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Vignette 17: Salish Sea Jellyfish

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17 SALISH SEA JELLYFISH

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The Salish Sea is home to a diverse community of gelatinous zooplankton (or "jellies") composed primarily of species from the phyla *Cnidaria* and *Ctenophora*. These include conspicuous large scyphozoan medusa such as lion's mane (*Cyanea capillata*) and egg-yolk jellies (*Phacellophora camtschatica*), to smaller hydrozoans such as crystal jellies (*Aequorea* spp.) and ctenophores (e.g., *Pleurobrachia* spp.). One abundant species is the moon jelly (*Aurelia* labiata), which forms huge aggregations (or "smacks") easily observable from the air as well as in the water (Figures 1 and 2; see Eyes Over Puget Sound, Schaub et al. 2018).

In their adult forms, jellies comprise a relatively large proportion of the biomass in the Salish Sea. For example, the Puget Sound Ecopath model (Harvey et al. 2010) estimated total biomass at nearly 8.5 and 6.4 mt/km^2, for "jellyfish" and "small gelatinous zooplankton", respectively. These values were comparable to other invertebrates ("shrimp", 8.1 mt/km^2) as well as the more abundant fishes such as Pacific herring (5.9 mt/km^2 in total) or "small-mouthed flatfishes" like English sole (7.9 mt/km^2). Hence, they likely play important roles as predators and competitors in the Salish Sea's pelagic ecosystem.

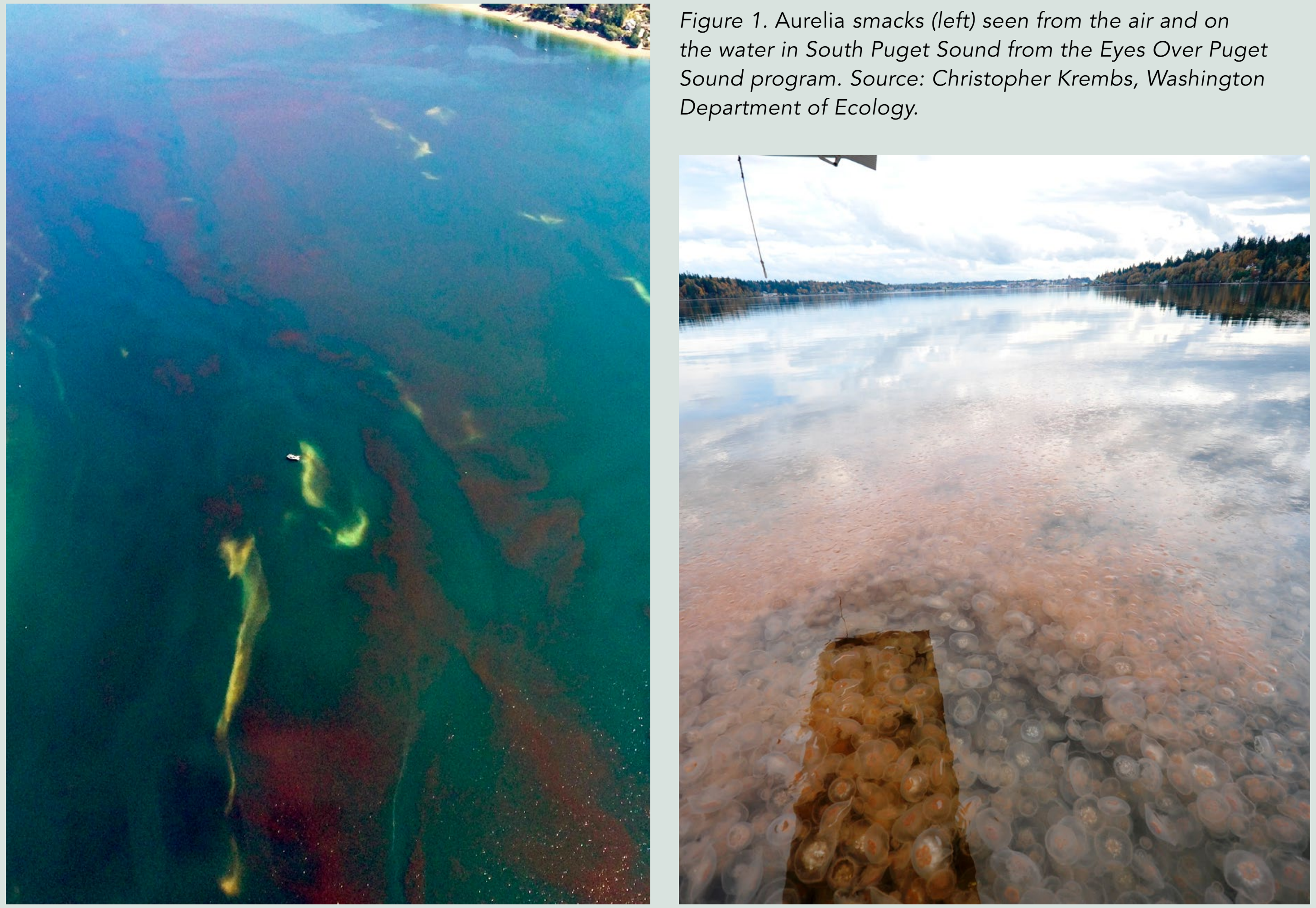

Figure 1. Aurelia smacks (left) seen from the air and on the water in South Puget Sound from the Eyes Over Puget Sound program. Source: Christopher Krembs, Washington Department of Ecology.

Figure 2. Underwater view of Aurelia in a smack. Mature adults are typically 10-30 cm diameter and have been found in densities >170 m-3. Source: C. Greene, Unpublished data.

Around the world, scientists have observed increases in the abundance of jellies over the last 50 years. These patterns have been associated with eutrophication, intensive fishing, and changing climate (Purcell et al. 2007), although other research has pointed to large-scale climate variation driving jellyfish blooms (Purcell 2012; Condon et al. 2013; Greene et al. 2015). Are similar changes occurring in the Salish Sea? Are these changes having large impacts to the ecosystem?

These questions have been difficult to address, in part because of a lack of consistent monitoring. Jellies are often ignored as uninteresting bycatch in monitoring studies of pelagic fishes, although interest has recently grown in part due to large blooms recently observed in the northern California Current (Ruzicka et al. 2016). Data synthesized from historical and recent surface trawl data in two sub-basins of Puget Sound indicate that jellyfish catches may have increased since the 1970s (Greene et al. 2015; Figure 3).

While these patterns may appear ominous, they may also reflect natural annual variation (e.g., anomalously high abundances could have occurred in 2003 and 2011), and continuous monitoring can better address long-term changes in biomass. Figure 4 summarizes the only continuous time-series of jellies in the Salish Sea (Greene & Munsch 2020), based on annual surface trawling in Skagit Bay (Northern Puget Sound). Estimates of total jelly biomass per tow illustrate that substantial annual variation exists. High biomass was observed during the marine heatwave of 2015–2016. In subsequent years, however, biomass declined to the second lowest level observed since recording started in 2003, and has subsequently remained below average through 2019. This occurred despite above-average water temperatures in 2019, indicating that water temperatures are not the sole predictor of blooms. Furthermore, individual species appear to respond differently to warming. As exemplified in the lower panel of Figure 4 by the two largest species, the egg yolk jelly and the lion's mane jelly exhibited strikingly opposite patterns during the 2014-2016 marine heatwave period. Occurrence of both large species was low in the last three years, when smaller jellyfish dominated the biomass. Collectively, these results suggest that the jellyfish community is sensitive to climate signals such as marine water temperatures, although jellyfish do not appear to be systematically increasing in abundance over time.

Whether jellies are on the rise or are episodic in the Salish Sea, the question of their role(s) in the pelagic ecosystem remains an important one with respect to managed species such as Pacific salmon. In this

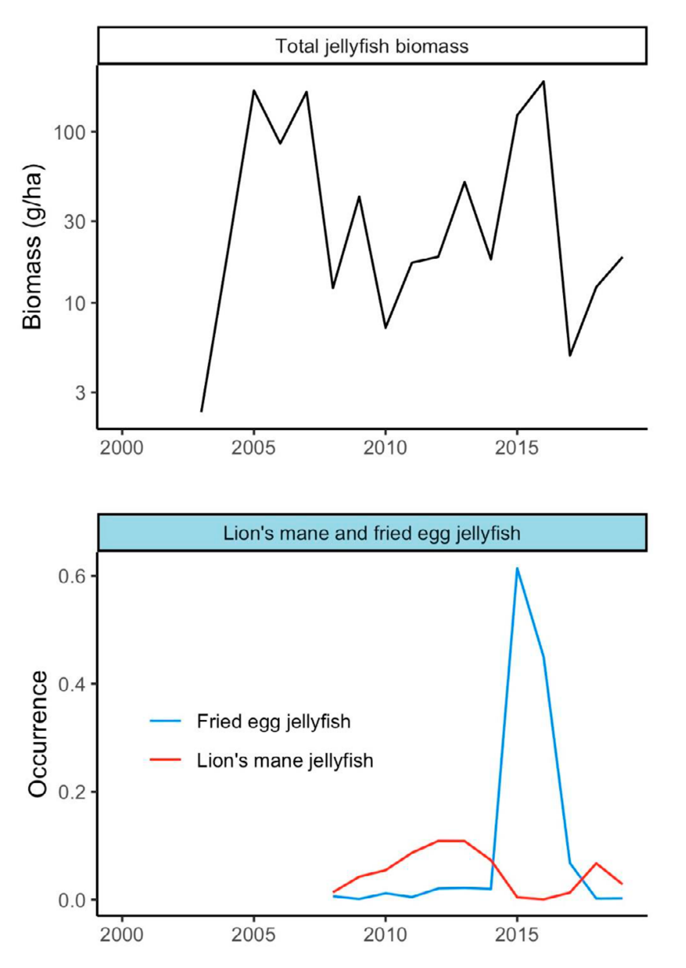

Figure 3. Annual trends in A. total jelly biomass (average g/hectare on a logarithmic axis, top panel) or B. occurrence (probability of presence, bottom panel) of lion's mane (red line) and fried egg (blue line) jellies from surface trawls in Skagit Bay. Predicted trends account for seasonal variability, spatial autocorrelation, and water volume swept through net tows. Source: C. Greene, unpublished data.

respect, one of the key species may be the moon jelly, whose huge aggregations can occupy large portions of inlets in the Salish Sea. Species of the genus *Aurelia* are found worldwide and are among those that commonly form huge, nuisance blooms. *Aurelia* have been reported to clog fishing nets and power plant intakes, deter tourism, and interfere with aquaculture (Purcell et al. 2007), all leading to significant regional economic losses. *Aurelia* are also indicators of degraded ecosystem health, often associated with eutrophic habitats, and sometimes low oxygen conditions (Arai 2001).

Aurelia entrain their prey through fluid motions created during swimming, the relative velocity of which, compared to the escape response of their prey, primarily determines prey selection (Costello & Colin 1994). In one study, *Aurelia* shifted their diets from primarily small jellyfish to include more copepods as they grew (Sullivan et al. 1994, Suchman et al. 2008). Mid- to large-size medusae may preferentially select copepods and fish eggs (Pereira et al. 2014) and also can prey on ichthyoplankton (Bailey & Batty 1983; Figure 5 upper panel), simultaneously serving as competitors and predators of fish.

Aurelia also have the potential to increase primary production by removing zooplankton grazers (Figure 5, middle panel). The increase in turbidity commonly associated with eutrophication gives an advantage to non-visual predators such as *Aurelia* (Purcell 2012), particularly when feeding on prey with good visual acuity, such as fish larvae. Hence, *Aurelia* may impact forage fish, Pacific salmon, and pelagic early life stages of demersal fish species via both direct and indirect pathways through predation and competition, respectively. Note that changing turbidity levels might also provide benefits to fishes from visually orienting predators such as birds and pinnipeds.

Large aggregations of *Aurelia* may also affect water chemistry and nutrient levels through their metabolism, and through decomposition after death. Through their metabolism, aggregations may reduce dissolved oxygen, increase ammonium levels, and allow phytoplankton to proliferate. Hence, *Aurelia* may facilitate bacterial production (Figure 5, bottom panel) that promote eutrophic conditions, to which jellyfish are relatively insensitive compared to fish species (Richardson et al. 2009). Because *Aurelia* has few natural predators, jellyfish medusae may accumulate biomass and in death transfer pelagic carbon to the benthos, acting as trophic "dead ends" and fueling benthic detritivores (Richardson et al. 2009). Alternately, proliferation of pelagic jellyfish parasites such as hyperiid amphipods may result in retention of carbon biomass within pelagic ecosystems (Hamilton 2016) as they are consumed by fishes (Riascos et al. 2012; Weil et al. 2019).

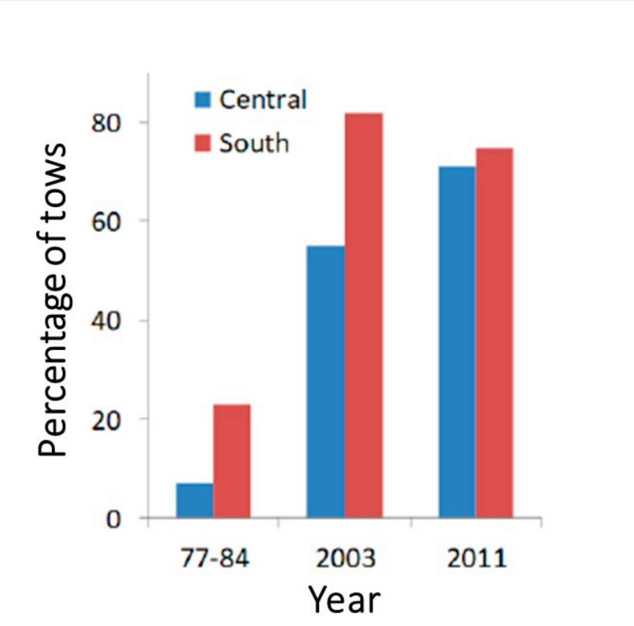

Figure 4. Percent of surface trawl sets in which jellyfish were >75% of the catch biomass in Central and South basins of Puget Sound in 1977-1984, 2003, and 2011. Source: Data from Greene et al. (2015).

In sum, multiple pathways may link jellies to components of the Salish Sea's food web that are more important to people. As we learn more about these trophic linkages through ongoing experimental and field research, we are also improving our ecosystem models, which will allow us to put jellies in the context of species like Pacific salmon, geoducks, and rockfish. Combined with better monitoring of distribution and abundance (Eyes Over Puget Sound; Schaub et al. 2018), these models will allow us to examine cascading effects of jellies in the ecosystem and to test scenarios like increasing long-term trends or episodic changes in jelly abundance. Within the next few years, we may have a much better perspective on the roles jellies play (and have played) on the Salish Sea's pelagic ecosystem as these ongoing studies develop.

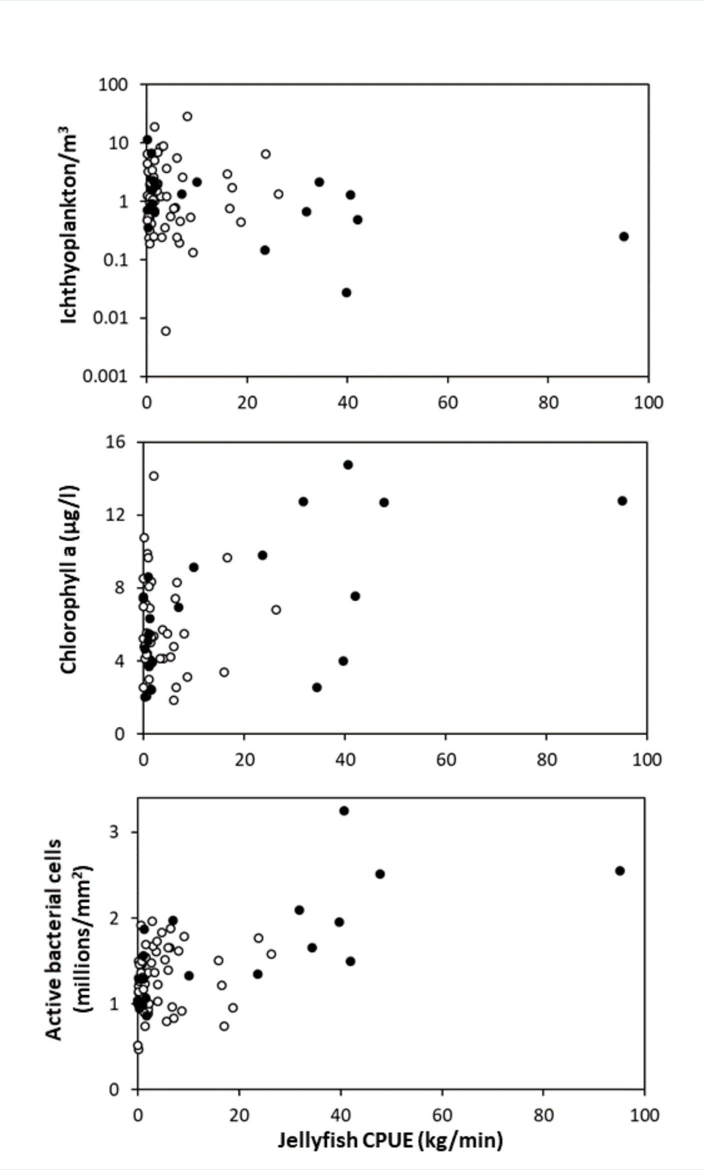

Figure 5. Relationships between ichthyoplankton density, chlorophyll concentration, and metabolically active bacteria as functions of total jellyfish catch per unit effort (CPUE) sampled at 85 sites across Puget Sound in 2011. Filled circles are large embayments, where Aurelia aggregations tend to occur within Puget Sound. All measurements of total jellyfish CPUE surpassing 35 kg/min were dominated by Aurelia biomass; hence those sites were sampled in the vicinity of Aurelia aggregations. Source: C. Greene, Unpublished data.