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The reproductive biology of the exploited razor clam, *Ensis siliqua*, in the Irish Sea

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ABSTRACT

Knowledge of the reproductive cycle of a species is a prerequisite for sustainable management of a fishery. The infaunal marine bivalve, *Ensis siliqua*, is a commercially important species in Europe, and is exploited in many countries, including Ireland, where it is sold by wet weight. Seasonal variations in the reproductive cycle of subtidal razor clams from the Skerries region of the Irish Sea, an important fisheries area, were examined between June 2010 and September 2011 while monitoring weight. Histological examination revealed that the *E. siliqua* sex-ratio was not different from parity, and no hermaphrodites were observed in the samples collected. In the summer months of 2010 all female clams were either spent or in early development, with just a small percentage of males still spawning. The gonads of both sexes developed over the autumn and winter months of 2010, with the first spawning individuals recorded in January 2011. Spawning peaked in March 2011, but unlike in 2010, spawning continued through June and July with all animals spent in August 2011. The earlier and longer spawning period found in this species in 2011 compared to 2010 may have been due to the colder than normal temperature observed during the winter of 2010 plus the relatively warmer temperatures of Spring 2011, which could have affected the gametogenic development of *E. siliqua* in the Irish Sea. It was noted that wet weight dropped in the summer months of both years, immediately after the spawning period which may impact on the practicality of fishing for this species during this period. Timing of development and spawning is compared with other sites in the Irish Sea and elsewhere in Europe, including the Iberian Peninsula.

1. Introduction

Ensis siliqua is a native species in Europe, and is distributed along the European Atlantic coast from the Norwegian Sea and the Baltic, south to the Mediterranean and along the Atlantic coast of Morocco (Costa et al., 2010; Darriba et al., 2005; Fernández-Tajes and Méndez, 2007; Gaspar and Monteiro, 1998; Varela et al., 2007). It is abundant in the British Isles, and widely distributed along the east coast of Ireland (Fahy, 1999). Commonly known as the razor clam or pod razor, *E. siliqua* inhabits fine sand, silt or muddy sediments along the coast of Europe, and can be found at depths ranging from 0 to 58 m, though they are thought to be most abundant at 3–7 m depth (Costa et al., 2010; Encyclopedia of Life, 2010; Fahy, 1999; Gaspar and Monteiro, 1998). The valves of *E. siliqua* shells usually reach a maximum of 21 cm in length (Conchological, 2008; Encyclopedia of Life, 2010; Holme, 1951), though larger individuals of up to 24 cm have been recorded in Northern Europe (Muir and Moore, 2003). This clam species has a very large and powerful foot and is capable of rapid vertical burrowing in the fine sediments that it favours (Encyclopedia of Life, 2010; Fahy and Carroll, 2007; Fernández-Tajes et al., 2007). Razor clams are usually found to have a sex ratio of 1:1, with a very low incidence of hermaphroditism (Gaspar and Monteiro, 1998; South Wales Sea Fisheries Committee, 1999).

E. siliqua is currently harvested by commercial fisheries in Spain, Portugal, and Ireland (Costa et al., 2010) and is regarded as an increasingly valuable fishery resource with potential for commercial aquaculture in many European countries (Arias-Pérez et al., 2011; Fernández-Tajes et al., 2007; Varela et al., 2007; Wootton et al., 2003). By 2004, the importation rates of razor clams were quite significant in Europe, representing a total value of €550 million, with Spain, Italy, France, Portugal and the Netherlands being the most significant importers (Fernández-Tajes and Méndez, 2007; Fernández-Tajes et al., 2007).

In 1997, a razor clam fishery began in the Republic of Ireland when a large bed of *Ensis* spp. which measured 21 km^2, was discovered at Gormanstown, off the Meath coast (Fahy, 1999; Fahy and Carroll, 2007). In 1998, landings of *Ensis* were in the order of c. 500 tonnes and valued at €1,000,000 EU, making Ireland the largest supplier of *Ensis* in Europe in the space of two years (South Wales Sea Fisheries Committee, 1999). This continued until 2000, as the Republic of Ireland led the world in wild-caught landings

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(Hauton et al., 2007). Though official landing details of razor clams is unavailable for subsequent years, it is thought that the Irish fishery experienced problems in *Ensis* landings caused by over-fishing, poor recruitment and winter mortality in some beds (Hauton et al., 2007).

Of the three species of the genus *Ensis* that occur in Ireland – *E. siliqua*, *Ensis arcuatus* and *Ensis ensis* – *E. siliqua* makes up the vast bulk of landings (Fahy and Carroll, 2007). Because of the large global demand for shellfish, including *E. siliqua*, natural beds of this species are under pressure (Darriba et al., 2005; Hauton et al., 2007). The future commercial exploitation of these species will need careful management to ensure sustainability and avoid fishery over-depletion. To manage an exploited species, knowledge of the reproductive cycle of the species is essential, as it provides valuable data for recruitment, age and growth studies (Morsan and Kroeck, 2005). In particular, the effect of the gametogenic cycle on the weight of individuals would have an economic impact, as *E. siliqua* is currently sold by wet weight.

Previous work on this species has outlined the reproductive cycle of *E. siliqua* in other areas. In Southern Portugal *E. siliqua* gametogenesis has been recorded as beginning in December with spawning individuals first observed in May and all individuals spent by July (Gaspar and Monteiro, 1998). Similar gonadal development and spawning times of *E. siliqua* were reported in razor clams sampled in the Gormanstown Bed of the Irish Sea by Fahy in 1999. However, site specific variation in this cycle appears to exist, as *E. siliqua* individuals from North western Spain were examined histologically in 2000, supplying evidence of gametogenesis beginning in November and spawning taking place in April in razor clams from this area (Darriba et al., 2005). In all of these studies the gametogenic cycle of this species was found to be annual, with a long sexual rest period during the summer and autumn months. Less detailed reports of *E. siliqua* spawning periods in March and April in Plymouth, United Kingdom (Lebour, 1938), and July and August in North Wales (Henderson and Richardson, 1994), and the Clyde Sea of Scotland (Muir and Moore, 2003) have also been recorded.

The effects of environmental conditions, including temperature, have been shown to influence the gametogenesis and spawning of a range of bivalve species such as *Mya arenaria* (Brousseau, 1978; Cross et al., 2012; Gauthier-Clerc et al., 2002), *Crassostrea gigas* (Ruiz et al., 1992a), *Ostrea edulis* (Cano et al., 1997; Ruiz et al., 1992b), *Pecten maximus* (Pazos et al., 1997), *Pinna rugosa* (Ceballos-Vazquez et al., 2000), *Argopecten ventricosus* (Luna-Gonzalez et al., 2000), and *E. arcuatus* (Darriba et al., 2004) by affecting the timing and length of the spawning period. To allow for the on-going management and future exploitation of *E. siliqua* in Irish waters, the main objective of the present study was to determine the current reproductive cycle of this clam in the Irish Sea and examine any relationship between gametogenesis, individual weight, length, and temperature, on a monthly and seasonal scale.

2. Materials and methods

2.1. Study site and sampling

The Skerries region of the Irish Sea is located off the coast of Dublin city, in the region of N 52°13′06.9″, W 006°47′38.1″. Thirty live *E. siliqua*, which had been fished off shore by trawlers, in the Skerries region, were obtained monthly from June 2010 to September 2011, from a commercial shellfish wholesaler on the east coast of Ireland. All sampled clams were identified as *E. siliqua* using the method described by Fernández-Tajes et al. (2007), in which amplification of the internal transcribed spacer 1 (ITS-1) of razor clams is used to differentiate diverse species, including *E. siliqua*. No sample could be obtained in November 2010 due to severe weather conditions preventing trawling in the sampling area.

2.2. Histological techniques

The total wet weight (g) and shell length (cm) of each individual clam was recorded. The soft tissue of each clam was dissected within 24 h of collection. A section of the body of the animal was cut out, which contained the gonad, renal gland and digestive tract, and sections of the gill and mantle. The tissue was fixed in Davidson's solution for 48 h and stored at 4 °C. Slides were prepared using standard histological techniques, where tissues were dehydrated in alcohol, cleared in xylene, embedded in paraffin wax, sectioned at 7 μm, and stained with Harris' Hematoxylin and Eosin before being mounted (Porter, 1974). The prepared microscope slides were examined using 10×, 20×, and 40× magnifications, to determine sex and stage of reproductive development.

Using a Wilcoxon–Mann–Whitney-U test the wet weight and length of *E. siliqua* individuals were compared between seasons as follows; June 2010–August 2010 vs. December 2010–February 2011, and December 2010–February 2011 vs. June 2011–August 2011, to test for statistical significance.

2.3. Staging of gonadal development

Clam reproductive maturity was categorised into six stages using a modification of the maturity scale described for *E. siliqua* by Gaspar and Monteiro (1998) who designated these stages as 'inactive, early active gametogenesis, late active gametogenesis, ripe, partially spawned and spent'. In the present study, these stages were renamed to 'inactive, early development, late development, ripe, spawning and spent', respectively, to reflect the stages observed, though the definition of each stage remained the same. When more than one stage was present in a single individual, the maturity was scored based on the condition of the majority of each section.

2.4. Surface seawater temperatures

The mean, minimum and maximum monthly surface seawater temperatures in the Skerries region, from January 2009 to December 2011, to cover the study period and the year prior to the study commencing were obtained from the Marine Institute (www.marine.ie).

3. Results

3.1. Wet weight

Of the 450 individuals collected over 16 months from June 2010 to September 2011 the average wet weight of all *E. siliqua* individuals was 80.0 ± 2 g, with the lightest individual collected weighing 31.0 g and the heaviest 153.0 g. Over the study period, the mean monthly values of *E. siliqua* weight ranged from 40.68 ± 0.9 g in June 2011 to 117.2 ± 2.4 g in January 2011 (Fig. 1). Razor clams sampled during the sexual rest period of June to August in 2010 and 2011 were not statistically significantly lighter than those collected during the months of December to February 2011, when the spawning period began (Wilcoxon–Mann–Whitney U test: the two samples are not statistically different. $P \geq 0.05$, two tailed test). The average weight of female *E. siliqua* was 80.4 ± 4.0 g while the average weight of sampled male *E. siliqua* was 80.5 ± 3.0 g.

3.2. Length

The average length of all razor clams collected was 17.5 ± 0.2 cm. Individuals collected measured from 12.8 cm to 21.4 cm in length, with mean monthly lengths ranging from 14.5 ± 0.1 cm to 19.4 ± 0.1 cm (Fig. 2). Similar to wet weight values, the average