Pyrosoma atlanticum Grazing in the Southern California Current

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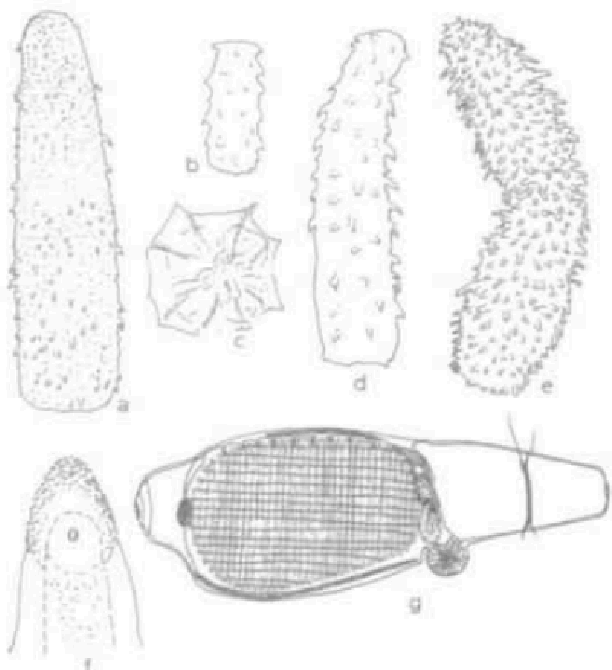
ABSTRACT

Since 2014, likely as a result of climate change and abnormal ocean warming events, the range of gelatinous zooplankton *Pyrosoma atlanticum* has been expanding significantly off the west coast of the United States and British Columbia. The colonial pelagic tunicate *P. atlanticum* is the most widespread and most common pyrosome species[1]. Thus, such a large range expansion coupled with its resulting massive blooms may have lasting effects on the California Current Large Marine Ecosystem (CCLME)'s ecosystem dynamics and West Coast human industries. While previous studies have determined the effects of *P. atlanticum* in the Indian Ocean and the Northern California Current (NCC) on phytoplankton or have used stable isotope and fatty acid analysis to examine the general trophic level pyrosomes occupy in the CCMLE, no research approaches currently use gut pigment analysis and stable isotope analysis in the Southern California Current (SCC) so there is still much to be studied about the diet of *P. atlanticum*.

BACKGROUND

P. atlanticum, generally referred to in this paper as a pyrosome, is a pelagic tunicate with pink or yellow-pink thimble-shaped colonies and can grow up to 60cm, though they reach sexual maturity at 4-6 cm[1]. Its zooids, which are the thousands of individual zooplankton that make up a colony, are capable of reproducing both asexually to repair damage and grow and sexually to create new colonies, allowing pyrosomes to survive at low concentrations of nutrients but to form massive blooms in favorable conditions[2]. In a gelatinous tunic, zooids are arranged with the oral siphon facing the outside of the colony, while the atrial siphon faces the lumen (Fig. 1), allowing for the excurrent water from feeding to provide pyrosomes with a weak propulsive force[1]. This propulsion allows for the nightly migration, also known as diel vertical migration (DVM), that pyrosomes exhibit, traveling from up to 760m deep to 37.5m below the surface[3].

Fig. 1



The atrial siphon (the left end of Figure g) is where the zooid of the pyrosome expels the filtered water coming from the oral siphon (the right end of Figure g). Figures a, b, d, and e are habits of *P. atlanticum*, Figure c is a habit of a juvenile colony, and Figure f depicts a colonial projection.[1]

Previously only found south of Santa Barbara, the 2014 occurrence of the ‘warm blob’ and the 2016 El Niño, was followed by a significant increase in pyrosome density compared to previous years, expanding north to Oregon[4]. Then, in 2017, pyrosome colonies reached a density of 60,000 kg m^{-3} in bloom from northern California to Alaska, then again in 2018 off the coast of Oregon and in 2019 in the northernmost portion of the NCC[2,4]. As a result, ocean warming events are generally linked to an increase in the range and occurrence of *P. atlanticum* (Fig. 2)

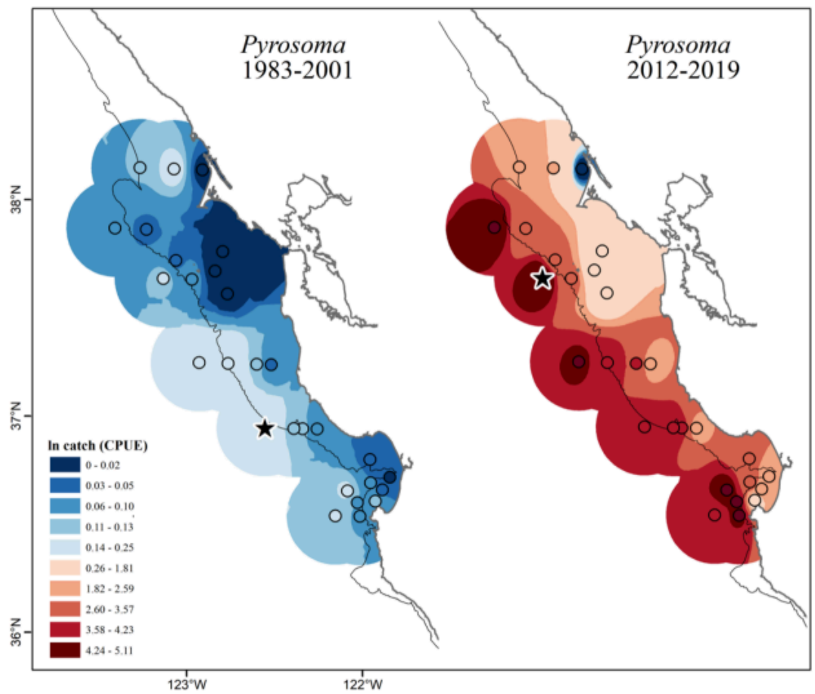


Fig. 2

Likely due to climate change, the density and distribution of *P. atlanticum* off the coast of California have increased in recent years.[2]

Pyrosomes' transparency, large size, and low organic matter-to-volume ratio often make them unfavorable for predation compared to copepods or euphausiids, and they possess few known natural predators in the CCLME[5]. Moreover, zooids are organized in such a way that allows for continuous filtration, meaning that they can filter a larger volume of water compared to copepods and euphausiids[4,5]. Using a mucous net, pyrosomes can filter large amounts of water for a comparatively wide and diverse range of particles, including those too small to be caught by adult suspension-feeding copepods[5]. The consumption of such smaller particles may lead to a reduced phytoplankton population as pyrosomes consume phytoplankton precursors. Pyrosomes also demonstrate a life history that allows them to take advantage of food supplies to reproduce while also being able to exist without reproducing when food is low [5]. Because of the ability of *P. atlanticum* to filter more water for more diverse particles, they are a strong competitor against indigenous zooplankton and are able to survive remarkably well in their non-native environment. The large number of slow-sinking fecal pellets produced by pyrosomes and the decomposition of corpses from large pyrosome extinction events both result in a massive return of carbon into the water that has possible effects on the SCC's ability to sequester carbon[5].

In addition to effects on plankton, *P. atlanticum* blooms mirror other mass occurrences of gelatinous pelagic tunicates, such as Scyphozoans, which clogged water intakes for coastal facilities such as hydropower plants and reduced the efficiency of the fishing industry by damaging fishing lines, nets, and boat engines[2]. Pyrosomes often take advantage of biologically productive areas produced by upwellings, which are often also fisheries, further disrupting the West Coast seafood industry[6]. With tremendous effects on both human industries and ecological environments, it is imperative that we study the diet of *P. atlanticum* to better understand its effects on marine food chains.

MATERIALS/METHODS

The samples analyzed come from pyrosomes collected in oblique bongo tows from the CCE-P2107 cruise under the CCE-LTER Process cruises aboard the R/V Roger Revelle through July and August of 2021, with recorded longitudes, latitudes, and water volume (Fig. 3). Daytime tows were conducted between 0800-1100h and 2100-2300h. Cycles 1-3 used a Lagrangian drift array to follow the same water pocket for 3-6 days[7].

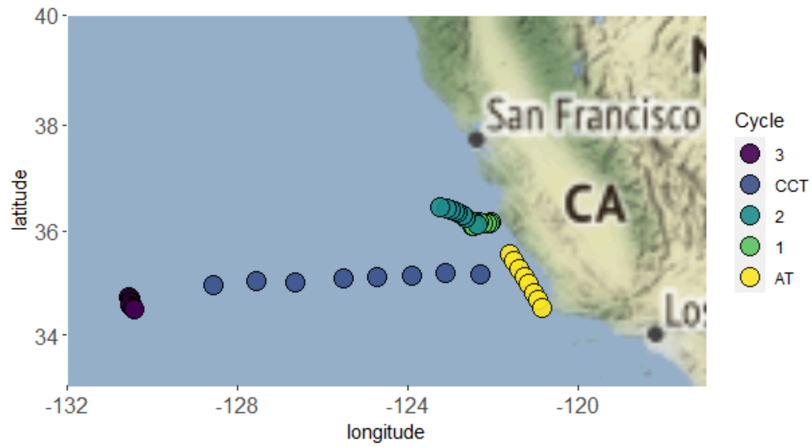


Fig. 3

Map of the CCE-LTER cruise. CCT is the California Current Transect, and AT is the Alongshore Transect.

Samples were split into halves, with 50% preserved in formalin and 50% frozen in a -80℃ freezer until processing. Then, samples were processed from November 2021 to May 2022 and from July 2023 to August 2023. Each pyrosome was defrosted, cut into 2-12 pieces depending on size, and weighed for wet weight. Half the samples were dried, weighed for dry weight, and sent for stable isotope analysis. The remaining samples were sonicated and chlorophyll a was extracted in acetone for 2-24 hours in a -20℃ freezer. After extraction, the samples were centrifuged, and 4mL were analyzed through a Turner 10AU fluorometer to measure the concentration of chlorophyll, which may reveal differences in phytoplankton consumption based on location or size. Any data collected was consolidated in Excel and analyzed using Kruskal-Wallis ANOVAs in R ($p<0.05$).

RESULTS/DISCUSSION

Through analysis, length was found to vary significantly based on location – Cycle 3, which was much further away from shore than Cycles 1 and 2, had significantly shorter pyrosomes (Fig. 4). This may be due to nearshore coastal upwelling in Cycles 1 and 2, which is high in nutrients, compared to the oligotrophic (nutrient-poor, oxygen-rich) waters of Cycle 3, which likely limits the size that pyrosomes may grow. In addition to longitude and latitude, factors such as temperature salinity, and sunlight may also impact phytoplankton consumption, as there was a significant difference in gut pigment normalized by wet weight between the closely located Cycles 1 and 2 (Fig 4). Length also impacts phytoplankton consumption, as Cycle 3 pyrosomes had significantly less gut pigment than in Cycles 1 and 2, implying that shorter, and thus smaller, pyrosomes consume less phytoplankton overall (Fig 4).

DVM may also influence the length of pyrosomes collected in hauls, as Cycle 2 pyrosomes collected in night tows are significantly longer than those collected in day tows (Fig 4). Longer pyrosomes tend to travel to the surface from lower depths than shorter pyrosomes[3], so day tows may tend to collect smaller pyrosomes than night tows. Additionally, DVM is theorized to be due to feeding, and analysis of gut pigment normalized by gut pigment revealed that for Cycle 1, pyrosomes consume significantly more phytoplankton at night than day (Fig 4).

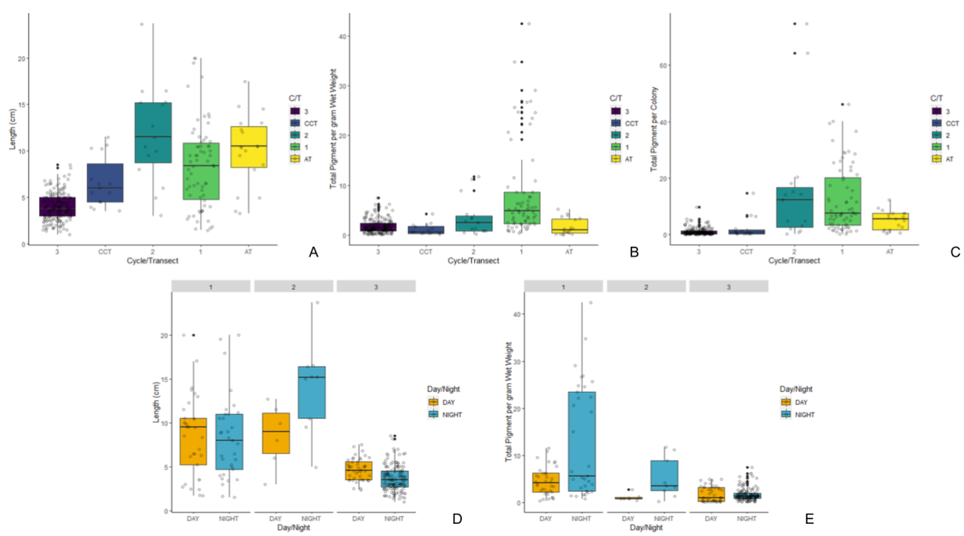


Fig. 4

Figure A: Median (± SE) colony length for every cycle and transect, colored according to the cruise map — Cycle 3 is purple, the CCT is dark blue, Cycle 2 is turquoise, Cycle 1 is green, and the AT is yellow. **Figure B**: Median (± SE) total pigment normalized by wet weight for each cycle and transect. Colors same as Fig. A. **Figure C**: Figure 6. Median (± SE) total pigment per pyrosome colony, a function of total pyrosome wet weight and pigment per gram wet weight, for every cycle and transect. Colors same as Fig. A. **Figure D**: Median (± SE) colony length for every cycle by day and night. Day hauls are orange, night hauls are blue. Transects were done throughout the day and are not represented here. **Figure E**: Median (± SE) total pigment per gram wet weight for Cycles 1-3. Colors same as Fig. D.

FURTHER DIRECTIONS

Samples sent out for stable isotope analysis will analyze $\delta^{13}C$ for primary producer consumption and $\delta^{15}N$ for trophic level, which will shed light on the trophic niche pyrosomes occupy in the CCLME. Observations regarding length and consumption will impact research working to convert gut pigment into grazing rate per day, which will be different depending on night and day tows. Using the determined grazing rate per day, the grazing impact of the SCC pyrosome population can be estimated, similar to how the NCC's grazing impact was calculated[4]. Continued research is crucial, as the range expansion of gelatinous zooplankton is already significantly changing the diet of commercially and ecologically valuable fishes[8].

DATA AVAILABILITY

Data and code are available at https://gitfront.io/r/user-4999846/oB6TjFoepkog/Pyrosome-data/

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RECOMMENDATIONS & FURTHER READING

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