Brittle Stars:
A Story of Success in Biodiversity

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Brittle stars, a fascinating and diverse group of organisms, make up the largest portion of Phylum Echinodermata (Pearse et al. 1987). They are classified in the Subphylum Asterozoa, Class Stelleroidea, Subclass Ophiuroidea. Approximately 2000 species of echinoderms are considered to be ophiuroids (Pearse et al. 1987). With a large number of species in one subclass, a great diversity of physical characteristics, ecology, and life histories are observed. The evolutionary record reveals that, through asexual and sexual reproduction, anti-predation mechanisms and generalist feeding brittle stars are an adaptable invasive species (Hendler et al. 2012). Their diverse adaptations allowed brittle stars such as Ophiothela mirabilis to invade other environments.

All echinoderms are considered to be the sister group to our Phylum, Chordata (Pearse et al. 1987; Stohrs & Thuy 2012). There are gaps in the knowledge of ophiuroids, but the fossil record suggests a very close evolutionary relationship within the echinoderms between Subclass Ophiuroidea (brittle stars) and the Class Asteroidea (sea stars) (Stohrs & Thuy 2012). These two classes of stars evolved divergently from a common ancestor (Pearse et al. 1987). A defining characteristic of this divergent evolution is that sea stars retain locomotion as the primary function of tube feet (Pearse et al. 1987; Stohrs & Thuy 2012). Sea stars possess broad arms that are used to capture large prey (Pearse et al. 1987; Stohrs & Thuy 2012). Whereas, brittle stars evolved narrow fragile arms for fast motility and feeding on a diet primarily of small food particles (Pearse et al. 1987; Stohrs & Thuy 2012). Ophiuroids diverged from sea stars and the characteristics that differ are adaptations that allowed brittle star species to thrive in many habitats (Hendler et al. 2012).

A variety of reproductive methods have contributed to the extensive range of ophiuroids (Hendler et al. 2012). Adult ophiuroids, including O. mirabilis, reproduce asexually through fission, by spitting into two parts (Stohrs & Thuy 2012). The central disc separates into two, and both segments re-grow missing arms and organs (Stohrs & Thuy 2012). This method allows for rapid population growth of clonal colonies (Hendler et al. 2012).

Also, most brittle stars reproduce sexually (Stohrs & Thuy 2012). Brittle stars can be dioecious, existing as separate sexes, or hermaphroditic, where one organism possesses both male and female gonads (Boschen et al. 2013; Stohrs & Thuy 2012). Unlike most echinoderms, the sex of some ophiuroids can be distinguished externally through sexual dimorphism, males being smaller than females, or males exhibiting enlarged spines on the aboral surface (Parameswaran et al. 2013; Stohrs & Thuy 2012). If the organism is dioecious brittle stars release gametes (eggs and sperm) into the water column and

external fertilization occurs (Pearse et al. 1987). After fertilization, swimming feeding larvae, called pluteus larvae, disperse and metamorphose into fully developed larvae, called the ophiopluteus (Pearse et al. 1987).

In other instances of sexual reproduction unique to brittle stars, gonads open into the bursa, a sac between arms, at the disc (Pearse et al. 1987). Gametes are released into the bursa and fertilized there (Pearse et al. 1987). Then embryos brood in the bursa and parents provide shelter and nourishment to offspring (Pearse et al. 1987; Pechenik 2010). Extraordinarily, some species of brittle star alternate their method of reproduction in response to environmental conditions (Williams 2003). They reproduce sexually when brittle stars are abundant, and therefore create greater genetic diversity (Williams 2003). When they reproduce asexually, only one genetic type of offspring is produced. This method sustains the species when numbers are in decline because populations can grow quickly (Williams 2003). This reproductive flexibility is another reason why ophiuroids adapt successfully (Hendler et al. 2012).

Brittle stars not only regenerate limbs to asexually reproduce, but also drop limbs to evade predators (Pechenik 2010). Brittle stars are prey to crabs, fish, birds, and other members of the Phylum Echinodermata, such as, Asteroids (sea stars) (Boschen et al. 2013; Grober 1988; Pearse et al. 1987; Sides 1987). Ophiuroids avoid capture in many ways. They remain dormant during the day, feeding only at night avoiding diurnal predators (Pechenik 2010). Some species rely on colors and patterns to confuse predators (Grober 1988). Large aggregations, sometimes of millions of individuals, will use color variation to ensure predators, such as fish, cannot form a consistent hunting image (Grober 1988; Pechenik 2010). Other species use bioluminescence to deter predators (Grober 1988). Bioluminescence acts as an aposematic signal, a warning to predators (Grober 1988).

Many species of ophiuroids may use one or several of these methods, but all exhibit fragmentation when disturbed, demonstrated in Figure 1 (Nilsson & Skold 1996; Pechenik 2010; Sides 1987; Stohrs & Thuy 2012). When a brittle star is attacked, one or more arms will detach from its central disc (Sides 1987). The autotomized arm will continue to move, providing a distraction to allow the brittle star to escape (Sides 1987). Interestingly, many predators will use sub lethal force when eating brittle stars (Nilsson & Skold 1996; Pearse et al. 1987; Pechenik 2010; Sides 1987). The regeneration capability of ophiuroids prompted the observation that predators can ensure a constant supply of food by injuring brittle stars, and only eating a part, such as an arm, rather than the entire animal (Sides 1987). More often that not, brittle stars are found in the wild with at least one arm regenerating (Pechenik 2010; Sides 1987). This method of evasion is a highly successful adaptation, outweighing energy costs during the several months required regenerating a limb (Nilsson & Skold 1996; Pechenik 2010).

Figure 1. Arrow shows fragmented arm of brittle star. Observed at Bamfield Marine Science Centre, Vancouver Island, 2014, photo taken by author.

Brittle stars have as many ways to escape predation as they do to capture food. Many are filter feeders that strain small food particles from water or ingest food within sediment (Pechenik 2010). Some brittle stars are suspension feeders (Pechenik 2010). They capture food by raising their arms and use their tube feet as suction cups to collect food (Pearse et al. 1987). In some species, mucus is secreted from tube feet that streams into the water to become a sticky extension of the arm capturing food as it passes (Pearse et al. 1987). Small organic food particles make up the majority of the brittle star diet, but in some instances, ophiuroids have been known to be carnivorous, ingesting small animals (Pearse et al. 1987; Pechenik 2010). Tube feet enable them to capture and imprison prey within their arms to await digestion (Pearse et al. 1987). Other species use their spines to capture prey, such as planktonic animals (Pearse et al. 1987).

Also, other species are scavengers, not at all selective in their meals, eating dead animal matter, for example fish (Pearse et al. 1987; Pechenik 2010). In ophiuroids, the digestive system is confined to the central disc; whereas, other echinoderms have parts of their digestive systems in their arms (Pechenik 2010). Food is passed from tube foot to tube foot down the length of the arm to the mouth (Pearse et al. 1987). Around the mouth are specialized tube feet, called buccal podia, which aid in digestion by compressing food into small pellets (Pearse et al. 1987). Brittle stars do not have complete digestive systems; as a result, any undigested matter is expelled from the mouth (Pearse et al. 1987; Pechenik 2010; Stohrs & Thuy 2012).

The name Ophiothela mirabilis stems from the Greek root ophis, meaning snake, aptly describing the serpent-like movement of brittle star arms (Stohrs & Thuy 2012). Their locomotion and dispersal have allowed populations to expand into a variety of geographical areas and ecosystems (Hendler et al. 2012). O.

mirabilis is a 6-armed brittle star; whereas, most brittle stars are pentamerous, or five-armed (Stohrs & Thuy 2012). Brittle stars are the most motile, or capable of movement, of all echinoderms. Although brittle stars exhibit radial symmetry, they move along a bilateral axis extending one arm in the direction of movement while the other four arms grip or hook onto objects and pull the organism forward (Pearse et al. 1987).

Ophiuroids are strictly marine animals found in all oceans from the tropics to the poles as demonstrated in Figure 2 (Boschen et al. 2013; Pearse et al. 1987; Stohrs & Thuy 2012). They live at all depths, ranging from interstitial environments (in sand or mud), in the intertidal, to benthic (on surfaces), and even the abyssal (deep ocean) habitats in the deepest part of the sea (Boschen et al. 2013; Stohrs & Thuy 2012). Brittle stars hide under rocks, in crevices, and beneath sand or mud (Pechenik 2010; Stohrs & Thuy 2012). Tube feet on the oral surface of the arms enable brittle stars to adhere to substrates or burrow deeply into sand (Pearse et al. 1987; Pechenik 2010). All species are motile and most ophiuroids produce mobile larvae which enables them to expand their distribution (Pearse et al. 1987).

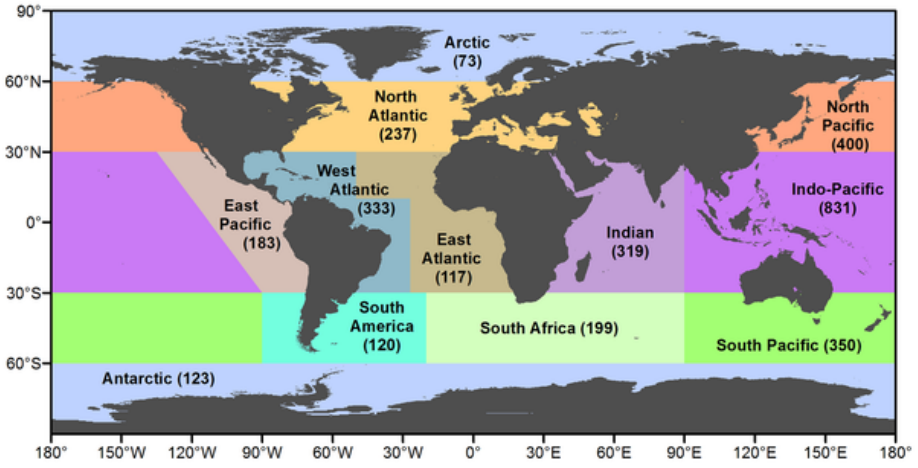

Figure 2. Global distribution of known species of Ophiuroidea. The oceanic area displaying the greatest species diversity is the Indo-Pacific region, the native ocean of Ophiothela mirabilis. The diversity of species is shown for each region. Total number of species in all regions is 2064. Some species may occur in more than one region (Stohrs & Thuy 2012).

Some species are able to raft, or travel long distances attached to drifting seaweed or debris (Hendler et al. 2012; Pearse et al. 1987). The expansion of their range could pose a threat to existing coral reefs in areas previously uninhabited by brittle stars (Hendler et al. 2012). For example, O. mirabilis has expanded from the Pacific Ocean into the Atlantic, most likely by attaching to ships and have become an invasive species (Hendler et al. 2012). The small yellow-orange brittle stars were first spotted off the coast of Brazil in 2000

(Hendler et al. 2012). They are prolific here because there are no natural predators (Hendler et al. 2012). It is not yet known the effect they will have on existing marine communities; however, there is cause for concern because they have been found in large numbers, colonizing sponges and sea corals as shown in Figure 3 (Hendler et al. 2012). Further research will determine if the relationship is negative in nature.

Figure 3. Brittle stars invading new habitats in the Atlantic Ocean. A) Ophiothela mirabilis (brittle star) colonizing a sponge. B) Ophiothela mirabilis (brittle star) colonizing a gorgonian, Leptogorgia punicea (M. Chris 1999).

Brittle star reproduction patterns, anti-predation devices, and many adaptations have allowed theses organisms to flourish and resulted in their great abundance. This poses threats to some ecosystems as they invade new environments. Additionally, humans have unknowingly aided the geographical expansion of O. mirabilis into the Atlantic Ocean on ships. The full implications of which, we are only beginning to discover.

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