**Holistic understanding of the effects of the 2014-2016 Marine Heatwave on the CCE**

As oceans warm, marine ecosystems will likely change, often in unpredictable ways (Checkley Jr. et al. 2017). The broad array of surveys within the CCE will enhance our capacity to understand changes and hopefully sustainably manage marine resources in a variable environment (Holsman et al. 2020; Karp et al. 2019). Water temperature along the west coast of North America displayed the highest 3-year average on record between 2014 and 2016 (Jacox et al. 2018), and it predicted that similar “marine heatwaves” (MHW) will become increasingly common in ensuing decades (Jacox et al. 2020). The combined marine surveys provide us with a comprehensive evaluation of the response of the CCE to the MHW and should help us make informed management decisions in the future. The myriad of west coast marine surveys detected changes to multiple trophic levels during and after the 2014-2016 MHW.

At a lower trophic level, there was a general redistribution of phytoplankton as taxa occurred further north than usual, and overall phytoplankton production was abnormally low. North of the CCE, net phytoplankton community production decreased when the water warmed in the Gulf of Alaska (Yang et al. 2018), and phytoplankton biomass was also unusually low off the Salish Sea (Pena et al. 2019) during the MHW. Further south, a subtropical brown algae was found 550 km north of its previous northernmost extent in Marina Del Rey, California (Morris and Smith 2020). Using combined CalCOFI and IMECOCAL data, Gomez-Ocampo et al. (2018) documented low phytoplankton production and biomass between Point Conception, California and Punta Eugenia, Baja California. Despite generally low productivity and biomass, diatoms in the genus *Pseudo-nitzschia*, which releases toxic domoic acid, thrived throughout much of the west coast of North America during the 2015-2016 warm water event (Bates et al. 2018).

At the next higher trophic level, zooplankton also displayed similar (and rather predictable) responses to warm water across regions within the CCE. Specifically, smaller bodied individuals and species were prevalent in several surveys. In the north, the abundance of relatively large bodied crustacean zooplankton was very low off Oregon during the MHW (Brodeur et al. 2019a) while small bodied and gelatinous (genus *Pyrosoma*) invertebrates were abundant in the ocean and the guts of predators (Brodeur et al. 2019b). In northern California, the body size of the krill *Euphausia pacifica* was much lower than average (McClatchie et al. 2016b). In southern California, CalCOFI surveys demonstrated that the 2014-2015 surface warming induced shifts to the zooplankton assemblage similar to the 1992-93 El Niño while the 2015-2016 assemblage was closer to the 1997-98 El Niño (Lilly and Ohman 2018). Further south, two krill species, *E. pacifica* and *Nematoscelis difficilis*, decreased by 95% relative to the previous decade while several tropical krill species increased significantly during the MHW off Baja California (Lavaniegos et al. 2019).

At the trophic level of forage fishes, assemblage responses to the MHW were more nuanced than for phytoplankton and zooplankton. In the Gulf of Alaska, larval abundances of typically dominant taxa such as walleye pollock (*Gadus chalcogrammus*) and Pacific cod (*Gadus macrocephalus*) were very low (Nielsen et al. 2020). Similarly, rockfishes (*Sebastes* spp.) and northern lampfish (*Stenobrachius leucopsarus*), which are very abundant in most years, were very low during the MHW off Vancouver Island (Nielsen et al. 2020). By contrast, overall larval abundances were very high, the assemblage was largely made up of species that are typically found to the south and offshore, and species such as Pacific sardine (*Sardinop sagax*) were observed spawning in the winter for the first time during the MHW on the Newport Hydrological Line off Oregon (Auth et al. 2018). In central and southern California, abundances of southern, mesopelagic taxa were at record highs both in RREAS (Thompson et al. 2019b) midwater trawls (Sakuma et al. 2016) and CalCOFI larval surveys (Thompson et al. 2021), which was not wholly unexpected as these taxa were abundant during past warm water events (Peabody et al. 2018). Atypically, northern anchovy (*Engraulis mordax*) (Thompson et al. 2019b) and multiple rockfishes (Schroeder et al. 2018) that previously flourished under cold conditions had extremely high recruitment from 2014-2016, and adult abundances of anchovy rose to record highs in subsequent years (Auth et al. 2018; Thompson et al. 2019b). In the southern CCE larvae of the same mesopelagic species that increased in southern California decreased in northern Baja California, likely because their preferred habitat shifted into southern California, while larvae of demersal taxa increased (Uribe-Prado et al. 2021). South of Punta Eugenia, larval abundances of tropical fishes increased, but these taxa did not move north of Punta Eugenia (Uribe-Prado et al. 2021). Examination of multiple surveys spanning most of the CCE revealed that the timing of strong shifts in fish assemblage structure were synchronous throughout the region even though the particular taxa that drove the changes differed among regions (Thompson et al. 2019a).

The distribution and abundance of top predators was also affected directly by events that occurred during the MHW. In particular, the surge in anchovy resonated with multiple marine predators. California sea lions (*Zalophus californianus*), which had endured unusual mortality events prior to the MHW due to scarce prey (McClatchie et al. 2016a), fed copiously on anchovy beginning in 2015 and had much enhanced pup condition from 2015-2018 (Thompson et al. 2019b). Another marine mammal, humpback whales (*Megaptera novaeangliae*), were closer to shore than usual, likely to feed on anchovy (Santora et al. 2020). Unfortunately, this caused some whales to become entangled in the gear of Dungeness crab (*Metacarcinus magister*) fishers, which resulted in whale mortality and intermittent closures of the fishery (Santora et al. 2020). Catch of Pacific Bluefin tuna (*Thunnus orientalis*) by the commercial passenger fleet off California was very high during the MHW as tuna associated with warm water and foraged on anchovy (Runcie et al. 2019). Seabird population dynamics differed during and after the MHW depending on prey needs. On the one hand, Brandt’s cormorant (*Phalacrocorax penicillatus*), which are capable of feeding on anchovy and provide regurgitate to nourish chicks had relative high production during and after the MHW (Thompson et al. 2019b). On the other hand, Cassin’s auklet (*Ptychoramphus aleuticus*) feed on smaller prey such as krill and fared poorly during the MHW (Jones et al. 2018).

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