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# Mass Mortality of the Sea Stars *Luidia clathrata* and *Luidia alternata alternata* on the Alabama Coast, December 2013

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## SHORT PAPERS AND NOTES

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MASS MORTALITY OF THE SEA STARS *LUIDIA CLATHRATA* AND *LUIDIA ALTERNATA ALTERNATA* ON THE ALABAMA COAST, DECEMBER 2013.—Mass mortalities among echinoderms are known to occur worldwide and can be of biotic or abiotic origin. Despite the importance of these observations, the vast majority of these catastrophic events are noted only anecdotally. Documentation of mortality events can provide important insights into the biology of the individuals involved, their ecological roles in communities, and the general health of marine ecosystems, as well as information of paleontological relevance (reviewed in Lawrence 1996). Among those mass mortality events documented and published in the literature, the majority have focused on sea urchins (e.g., *Lytechinus variegatus*: Beddingfield and McClintock, 1994; *Paracentrotus lividus*: Girard et al., 2012; *Strongylocentrotus purpuratus*: Hendler, 2013; reviewed in Lawrence, 1996). Fewer studies have documented mass mortality in sea stars. Eckert et al. (2000) reported significant mortality from “sea star wasting disease” in *Pisaster giganteus* and *Patiria miniata*, and to a lesser degree nine other species of common Pacific coast sea stars in a study conducted in the California Channel Islands in 1997. A similar epidemic of sea star wasting disease is currently underway along much of the Pacific coast of North America (J. S. Pearse, pers. comm.). Shorter-term sea star mass mortality events that are not density dependent or often as widespread as those caused by disease have been attributed to a host of abiotic factors including low seawater temperature (e.g., *Astropecten irregularis*: Crisp, 1964; Moysse and Nelson-Smith, 1964), rapid smothering by sediments (e.g., *Asterias rubens*, *Astropecten irregularis*: Schäfer, 1972), high currents and waves (e.g., *Luidia senegalensis*: Tiffany, 1978; *Asterias rubens*: Menge, 1979), low tide emersion (e.g., *Patiriella*, *Coscinasterias*, *Pentagonaster*: Hodgkin, 1959), low salinity exposure (e.g., *Asterias rubens* (as *Asterias vulgaris*): Smith, 1940), hypoxia (e.g., *Luidia clathrata*: Osborne 1979), anchor ice and ice scour (e.g., *Odontaster validus*: Dayton et al., 1970), and oil spills (e.g., *Asterias rubens*, *Marthasterias glacialis*: Smith, 1968). Moreover, there have been numerous anecdotal observations of sea stars washing up on beaches. For example, a recent 24 Jan. 2014 news headline

in the web-based *London Daily Mail* read “Thousands of dead starfish wash up on Lincolnshire Beach following stormy weather.” The ensuing news article and photograph reported a mass mortality of what was identified by a local expert to be *Asterias rubens* presumably caused by strong storm-generated currents (Reynolds, 2014).

Herein we report a mass mortality of the sea stars *Luidia clathrata* and *Luidia alternata alternata* as indicated by hundreds of dead individuals discovered littering the tide line of a high-energy sand beach in Orange Beach, AL, on 27 Dec. 2013.

*Methods*.—In order to document the mass mortality event, individuals of both *L. clathrata* and *L. a. alternata* were exhaustively hand-collected along a continuous 1.125-km stretch of beach immediately to the east of the East Jetty of Perdido Pass that opens into Perdido Bay, Alabama (30°16'14"N–87°33'11"W). The sea stars were separated into their respective species and the radius (R) of the longest arm was measured to an accuracy of 1 mm for all individuals. Two individuals of each species were preserved as voucher specimens (Fish and Wildlife Research Center, Saint Petersburg, FL). In order to evaluate the size classes of individuals that were most impacted in the mass mortality event, the size frequency of all the individuals collected from the shoreline were determined for each species. Moreover, the mean body size (R) of *L. clathrata* and *L. a. alternata* were statistically compared.

The mass mortality event also provided an opportunity to evaluate the first documentation of the incidence of arm regeneration in field populations of both *L. clathrata* and *L. a. alternata* along the northern Gulf of Mexico. Arm regeneration was defined as only those arms that showed discernable regenerative growth, not simply arms that had freshly broken off presumably due to damage caused by being cast on to the shore. Both the incidence of individuals with at least one regenerating arm was determined for each species (frequency of arm regeneration within the population), and the number of arms regenerating in individuals displaying regeneration (degree of regeneration within individuals) were recorded. The frequency of arm regeneration and the numbers of arms regenerating among individuals were statistically compared between the two species.

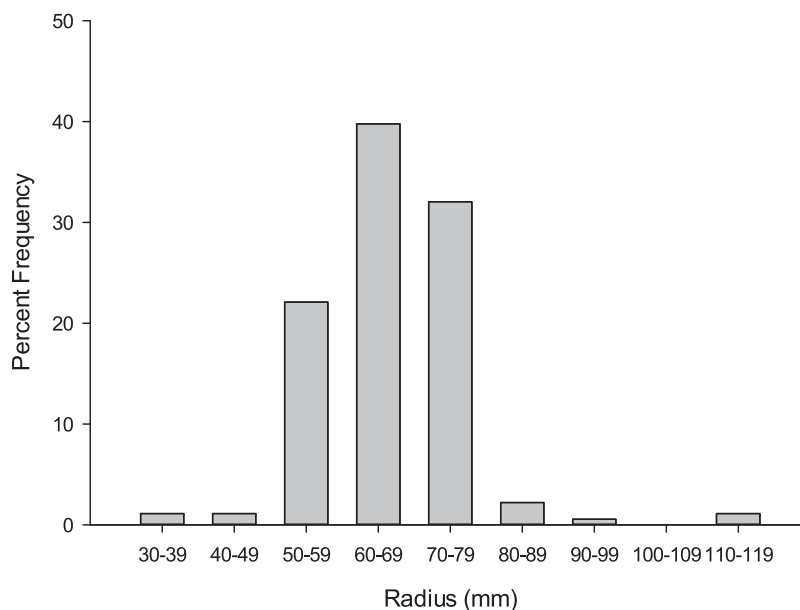


Fig. 1. Size frequency (radius) histogram of individuals of *Luidia clathrata* collected from the shoreline of Orange Beach, AL, following a mass mortality event observed on 27 Dec. 2013 (n = 195).

**Results and Discussion.**—The total number of *L. clathrata* and *L. a. alternata* collected were 195 and 226 individuals and their density along the shoreline sampled was 0.17 and 0.20 individuals  $m^{-1}$ , respectively. Dead individuals were found all along the shore but were not spread evenly and often were found clumped together with up to as many as ca. 10 individuals aggregated in a tight pile. This was likely the result of repeated strandings of dead individuals in zones of higher currents or surf. There appeared to be no pattern of differential distribution of the two species along the shore, but rather they generally occurred mixed together.

The vast majority of individuals of both species fell into large size classes (*Luidia clathrata*: 90% > 50 mm R; *L. a. alternata*: 100% > 50 mm R). Individuals of both species collected along the shore had unimodal size frequency distributions (Figs. 1, 2) indicating that either juveniles were not present in the populations impacted by the mass mortality event, or were less susceptible to stranding. *Luidia clathrata* has an annual reproductive cycle and spawns in the spring (Lawrence, 1973; Dehn, 1980; Watts and Lawrence, 1990; Pomory and Lares, 2000). If this were always the case, then early juveniles would have the potential to be represented in the impacted populations, but annual recruitment is known to be sporadic in echinoderms as it is dependent upon a number of biotic and abiotic variables (Mercier and Hamel, 2009, 2013). Despite the

overlap of the size frequencies of the two species, individuals of *L. clathrata* were significantly smaller than those of *L. a. alternata* (mean R  $\pm$  1 SD: 64.2  $\pm$  0.79 mm [n = 132] and 98.3  $\pm$  0.87 mm [n = 173] for *L. clathrata* and *L. a. alternata*, respectively;  $P < 0.001$ , two-sample Student's t-test,  $t = 28.971$ ,  $df = 418$ ). The fact that *L. clathrata* were on average one-third smaller than *L. a. alternata* is more likely a consequence of species-specific differences in maximum body size rather than size-specific differences in susceptibility to the factor (or factors) that caused the mass mortality.

Individuals of both species with one or more regenerating arms were relatively common and the incidence of regeneration was significantly higher in *L. clathrata* than in *L. a. alternata* (32.3% vs 23.4%, respectively;  $P = 0.0426$ ; two-by-two contingency table, chi-square uncorrected = 4.113). Moreover, the mean number of arms regenerating was also significantly greater in *L. clathrata* than in *L. a. alternata* (mean  $\pm$  1 SD: 1.83  $\pm$  0.79 (n = 63) and 1.45  $\pm$  0.75 (n = 53), respectively;  $P = 0.004$ , Mann-Whitney U-test). Both the higher incidence of arm regeneration in the population and the greater number of arms regenerating in a given individual indicate a higher susceptibility of *L. clathrata* to arm loss and has implications for allocations of material and energy to regenerating body components (Lawrence et al., 1986; Lawrence and Ellwood, 1991; Lawrence, 1992). Pomory and Lares (2000)

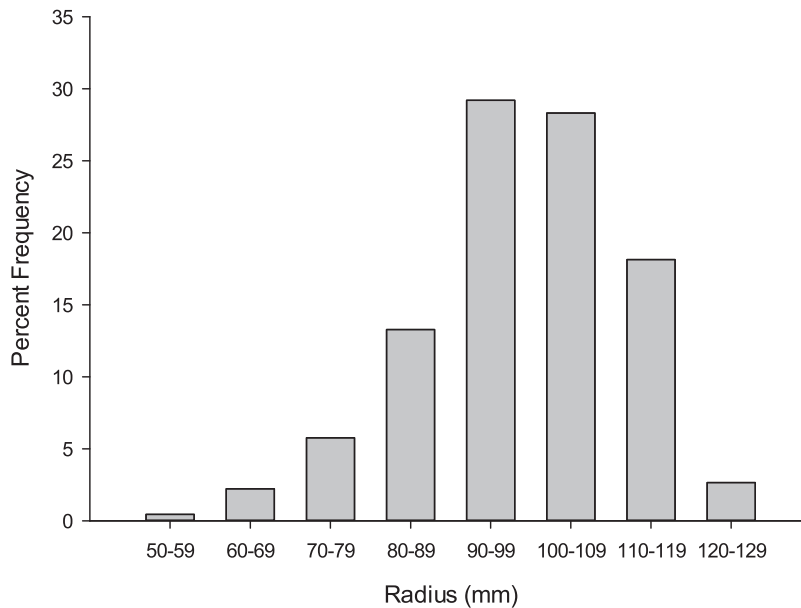


Fig. 2. Size frequency (radius) histogram of individuals of *Luidia alternata alternata* collected from the shoreline of Orange Beach, AL, following a mass mortality event observed on 27 Dec. 2013 ( $n = 225$ ).

attributed arm loss in *L. clathrata* to predation and recorded an even higher incidence of arm regeneration (60%) in a field population in Old Tampa Bay, FL. There are several possibilities that could explain the species-specific differences in the incidence and degree of arm regeneration. One is that the tissue and ossicles are arranged such that the body wall of arms of *L. clathrata* is inherently weaker than that of *L. a. alternata*, rendering individuals more susceptible to predation. This is supported by the anecdotal observation that fresh arm breakage was not uncommon in *L. clathrata* but almost nonexistent in *L. a. alternata* collected from the high-energy shoreline (J. B. McClintock, pers. obs.). It is also possible that *L. a. alternata* is less prone to predation because of a chemical defense or some behavioral attribute such as a higher incidence or degree of burial in soft sediments.

The causative agent (or agents) for the mass mortality of sea stars observed in Orange Beach, AL, and documented in the present study are unknown. However, it seems unlikely that disease was a factor. Individuals cast on the shore, although all dead, appeared in good condition with no evidence of tissue necrosis that might be attributable to an infectious agent such as that causing sea star wasting disease (Eckert et al., 2000). Among abiotic factors, sediment burial, low salinity, emersion, and hypoxia would seem unlikely to have caused

mortality. Although Orange Beach was the recipient of oil released during the April 2010 Deepwater Horizon oil spill in the Gulf of Mexico, and residual oil is known to occur in beach sediments that are coincident with the nearshore habitat of *Luidia* spp. in the Gulf of Mexico (Hayworth et al., 2011), it seems unlikely that hydrocarbons would have caused this mass mortality event as it occurred over such an abrupt time frame. Local tidal conditions for the week leading up to the mass mortality event reflect a moderate tidal cycle. However, data from a National Weather Service (NWS) ground station in Pensacola, FL, indicate that wind speeds were relatively high during several days of the week leading up to the recorded mass mortality (e.g., mean wind speeds of approximately  $24\text{--}32\text{ km h}^{-1}$  and gusts up to  $47\text{ km h}^{-1}$ ). It is possible that winds contributed to strong currents. The day the sea star mortality event was documented, 27 Dec. 2013, there was a very strong long-shore current. A 113-g fishing weight repeatedly cast approximately 25 m from the beach directly offshore was rapidly swept by in a westerly direction and beached within a 1- to 2-min period (J. B. McClintock, pers. obs.). Daily marine weather data from NWS Orange Beach buoy station 42102 ( $30^{\circ}3'55''\text{N } 87^{\circ}33'19''\text{W}$ ) indicated that sea surface temperature had declined to  $20^{\circ}\text{C}$  by 11 Dec. 2013, and had remained in the  $18\text{--}20^{\circ}\text{C}$  range until the 27 Dec.

2013 mass mortality event. *Luidia clathrata* in Old Tampa Bay have little locomotor activity in winter when the seawater temperature is ca. 20°C (Watts and Lawrence, 1986). The most parsimonious hypothesis for the mass mortality appears to be stress associated with exposure to relatively low seawater temperature combined with strong onshore currents that swept individuals of *L. clathrata* and *L. a. alternata* from the shallow soft-bottom benthos onto the shore.

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*Note Added in Proof*— Since the December 2013 starfish mortality event reported in the present study, there have been three reports of additional mortality events in the area, all in March 2014; at Bon Secour National Wildlife Refuge, Alabama (both *Luidia clathrata* and *L. a. alternata*), at Alabama Point, Alabama (*L. a. alternata* only) and at Perdido Key, Florida (both *L. clathrata* and *L. a. alternata*).