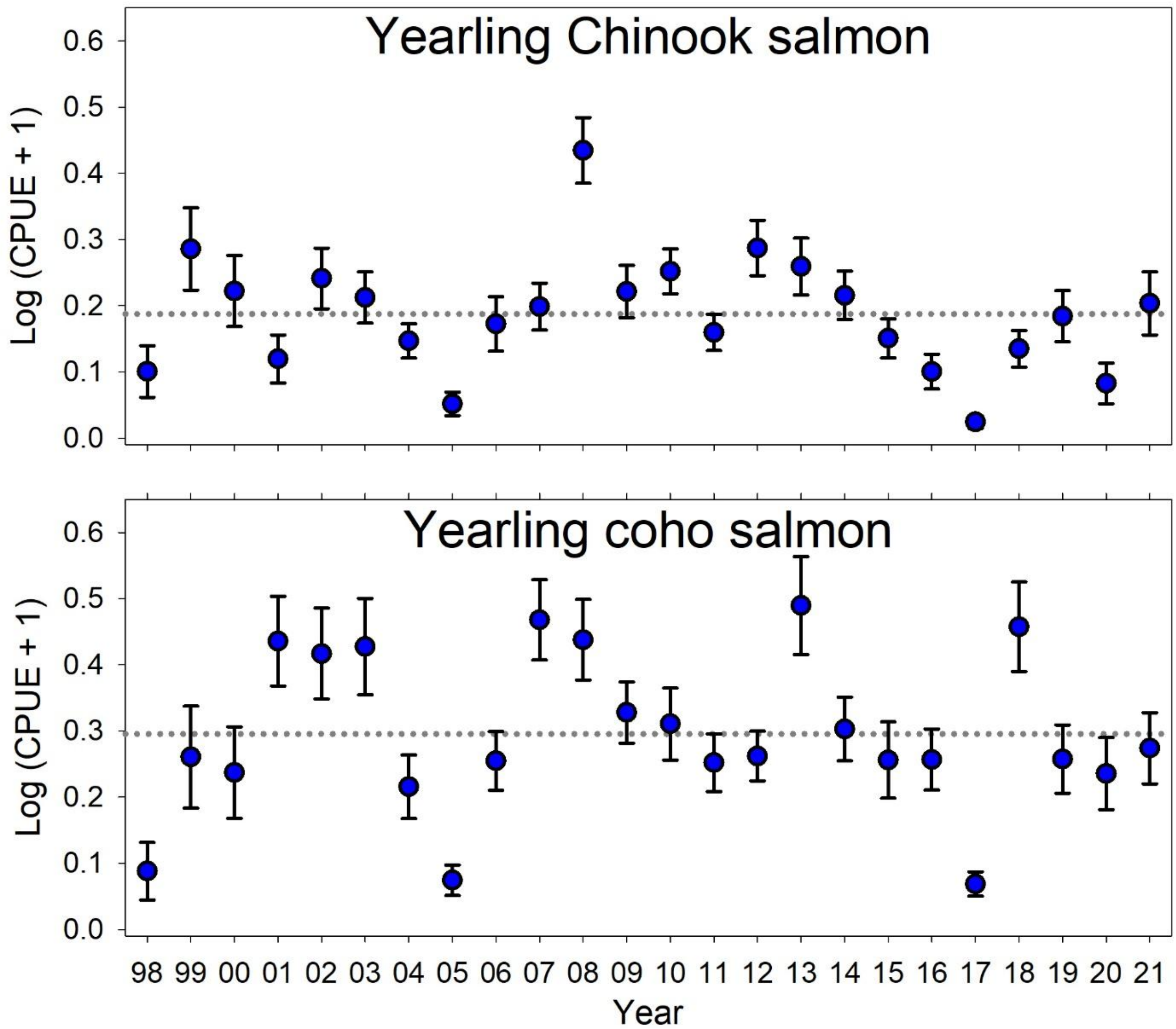
JSOES Figure 2. Catch per unit effort Mean(Log10((Number per km trawled +1))) of yearling Chinook and coho salmon off Washington and Oregon from 1998-2021. The gray dotted line is the time-series mean catch.

JSOES Figure 3. Catch per unit effort Mean(Log10((Number per km trawled +1))) of California market squid and Pacific Pompano off Washington and Oregon from 1998-2021. The gray dotted line is the time-series mean catch.

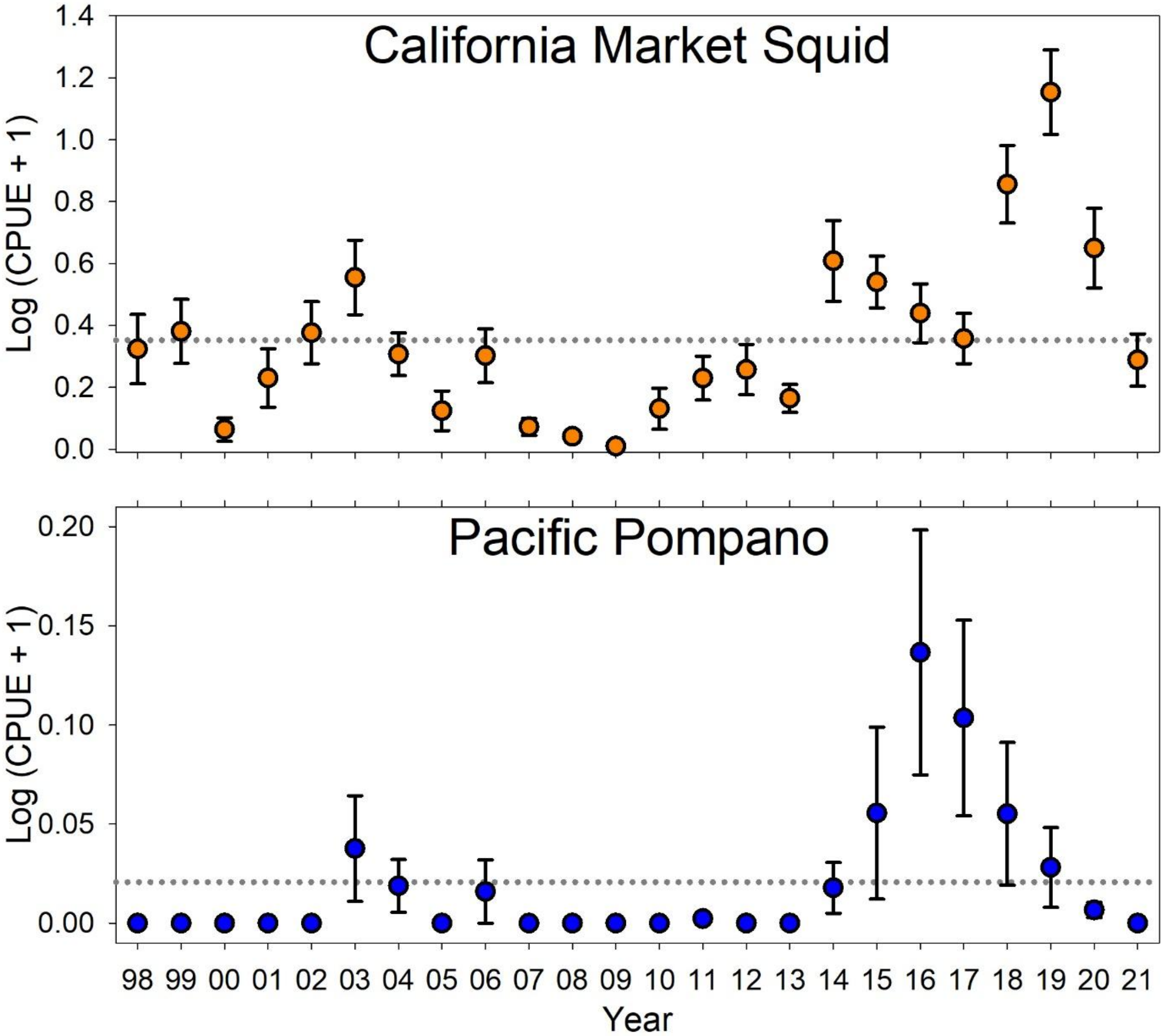
JSOES Figure 1



JSOES Figure 2



JSOES Figure 3



Regional. Northern CCE. Newport Hydrological Line Ichthyoplankton

In Jan-Mar of 2021, the biomass of winter-spawned coastal ichthyoplankton was above average, which suggests above average food availability for predators of juvenile fishes in spring and summer 2021 in the northern California Current (NCC). The ichthyoplankton species composition in winter was a mixture of both coastal and offshore ichthyoplankton and may be a result of the warmer than average ocean pre-conditioning period of late 2020, and the stronger upwelling and colder ocean conditions observed in early 2021. During the colder ocean conditions of our time series (1998-2021), taxa such as juvenile Pacific sand lance, juvenile hexagrammids like lingcod and greenlings, and adult krill were increasingly sampled and/or consumed by juvenile salmon; we also observed these conditions in 2021. And yet, in winter of 2021, sardine eggs and larvae were captured at our most inshore stations (1-5 nm from shore), and juvenile sardine (21-69 mm) were captured in May and June in the NCC surface waters. Winter-spawned sardines in nearshore waters of the NCC were last observed during the marine heat waves of 2015-2018, so were unexpected during this colder than average year.

Many winter-spawned ichthyoplankton in the northern California Current (NCC) are consumed in spring and early summer by juvenile salmon upon entering the marine environment. By spring and summer, these winter-spawned prey fish are in their late-larval or early-juvenile stages and have grown to a size favored by juvenile salmon during their early marine residence, which is a critical time during the salmon life cycle (Daly et al. 2019; Thalmann et al. 2020; Crozier et al. 2021). Due to challenges in directly sampling the late-larval and early-juvenile life stages of most marine fishes (Brodeur et al. 2011), we utilize the winter ichthyoplankton biomass of coastal taxa (Index of Coastal Prey Biomass [ICPB]) as well as the community composition of winter ichthyoplankton as indices of prey availability and quality for salmon migrating in late spring and early summer. Obviously, in using these indices, we are assuming some level of consistency in the mortality rates from larval to juvenile stages of these marine fish; an assumption that may vary over time. Samples are collected every two weeks from January-March (weather/boat permitting) from the Newport Hydrographic (NH) line at 44.65˚N, 124.18–124.65˚W, and only stations 9-46 km from shore were included in the indices due to consistency of sampling.

In winter (January-March) of 2021, the ICPB was above the long-term mean and the 6th highest biomass in the 24-yr time series, suggesting above average prey biomass for out-migrating salmon (NCC Table 1; NCC Fig. 1). Additionally, as we observed in 2010 and 2015-present, there was a considerable amount of offshore taxa biomass in the ichthyoplankton community during winter 2021. The community composition of ichthyoplankton in 2021 was a mixture of both coastal and offshore taxa, placing it in the middle of the ordination plot between warm and cold ocean conditions (NCC Figs. 2-3). These results suggest close-to-average (community) and above-average (ICPB) prey conditions for piscivorous juvenile salmon that out-migrated in 2021 (NCC Figs. 1-3). Also see NCC Fig. 5 for non-metric multidimensional scaling of the winter ichthyoplankton community.

Ocean conditions in fall/early winter have been anomalously warm for the last seven years, which includes the above-average SSTarc (Johnstone and Mantua 2014) anomalies observed in fall/winter of 2020 (NCC Fig. 3). The fall season is the physical and biological pre-conditioning period in the NCC (Schroeder et al. 2013; Santora et al. 2020), which is correlated with the winter-spawned ichthyoplankton community and biomass (Daly et al. 2019). The ICPB was higher in January-March 2021 than would be expected given the above-average October-December 2020 ocean SSTarc anomalies. The returns of adult coho salmon in 2021 (out-migrated as juveniles in spring of 2020) were the highest seen since 2013 out-migration year (NCC Fig. 4), and typically when coho salmon return at higher than average levels, the other salmon do as well (though remain in the ocean for two years), and thus juvenile Chinook salmon and steelhead could return in higher numbers in 2022.

The most inshore station (2 km from shore) along the Newport Hydrographic line (NH-01) is not part of either of the ichthyoplankton indices, yet was sampled four times in 2021 and also quantified for fish eggs and larvae. Of note, eggs and larvae of Pacific sardine (*Sardinops sagax*) were observed in 2021, which was last observed during the marine heat waves of 2015-2018 (Auth et al. 2018). Collections of sardine eggs and larvae (NH-01) and eggs (NH-05) is an anomalous shift in sardine spawning location in latitude (further north by several hundred km), timing (3-6 months early), and distance from shore (inshore at 2-9 km versus off the shelf) in 2021 (Auth et al. 2018). Juvenile sardines (21-33 mm SL) were captured in high abundance at all thirty stations sampled during the Juvenile Salmon Ocean Ecosystem Survey (JSOES) in May 2021. Stations sampled were inshore to the shelf break from 46-48° N. Larger juvenile sardines were sampled in the June JSOES survey, though in lower abundances and frequency, were closer to the shelf break, and ranged in size form 37-69 mm. Also of note, the salmon prey biomass (juvenile fishes <80 mm, adult krill and crab larvae, and other small pelagic invertebrates) caught in 2021 was many times higher than what was caught in 2017-2018 (Daly et al. 2021).

Auth, T.D., Daly, E.A., Brodeur, R.D., and Fisher, J.L. 2018. Phenological and distributional shifts in ichthyoplankton associated with recent warming in the northeast Pacific Ocean. Glob. Chang. Biol. 24:259-272.

Brodeur, R.D., Auth, T.D., Britt, T., Daly, E.A., Litz, M.N.C., and Emmett, R.L. 2011. Dynamics of larval and juvenile rockfish (Sebastes spp.) recruitment in coastal waters of the Northern California Current. ICES CM 2011/H:12.

Crozier, L.G., Burke, B.J., Chasco, B.E., Widener, W.L., and Zabel, R.W. 2021. Climate change threatens Chinook salmon throughout their life cycle. Commun. Biol. https://doi.org/10.1038/s42003-021-01734-w

Daly, E.A., Auth, T.D., and Brodeur, R.D. 2019. Changes in juvenile salmon prey fields associated with a recent marine heat wave in the Northern California Current. Anomalous ocean conditions in 2015: impacts on spring Chinook salmon and their prey field. N. Pac. Anadr. Fish Comm. Tech. Rep. 15. doi:10.23849/npafctr15/71.74.

Daly, E.A, Brodeur, R.D., Morgan, C.A., Burke, B.J., and Huff, D.H. 2021. Prey selectivity and diet partitioning of juvenile salmon in coastal waters in relation to prey biomass and implications for salmon early marine survival. N. Pac. Anadr. Fish Comm. Tech. Rep. 17 53-56.

Johnstone, J.A., and Mantua, N.J. 2014. Atmospheric controls on northeast Pacific temperature variability and change, 1900-2012. Proc. Natl. Acad. Sci. 111(40):14360-14365.

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NCC Table 1. Index of coastal prey biomass (ICPB) from 1998-2021 sampled in January-March along the Newport Hydrographic (NH) line, the rank of the biomass from highest (1) to lowest (24), Axis-1 principal coordinate community analysis on the composition of coastal and offshore taxa by year, and the rank of the community from coastal taxa dominated (1 = most coastal taxa) to offshore taxa dominated (24 = most offshore taxa).

Year	ICPB (Log_{10}[mg C 1000 m^{-3}])	Rank biomass	Coastal and offshore taxa composition axis 1 PCO scores	Rank PCO
1998	0.48	19	9.47	11
1999	1.64	4	20.44	6
2000	0.97	13	28.90	5
2001	1.27	7	14.48	8
2002	1.95	1	13.98	10
2003	0.4	23	2.29	13
2004	0.32	24	-19.37	18
2005	0.49	18	-33.14	22
2006	1.16	10	35.20	1
2007	0.48	20	-9.04	15
2008	1.64	3	31.77	3
2009	0.62	15	3.80	12
2010	1.87	2	-11.26	16
2011	1.21	9	29.42	4
2012	1.55	5	32.83	2
2013	1.09	12	16.73	7
2014	0.46	21	14.22	9
2015	0.51	16	-30.37	20
2016	0.49	17	-33.58	23
2017	0.64	14	-38.82	24
2018	1.12	11	-28.84	19
2019	0.43	22	-32.46	21
2020	1.25	8	-12.77	17
2021	1.39	6	-3.87	14

NCC Figure Captions.

NCC Figure 1. Annual average biomass of ichthyoplankton from winter (January-March) collected along the Newport Hydrographic (NH) line at stations NH05-25. Taxa listed in color are considered coastal and make up the index of coastal prey biomass (ICPB), and taxa in white pattern are considered offshore.

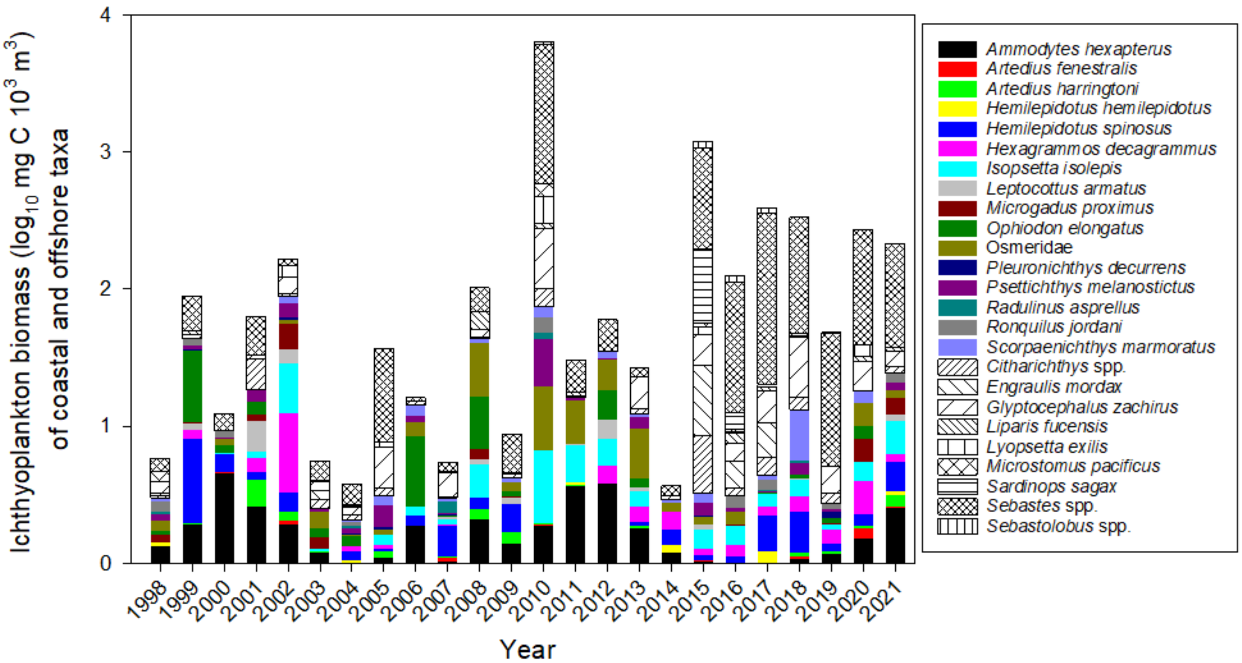
NCC Figure 2. Principal coordinate analysis of the prey composition of winter ichthyoplankton. Red symbols indicate warmer-than-average October-December sea surface temperatures (SSTarc) in the months prior to the winter ichthyoplankton collections, and blue indicates colder-than-average. The larvae were collected during winter (January–March) in 1998–2021 along the Newport Hydrographic (NH) line off the coast of Oregon (44.65˚N, 124.18–124.65˚W).

NCC Figure 3. Anomalies of the Index of Coastal Prey Biomass (ICPB), Ichthyoplankton PCO axis-1 scores, and the October-December sea surface temperature (SSTarc) lagged by 1-yr.

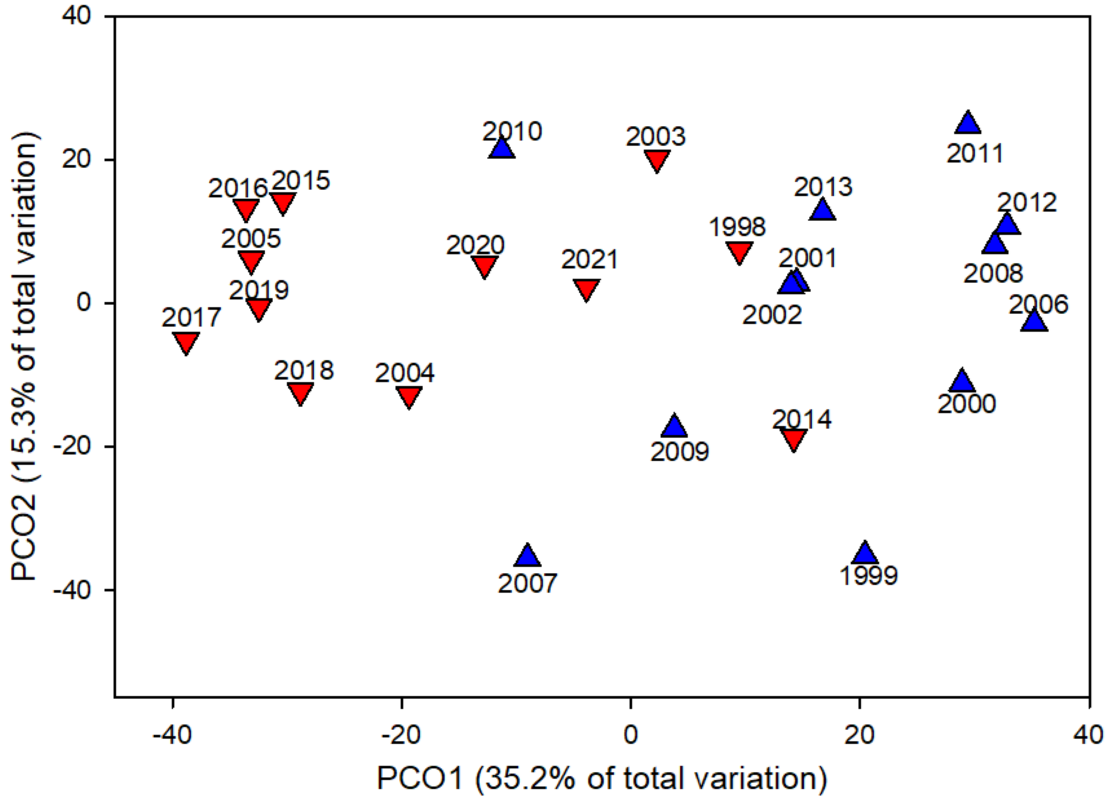
NCC Figure 4. Anomalies of the winter coastal ichthyoplankton biomass and the Axis-1 principal coordinate community analysis on the composition of coastal and offshore taxa (no lag) and the adult salmon counts at Bonneville Dam lagged by time typically spent in ocean (two years for spring and fall Chinook salmon and steelhead and unmarked steelhead, and 1 year for coho salmon).

NCC Figure 5. Non-metric multidimensional scaling of ichthyoplankton species by year for winter cruises at the Newport Hydrographic Line.

NCC Figure 1

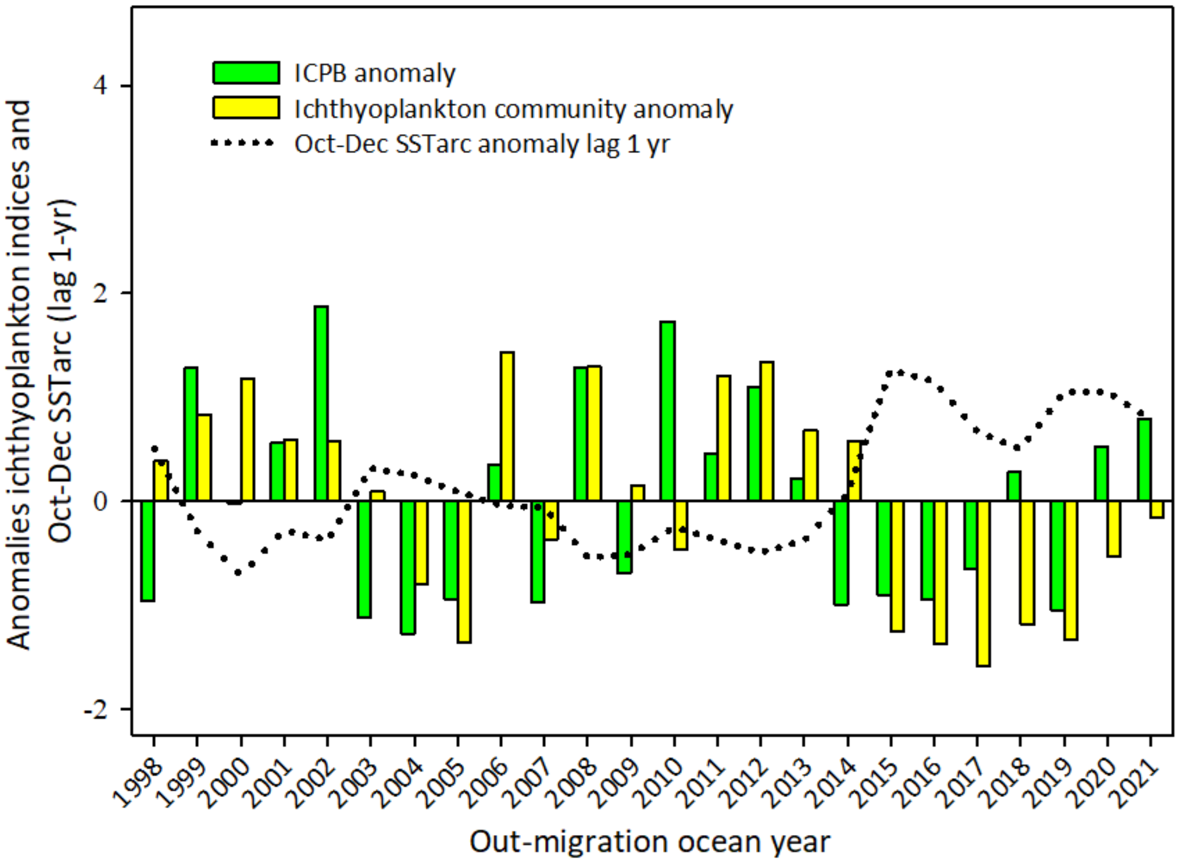

Ichthyoplankton biomass ($\log_{10}$ mg C 10^3 m^3) of coastal and offshore taxa
Year
0
1
2
3
4
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Ammodytes hexapterus
Artedius fenestralis
Artedius harringtoni
Hemilepidotus hemilepidotus
Hemilepidotus spinosus
Hexagrammos decagrammus
Isopsetta isolepis
Leptocottus armatus
Microgadus proximus
Ophiodon elongatus
Osmeridae
Pleuronichthys decurrens
Psettichthys melanostictus
Radulinus asprellus
Ronquilus jordani
Scorpaenichthys marmoratus
Citharichthys spp.
Engraulis mordax
Glyptocephalus zachirus
Liparis fucensis
Lyopsetta exilis
Microstomus pacificus
Sardinops sagax
Sebastes spp.
Sebastolobus spp.

NCC Figure 2

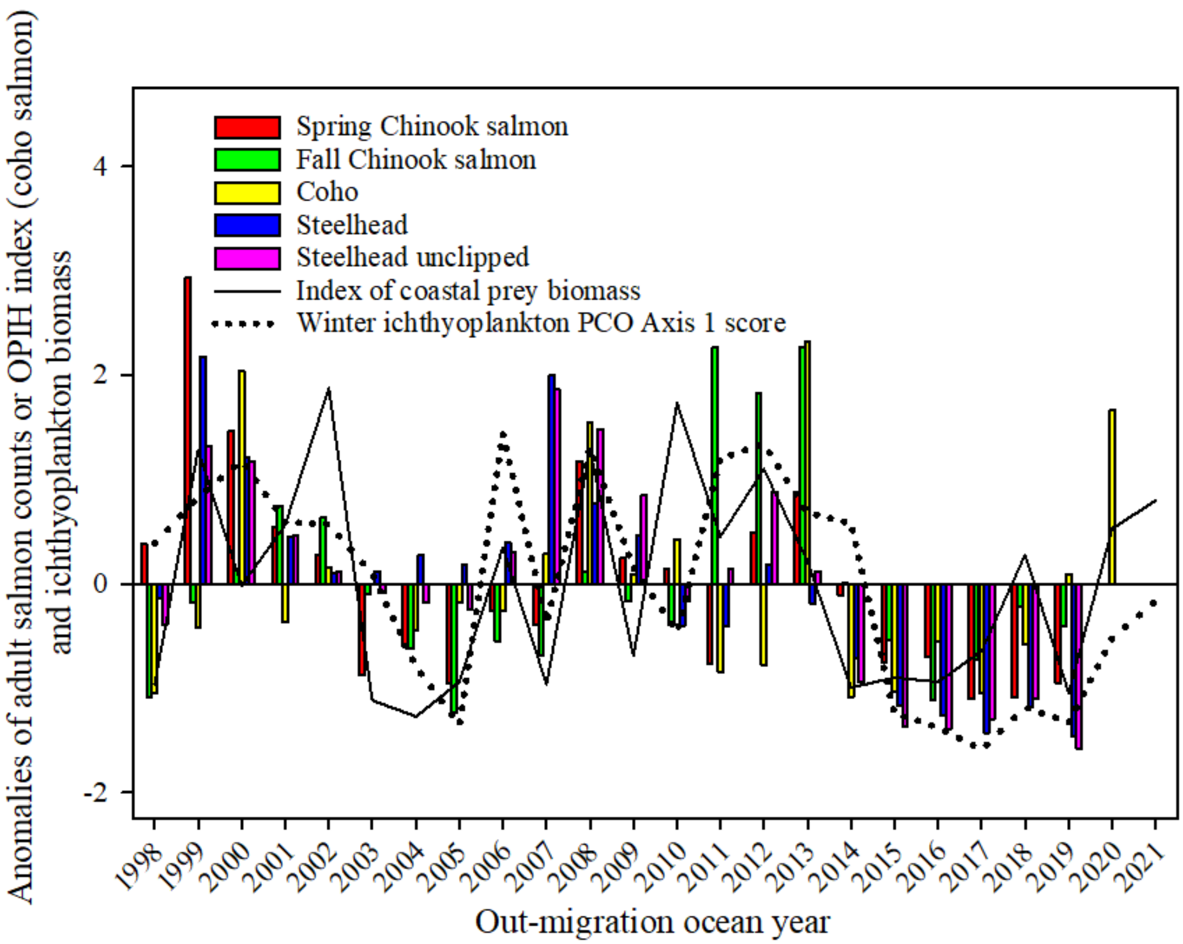


40
20
0
-20
-40
-40
-20
0
20
40
PCO1 (35.2% of total variation)
PCO2 (15.3% of total variation)
2010
2003
2016
2015
2013
2012
1998
2005
2020
2021
2001
2008
2019
2006
2002
2017
2018
2004
2000
2014
2009
2007
1999
2011

NCC Figure 3

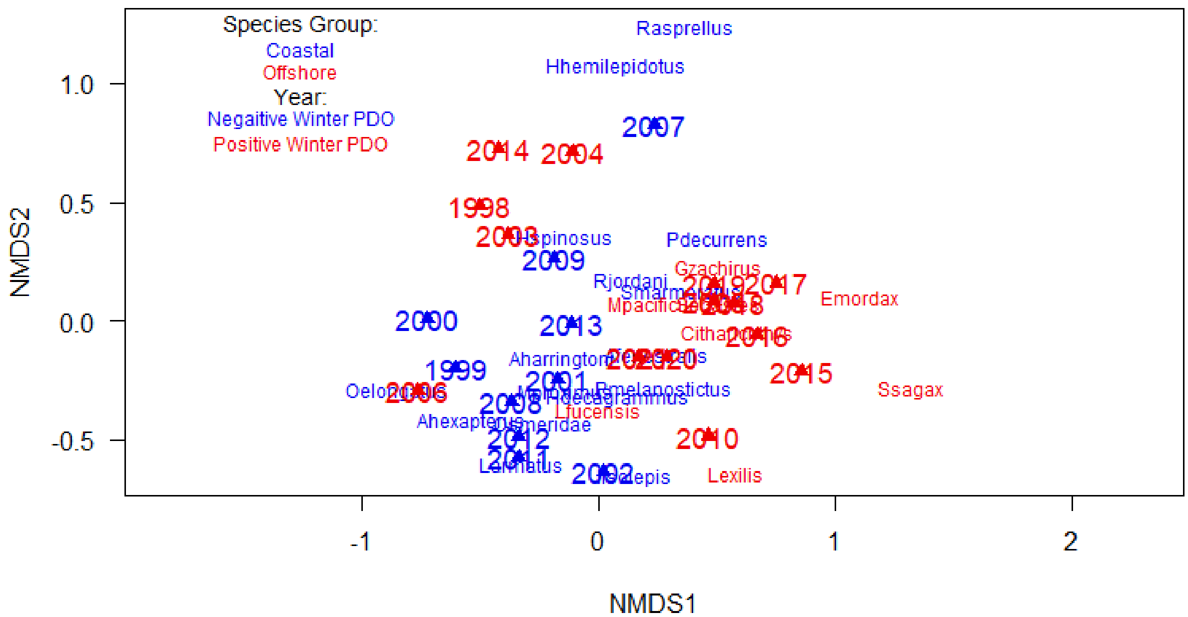

ICPB anomaly
Ichthyoplankton community anomaly
Oct-Dec SSTarc anomaly lag 1 yr
Anomalies ichthyoplankton indices and Oct-Dec SSTarc (lag 1-yr)
4
2
0
-2
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Out-migration ocean year

NCC Figure 4



Spring Chinook salmon
Fall Chinook salmon
Coho
Steelhead
Steelhead unclipped
Index of coastal prey biomass
Winter ichthyoplankton PCO Axis 1 score
Anomalies of adult salmon counts or OPIH index (coho salmon) and ichthyoplankton biomass
4
2
0
-2
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
Out-migration ocean year

NCC Figure 5



Species Group:
Coastal
Offshore
Year:
Negaitive Winter PDO
Positive Winter PDO
Rasprellus
Hhemilepidotus
2007
2014
2004
1998
Pdecurrens
2009
Gzachirus
Rjordani
2017
Emordax
2000
2013
2016
1999
Aharrington
2015
Ssagax
Pmelanostictus
Lfucensis
2008
Ahexapterus
2012
2010
Lexilis
2002
1.0
0.5
0.0
-0.5
-1
0
1
2
NMDS1
NMDS2

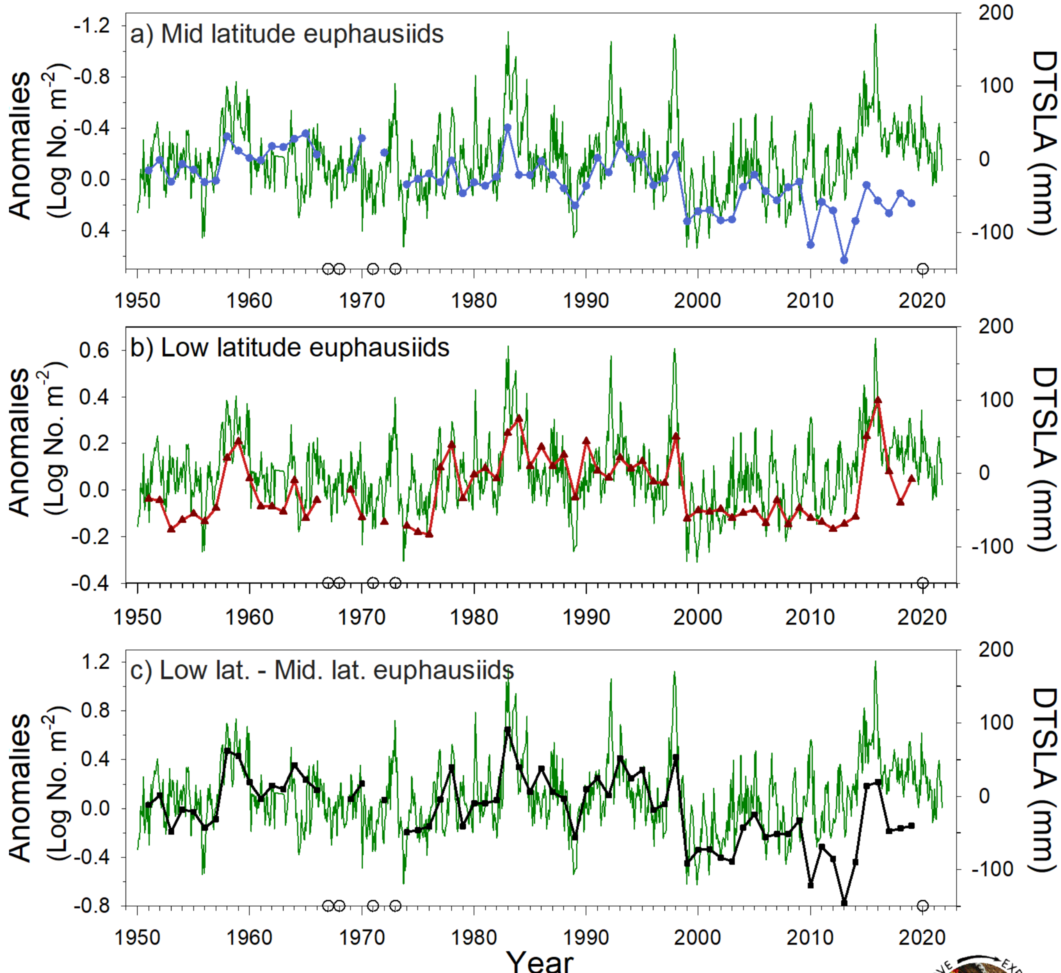
Regional. Southern California. CalCOFI. Krill

Krill were identified from an aliquot of spring southern California CalCOFI samples between 1951 and 2019 as described by Lilly and Ohman (2021). From 1951-2000 there was a strong correlation between the Detrended San Diego Sea Level Anomalies (DTSLA) and euphausiid species groups that held from approximately 1950-2000 began to change in approximately 2000. DTSLA is one measure of El Niño and other Warm Anomalies in the CCE (Lilly and Ohman 2021). This relationship began to fall apart in approximately 2000 due to a long-term increase in abundance of mid-latitude euphausiids, but no secular change in abundance of low-latitude euphausiids. Open circles on abscissa indicate no samples available. Euphausiids were enumerated from springtime CalCOFI cruises in Southern California as part of the California Current Ecosystem LTER program, supported by NSF.

CalCOFI Krill Figure 1. Time series of Detrended San Diego Sea Level Anomalies (DTSLA, green line) and anomalies of abundance of two groups of euphausiids (1951-2019): (a) four euphausiid species whose primary biogeographic distribution in the NE Pacific is in Middle latitudes (see Lilly and Ohman; note reversed scale), (b) four euphausiid species whose primary biogeographic distribution in the NE Pacific is in Low latitudes, and (c) the difference between Low latitude and Middle latitude euphausiid anomalies.

Lilly, L. E., and M. D. Ohman. 2021. Euphausiid spatial displacements and habitat shifts in the southern California Current System in response to El Niño variability. Progress in Oceanography 193: doi https://doi.org/10.1016/j.pocean.2021.102544

CalCOFI Krill Figure 1



Regional. Central California. Southeast Farallon Birds

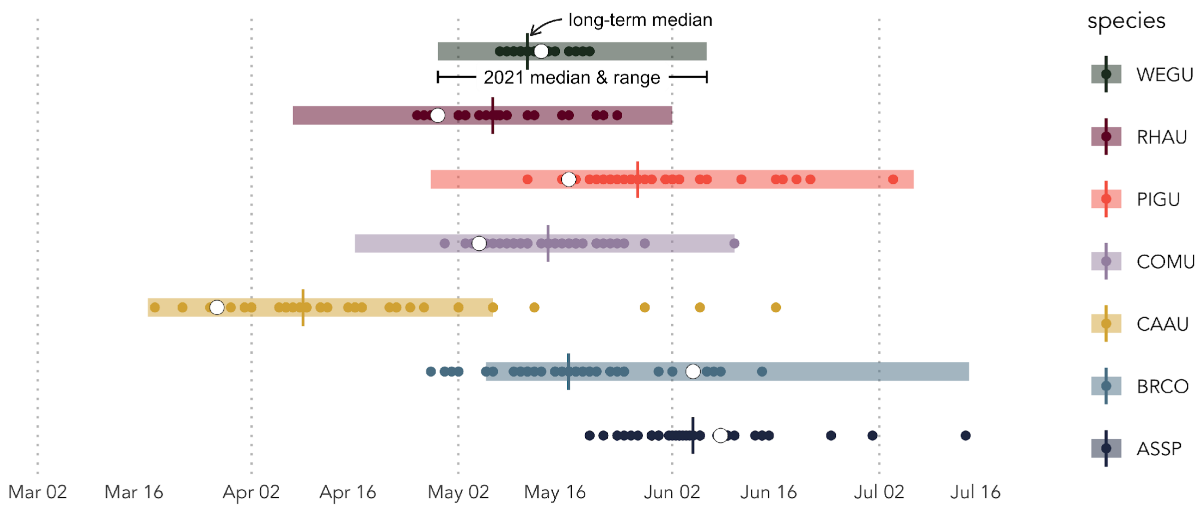
The 2021 seabird breeding season on Southeast Farallon Island (SEFI) exhibited higher productivity than 2020 and was also above the long-term mean for most species. This is likely attributable to strong northwest winds and improved upwelling conditions in the spring. Such favorable oceanic conditions early season were also reflected in early lay dates relative to the long-term median for planktivorous Cassin's auklets (*Ptychoramphus aleuticus*), which are considered a bellwether for marine productivity around the island, and most other species monitored (Southeast Farallon Fig. 1). Cassin's auklets exhibited high nest box occupancy and increased burrow densities across followed index plots, indicating favorable foraging conditions in the central CCS during the early season. Their reproductive success of 1.4 chicks per pair was slightly less than 2020, but remained higher than the long-term mean (Southeast Farallon Fig 2.). A high incidence of double brooding attempts likely meant a stable supply of available krill remained near SEFI until mid-season. However, many of these attempts failed during the incubation period, suggesting a decline in foraging conditions beginning in July. Piscivorous rhinoceros auklets (*Cerohinca monocerata*), pigeon guillemots (*Cepphus columba*), and common murres (*Uria aalge*) continued a trend of increasing reproductive success compared to the previous 2 years (Southeast Farallon Fig. 2). Juvenile rockfish (*Sebastes spp*.) represented roughly 16-18% of the chick diet for these three species, a low proportion compared to the long-term record and similar to what was observed in 2020. Northern anchovy, flatfishes, and other alternate prey made up for an apparent lack of abundance in juvenile rockfish around SEFI (Southeast Farallon Fig. 3). Both pelagic and Brandt's cormorants (*Phalacrocorax peligacus* and *Phalacrocorax penicillatus)* maintained similar higher than average productivity numbers compared to 2020, with Brandt's cormorants continuing a 5-year stable trend in reproductive success above the long-term mean. Ashy storm-petrels (*Oceanodroma homochroa*) had close to average reproductive success but showed lower than average capture rates during regular mist netting sessions. Overall, despite an apparent relaxation in upwelling mid-season, seabird trends at SEFI demonstrated an apparent abundance of krill and northern anchovy, and favorable oceanic conditions for marine predators in the Gulf of the Farallones.

Southeast Farallon Figure 1. Phenology for 7 seabird species on Southeast Farallon Island colored by species, for the first egg in first attempts only. Filled circles represent the long-term annual median lay dates, vertical line the median across all previous years, the shaded bar the range (min and max) of lay dates during 2021, and the open circle the 2021 median lay date for each species.

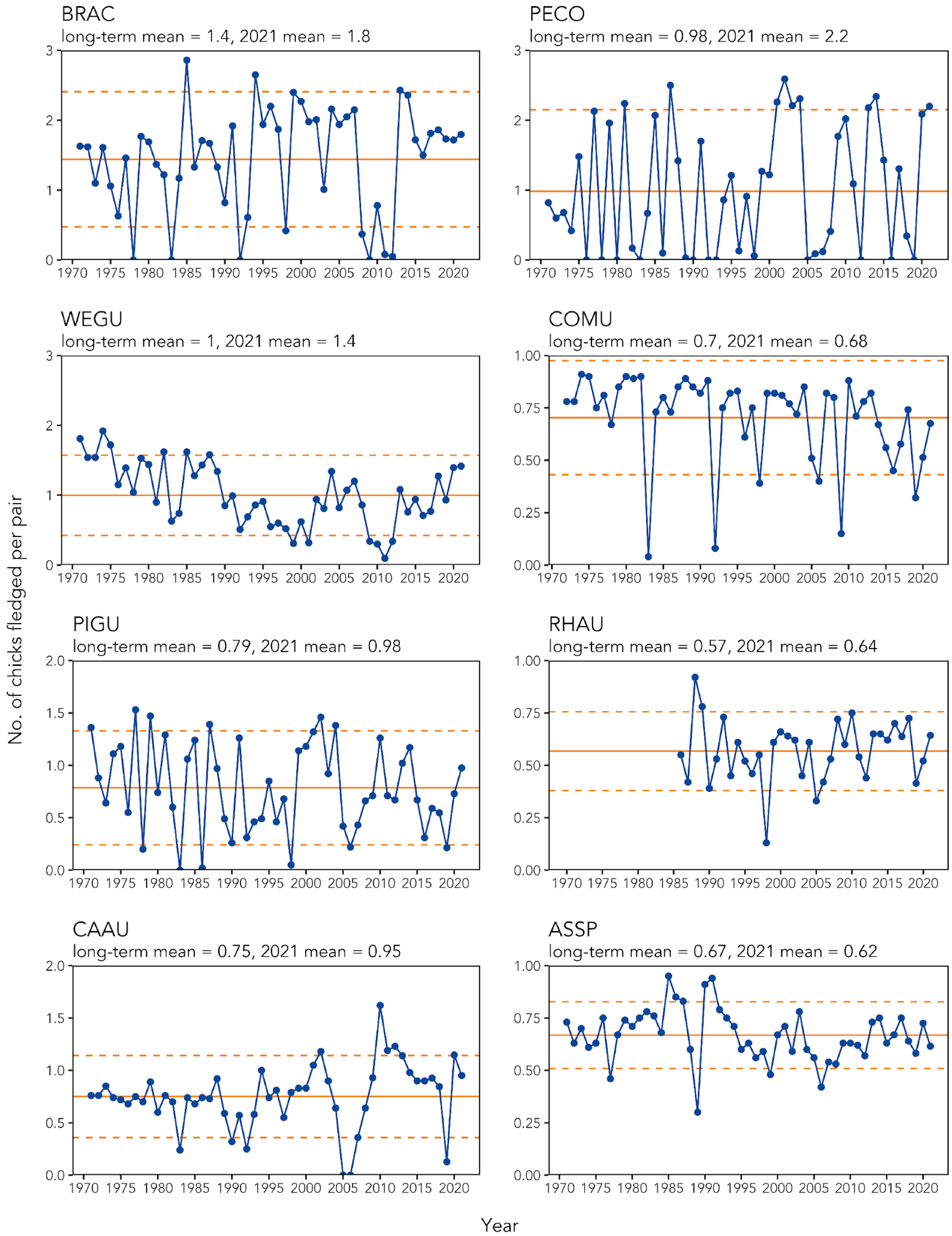
Southeast Farallon Figure 2. Productivity of 8 seabird species on Southeast Farallon Island, 1971 – 2021, measured as the number of chicks fledged per breeding pair (includes first attempts, relays, and second broods). The solid orange line indicates mean productivity from all attempts between 1971 and 2020. Dashed orange lines represent 80% prediction intervals around the long-term mean.

Southeast Farallon Figure 3. Annual proportion of common prey items in the chick diet of three species of seabirds on Southeast Farallon Island.

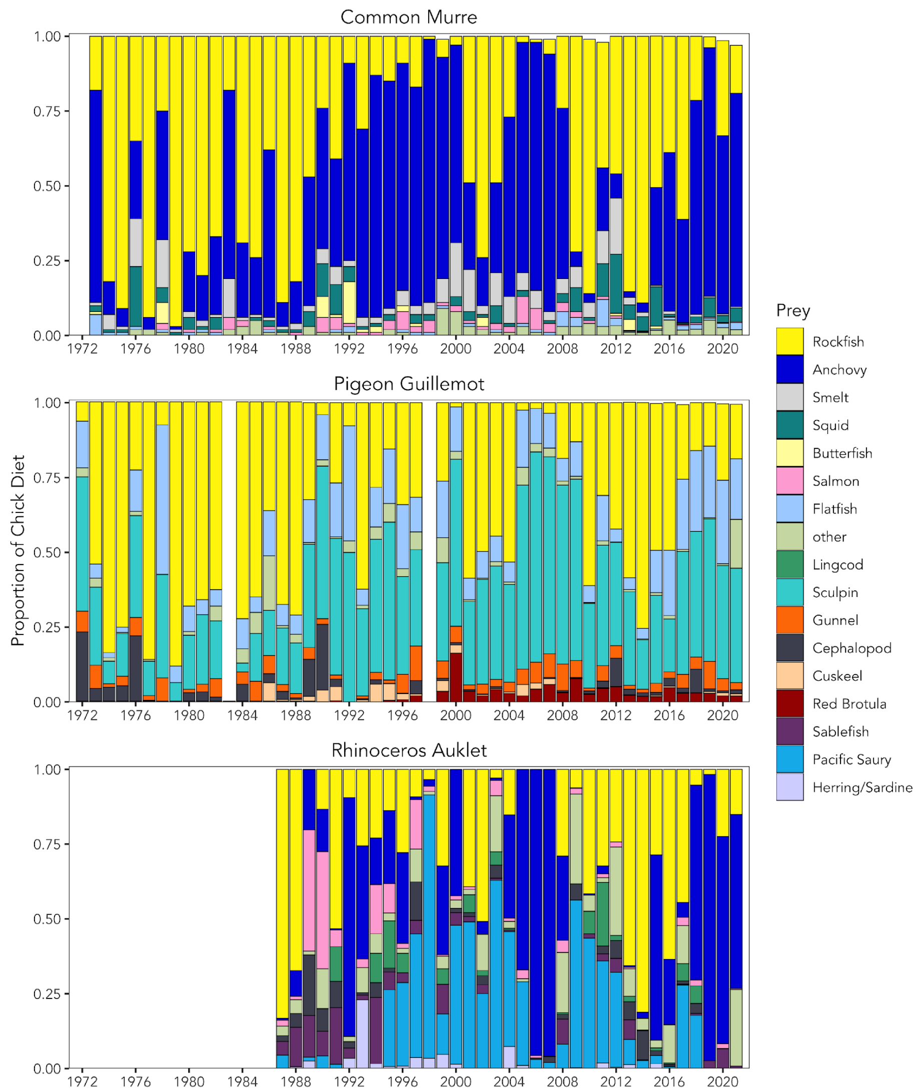
Southeast Farallon Figure 1



Southeast Farallon Figure 2



Southeast Farallon Figure 3



Regional Scale. CalCOFI Marine Mammal Sightings (CalCOFI MM)

CalCOFI marine mammal visual surveys were conducted during daylight hours while the ship was in transit between CalCOFI sampling stations. For the two 2021 surveys, two experienced observers were present; their visual observation protocol followed guidelines outlined in Campbell et al. (2015).

Nine species of cetacean were sighted during the 2021 CalCOFI visual surveys. Of those nine, three were in the taxonomic group mysticeti (baleen whales), and six were in the taxonomic group odontoceti (toothed whales). Two of the observed baleen whales, blue whales (*Balaenoptera musculus)* and fin whales (*Balaenoptera physalus)*, were sighted almost exclusively along the continental slope or further offshore during the summer 2021 cruise (CalCOFI MM Fig. 1). Additionally, the number of individual blue and fin whales was higher during the summer 2021 cruise than during previous years. Toothed whale sightings during both cruises were distributed inshore and offshore, with greater species diversity observed inshore (CalCOFI MM Figs. 2 - 4).

The winter and spring CalCOFI cruises did not include marine mammal observations in 2021 due to the COVID-19 pandemic, impairing our ability to monitor cetacean presence during those seasons. The summer 2021 cruise had noticeably high numbers of blue and fin whale sightings offshore, with the number of blue whale sightings being the highest in five years. La Niña conditions in the California Current may have driven increased offshore or continental slope prey availability for blue whales, who specialize on euphausiids, and generally prefer *Thysanoessa spinifera* to *Euphausia pacifica* (Nickels et al. 2019). Fin whales, similarly, may have experienced increased availability of their preferred prey, which generally consist of euphausiids and small pelagic schooling fish (Flinn et al. 2002). Toothed whale sightings from summer and fall had higher species diversity inshore than offshore, which is not surprising for this region (Rice et al. 2022). Short-beaked common dolphins (*Delphinus delphis)* are regularly observed in large groups offshore, however, their abundance was low during the summer and fall 2021 cruises compared to previous years (Rice et al. 2022). Cooler, more productive conditions in the California Current may have driven the observed changes in offshore distribution and abundance of cetacean predators.

Campbell, G. S., Thomas, L., Whitaker, K., Douglas, A. B., Calambokidis, J., & Hildebrand, J. A. (2015). Inter-annual and seasonal trends in cetacean distribution, density and abundance off southern California. *Deep Sea Research Part II: Topical Studies in Oceanography*, *112*, 143–157. https://doi.org/10.1016/j.dsr2.2014.10.008

Rice, A.C., Trickey, J.S., Giddings, A., Rafter, M.A., Wiggins, S.M., Frasier, K.E., Baumann Pickering, S., and Hildebrand, J.A. (2022). Passive Acoustic Monitoring for Marine Mammals in the SOCAL Range Complex April 2020–2021 and Abundance and Density Estimates from CalCOFI visual surveys 2004–2021. Marine Physical Laboratory, Scripps Institution of

Oceanography, University of California San Diego, La Jolla, CA, MPL Technical Memorandum #657 under Cooperative Ecosystems Study Unit Cooperative Agreement N62473-21-2-0012 for U.S. Navy, U.S. Pacific Fleet, Pearl Harbor, HI.

Nickels, C.F., Sala, L.M., Ohman, M.D. (2019). The euphausiid prey field for blue whales around a steep bathymetric feature in the southern California current system. *Limnology and Oceanography*, 64(1). https://doi/10.1002/lno.11047

Flinn, R.D., Trites, A.W., Gregr, E.J., Perry, R.I., (2002). Diets of fin, sei, and sperm whales in British Columbia: An analysis of commercial whaling records, 1963-1967. *Marine Mammal Science*, 31, 345-354. https://doi/10.1111/mms.12134

CalCOFI MM Figure Captions.

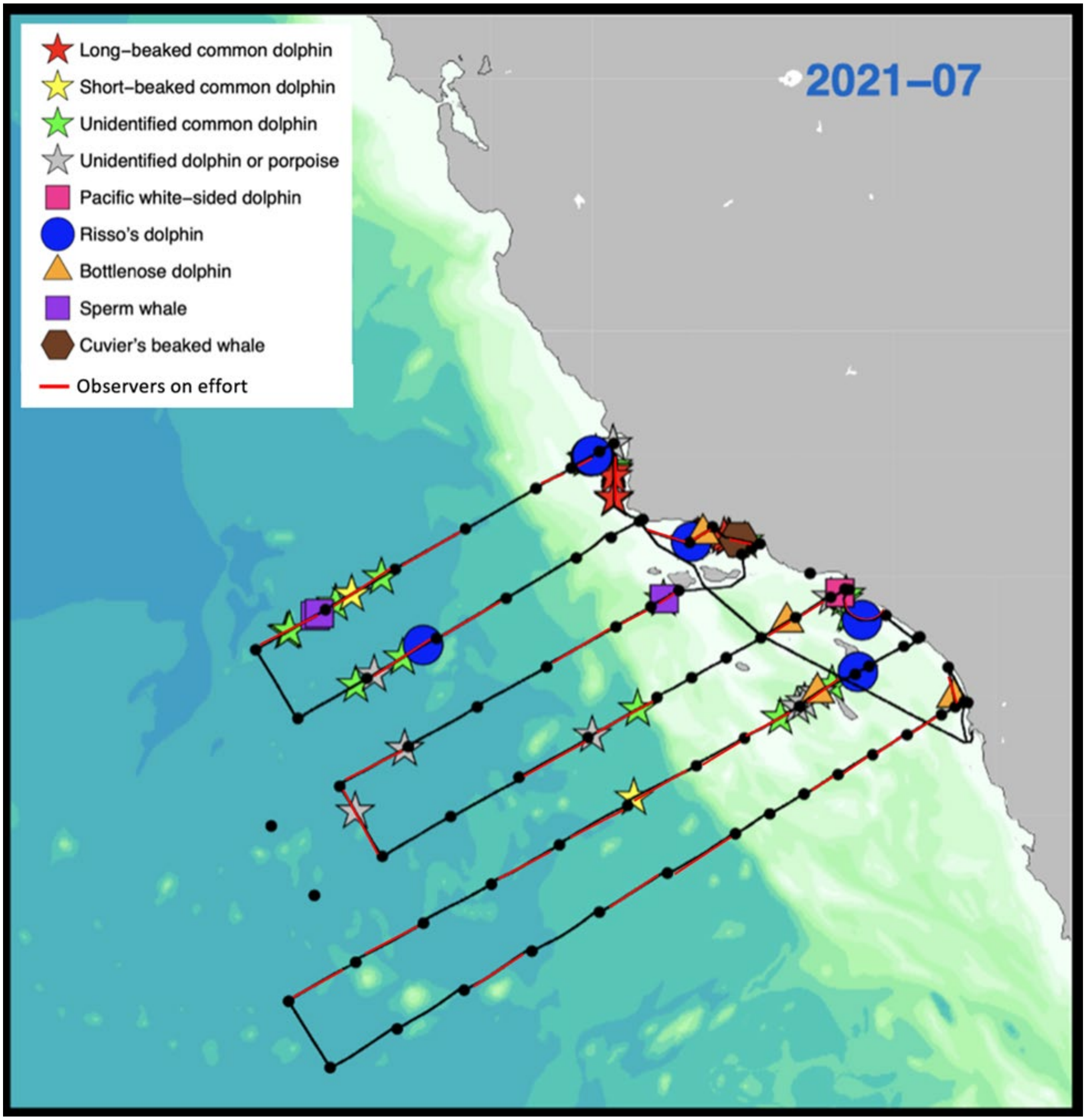
CalCOFI MM Figure 1. On effort odontocete sightings during summer 2021 CalCOFI cruise. CalCOFI stations are represented by black dots and the ship's trackline is represented as the black line and on effort times represented by red line. Symbol shapes and colors represent different odontocete species, as per legend.

CalCOFI MM Figure 2. On effort mysticete sightings during summer 2021 CalCOFI cruise. CalCOFI stations are represented by black dots and the ship's trackline is represented as the black line and on effort times represented by red line. Symbol shapes and colors represent different mysticete species, as per legend.

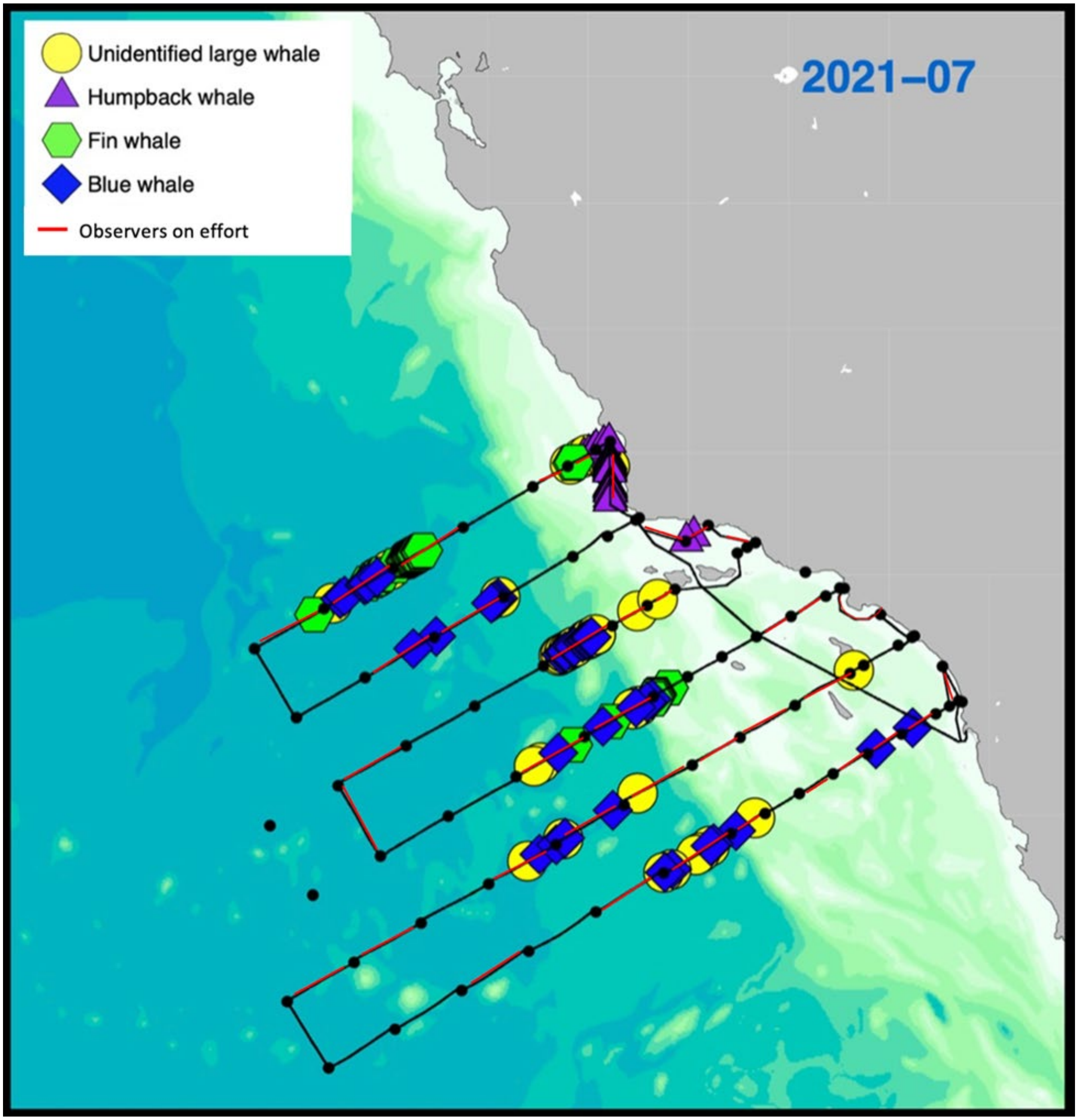
CalCOFI MM Figure 3. On effort odontocete sightings during fall 2021 CalCOFI cruise. CalCOFI stations are represented by black dots and the ship's trackline is represented as the black line and on effort times represented by red line. Symbol shapes and colors represent different odontocete species, as per legend.

CalCOFI MM Figure 4. On effort mysticete sightings during fall 2021 CalCOFI cruise. CalCOFI stations are represented by black dots and the ship's trackline is represented as the black line and on effort times represented by red line. Symbol shapes and colors represent different mysticete species, as per legend.

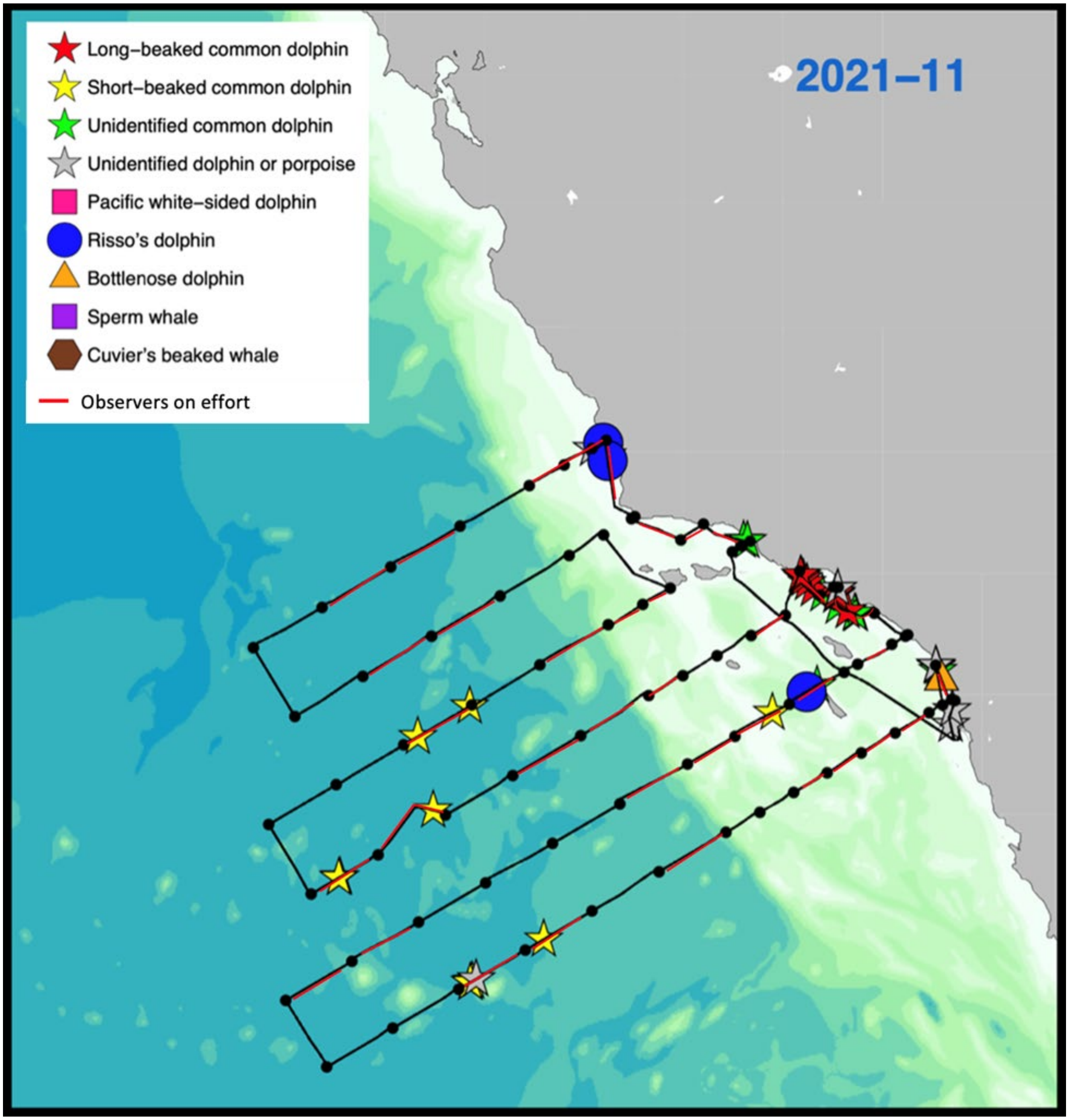
CalCOFI MM Figure 1



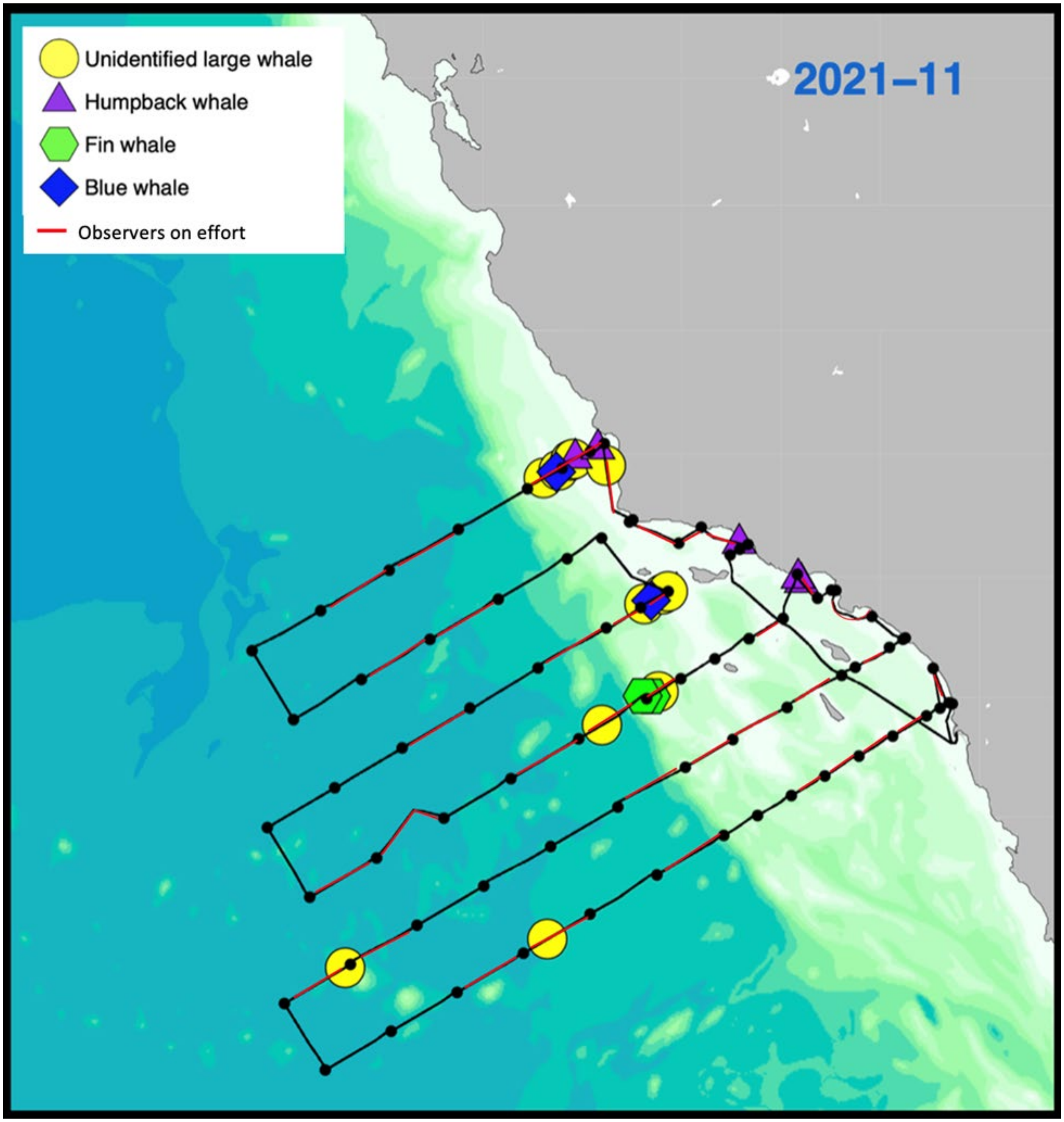
CalCOFI MM Figure 2



CalCOFI MM Figure 3



CalCOFI MM Figure 4


Unidentified large whale
Humpback whale
Fin whale
Blue whale
Observers on effort
2021-11