

## **Abstract**

### **Jellyfish Impact on Food Web Production and Ecosystem Structure in the Southeastern Bering Sea**

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We conducted a field study of jellyfish in the southeastern Bering Sea in summer 2000. The goal of the study was to elucidate the role of jellyfish in food web production and ecosystem dynamics. Certain aspects of the original study were unexpected, particularly the time required to complete diet analyses of the primary species, the large scyphomedusan *Chrysaora melanaster*. In addition, we have undertaken additional GIS analyses not part of the original project. We request here support to complete the diet studies and expand the GIS analyses of relationships among jellyfish distributions and population dynamics, fish stock recruitment, and environmental features, such as wind and water temperatures. The results will make an important contribution to our understanding of ecosystem structure in the southeastern Bering Sea and variability related to climate change on interannual and decadal time scales in general. In particular, this study will provide valuable insights into the impact of jellyfish, through predation and competition, on recruitment of fishes of high economic and ecosystem importance.

**Jellyfish Impact on Food Web Productivity in the Southeastern Bering Sea**

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From:

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Several species of jellyfish have been shown to actively select fish eggs from planktonic prey (Fancett, 1988; Purcell, 1994; Stoecker, 1987). When sufficient high quality food is available, medusae typically experience exponential growth (Arai, 1997) and can quickly become the dominant species in an ecosystem. In non-introduced species, this is often limited by predation from other medusae (Matsakis, 1991; Purcell, 1995; Hansson, 1997). In the Bering Sea there is only one documented case of this occurring (Hamner, 1982), where the large jellyfish *Cyanea capillata* preyed upon *Chrysaora melanaster*. Since *Cyanea capillata* remains in the oceanic and outer shelf domain, there may be little to check the increase of *Chrysaora melanaster* in the middle shelf domain should conditions become favorable for this species.

Jellyfish biomass in the Bering Sea grew gradually between 1979 and 1989 before undergoing explosive growth in the following decade, increasing tenfold in the early 1990s (Brodeur et al., 1999). In 1987, the ratio of pollock biomass/medusa biomass was found to be 0.19 according to the Russian survey aboard the R.V. Darwin (Brodeur et al., 1999b). While the data are by no means conclusive, it is possible that jellyfish now have a larger biomass than eastern Bering Sea pollock and have displaced pollock as the dominant consumer of secondary productivity on the eastern Bering Sea shelf, especially in the middle shelf domain. These jellyfish were not keyed to species until 1994, but since that time the biomass has been dominated by *Chrysaora melanaster*. While it is known that juvenile fish, including walleye pollock, may use jellyfish for shelter from predation in mid to late summer (Brodeur, 1998), the relationship in the spring and early summer, when jellyfish are likely to consume fish eggs and larvae, has not previously been examined. Because the density distribution of jellyfish on the southeastern shelf overlaps extensively with the distribution of spawning pollock, predation upon fish eggs may be an important factor in the dynamics of pollock and other fish stocks on the southeastern Bering Sea shelf.

Wind driven turbulence has been shown to be of importance for many species of larval fish (Mackenzie and Legget, 1991; Rothschild and Osborn, 1988; Sundby and Fossum, 1990; Sundby et al 1994; Cury and Roy, 1989). While the importance of turbulence has been little studied in gelatinous plankton, it has been noted that many jellyfish feed by pulsing a turbulent eddy through their feeding tentacles (Costello and Colin, 1995). This may be of particular importance in the ability of large medusae to prey upon fish eggs and larval fish as well as compete with juvenile fish residing in the middle shelf domain of the Bering Sea. Thus the inter-annual variation of wind-driven turbulence may be of importance to the mortality rate of fish eggs and the dynamics of the ecosystem overall.

A 60-day average of daily wind speed cubed was used as a proxy for turbulence during the late spring when jellyfish growth is critical. This index describes most of the inter-annual variability until 1992 (Figure 1). The data from 1992-1998 also fit well with the same model, but the correlation was not as strong and the two periods fit poorly within the same regression. Since this period followed much of the jellyfish biomass increase, it is hypothesized that carrying capacity became a factor in the later period. Change in biomass between years is highly correlated with the previous year biomass (Figure 2). This suggests that *Chrysaora melanaster* may now be limited by carrying capacity in the southeast Bering Sea middle shelf. Conversely, while biomass was a factor in the earlier period, the dominant force in biomass change seems to be turbulence followed by water temperature. None of these factors explain the biomass increase in the early 1990s.

It has been suggested that zooplankton biomass may have increased in the eastern Bering Sea following a 1989 climate regime shift (Hare and Mantua, 2000). The zooplankton data used

in that study show a dramatic increase in 1989 and 1990, and then a decline as the eastern Bering Sea jellyfish biomass increased. The 1989-1990 pulse could be the mechanism that allowed the jellyfish biomass to grow by an order of magnitude, as gelatinous zooplankton can increase their populations and biomass extremely rapidly to take advantage of additional resources. Unfortunately, the zooplankton data are extremely sparse in some years, and without comprehensive spatial and temporal resolution, such hypotheses are difficult to test.

We have also found inverse correlations between jellyfish biomass and recruitment success of flathead sole, Alaska plaice, and salmon in the eastern Bering Sea. Rock sole shares habitat with flathead sole and Alaska plaice, but has demersal adhesive eggs rather than pelagic eggs and has not declined as much in the presence of jellyfish as have flathead sole and Alaska plaice. Thus predation upon eggs may be of importance. Salmon, however, are unlikely to be vulnerable to direct predation and could be declining as a result of competition. While all Bristol Bay sockeye returns have an inverse correlation with the increase in jellyfish biomass, not all runs are significantly correlated. Fish that spend two years in the freshwater system have significant inverse correlations with the increase in jellyfish biomass while those that spend one year in the freshwater system do not. The strongest correlations occur in streams that enter the sea further westward along the Alaska Peninsula, near the higher densities of jellyfish. Yukon River chum experienced run failures that coincided with a northward expansion of the jellyfish biomass. This northward expansion seems to be continuing, while the southern biomass may have reached carrying capacity and does not seem to be growing. Yellowfin sole spawn in the inner shelf domain, which is an area of low jellyfish biomass. Yellowfin sole had higher recruitment levels in the 1990s and this was the only recruitment time series examined that did not have an inverse correlation with the increase in jellyfish biomass. While declines in pollock recruitment are not significantly correlated with the increase in jellyfish biomass, pollock accounted for over 90 percent of the fish eggs in *Chrysaora melanaster* stomachs, while they made up 52 percent of the eggs collected in oblique plankton tows. In the stomachs of jellyfish *Aurelia labiata*, 72 percent of the fish eggs were pollock while the remainder were flatfish.

Numerically the diet of *Chrysaora melanaster* was varied, with fish eggs and copepods making up the largest components. *Aurelia labiata* stomachs had a very large number of invertebrate eggs followed by smaller numbers of barnacle nauplii and fish eggs. In both species, the biomass of the gut contents was composed of over 60 percent euphausiids. This indicates that these species may directly compete with commercial fishes such as adult pollock. Since the jellyfish are primarily concentrated in the middle shelf domain, and adult pollock feed primarily in the outer shelf domain, it remains questionable to what extent *Chrysaora melanaster* and adult pollock would compete. The jellyfish could, however, deplete resources needed by juvenile pollock as well as juvenile salmon first entering the marine system.

When the turbulence proxy was applied to recruitment success of eastern Bering Sea pollock, a significant correlation was obtained for the years following 1977. This suggests that the health of pollock stocks may be partially determined by climatic conditions. This could explain why no significant relationship was found between pollock recruitment and jellyfish biomass. This model could potentially be greatly improved with the additional knowledge of the makeup of eastern Bering Sea pollock stocks, particularly if the input from shelf versus basin recruitment were discernable. Another potential improvement would be more detailed data on the timing of spawning and the hatching of eggs on an inter-annual basis, as the role of turbulence has the greatest impact on recently hatched larval fish.

The long term trend of wind speed has been downward at the Pribilof Islands over the past forty years. If large recruitment events of pollock are dependant on strong winds, this could mean smaller pollock stocks in the future. This decrease in wind speed is correlated with NOAA's estimates of global temperature anomalies. Climate models have shown that winds may decrease in the Bering Sea in the event of global warming (Schumacher and Alexander, 1999). This is also consistent with a stable isotope study in which it was hypothesized that primary productivity in the Bering Sea has declined by nearly a third over the past three decades (Schell, 2000). While this is extremely speculative, the potential ramifications are large enough that this issue should be further studied.

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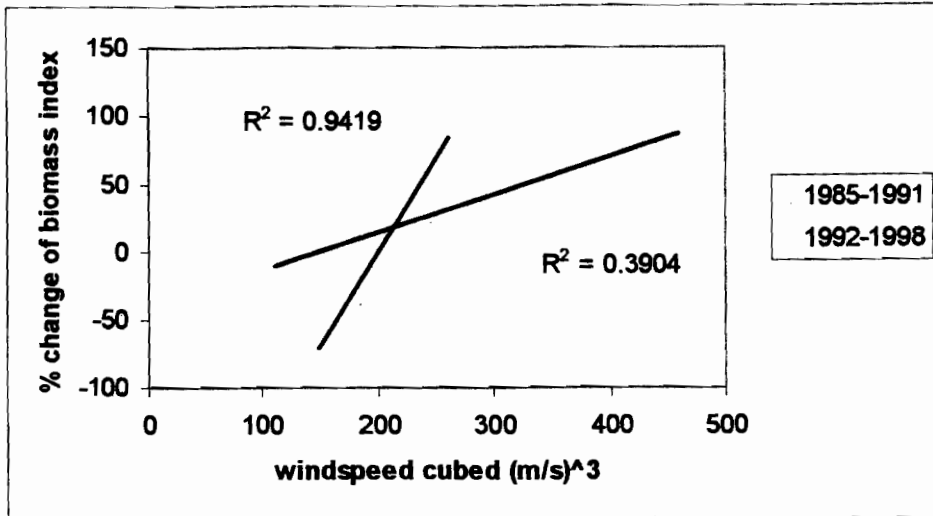


Figure 1. Percent change in jellyfish biomass index for the southeast Bering Sea middle shelf domain plotted against mean daily wind speed cubed at St. Paul from June 15 through July 5. The P-value for 1985-1991 is 0.0003, and the P-value for 1992-1998 is 0.13.

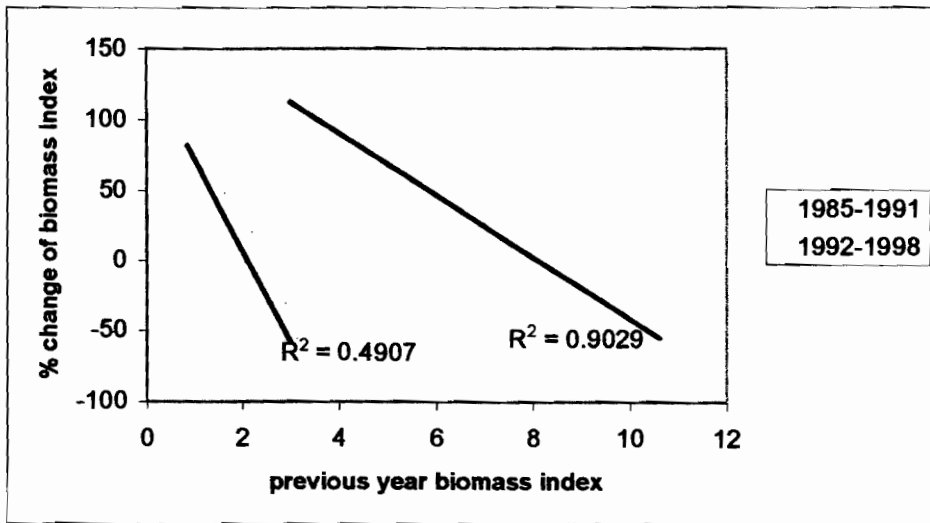


Figure 2. Percent change in jellyfish biomass index for the southeast Bering Sea middle shelf domain plotted against previous year's biomass index. The P-value for 1985-1991 is 0.08, and the P-value for 1992-1998 is 0.001.