Flat Oyster Reproduction – A memo

Eline van Onselen (The Rich North Sea)
With contributions from: Pauline Kamermans (Wageningen Marine Research) & Hein Sas (Sas Consultancy)
June 2020

European flat oysters (*Ostrea edulis*) are used in offshore nature enhancement projects in the North Sea as one of the most well-known native reef building species. For optimal reintroduction it can be useful to know the spawning period of flat oyster to introduce suitable settlement material for the oyster spawn to settle on. This memo gives a short introduction into the life cycle of European flat oysters and into the methods used to predict spawning time.

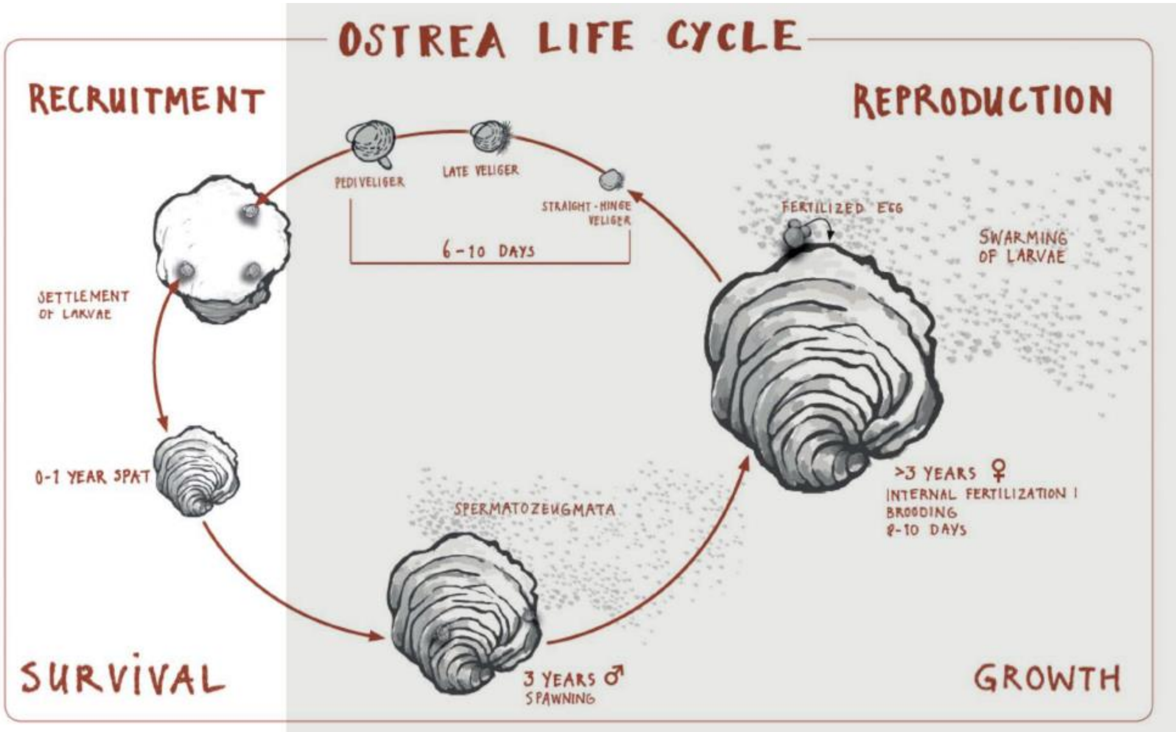

Figure 1. European flat oyster life cycle (from Sas et al. 2019).

The North Sea used to contain hard substrate habitats such as large oyster reefs, gravel fields and moorlog banks (Coolen, 2017). Due to (a.o.) mining, dredging, disease and (over)fishing, hard substrate habitats have drastically decreased in the North Sea during the 19th and 20th centuries (Airoldi and Beck, 2007; Smaal *et al.*, 2015; Coolen, 2017). Offshore wind farms (OWFs) offer hard substrate surfaces as well as less or no bottom habitat disturbance and have been identified as promising locations for nature enhancement and reintroduction of biogenic reef species in the North Sea (Smaal *et al.*, 2016; Kamermans *et* *al.*, 2018; Coolen *et al.*, 2019). European flat oyster (*Ostrea edulis*) is a native oyster species from which the decline in the North Sea has been relatively well documented (Pogoda *et al.*, 2019) and a logical candidate for re-introduction or nature enhancement.

Flat oysters have been intensively cultured in the Netherlands for at least a century, leading to introductions from other countries such as France, Ireland, England, Italy and Greece to keep the population high enough for exploitation (Drinkwaard, 1999). However, the increasingly lower numbers of flat oyster and decreasing profits led to the introduction of non-native species such as the Pacific oyster (*Crassostrea gigas*), effectively taking over the market and reducing the need for flat oyster production (Drinkwaard, 1999). Currently, only a few wild European flat oyster stocks are present in Dutch waters, making re-introduction from Dutch brood stocks a challenge (Smaal *et al.*, 2015). To make re-introduction or nature enhancement, including possible local production and offshore monitoring, as effective as possible, knowledge on the complete lifecycle of flat oysters is essential. This memo focusses on flat oyster spawning and its associated parameters.

European flat oysters are a so-called 'protandrous hermaphrodite', meaning an oyster starts life as male and may after several years change to female (Henshaw, 2018). Within one season the sex change may occur back-and-forth (Bayne, 2017). A male oyster releases sperm into the water column, fertilising up to 1 million eggs in the pallial cavity of the female (Lapègue *et al.*, 2006). Older oysters can spawn twice during one spawning season: once as a male and once as a female (Smaal *et al.*, 2015). Sperm cells are filtered out of the water phase by the females, and combined with egg cells in their shell cavity. The larvae are released from the female into the water after 8 to 10 days (depending on temperature), spending another 8 to 10 days in the water column before settling on a suitable surface (Lapègue *et al.*, 2006). The metamorphosis from mobile larvae to sessile spat probably mainly depends on food availability and can take up to two weeks (Smaal *et al.*, 2015). Because of the relatively brief mobile phase, dispersal of flat oyster is relatively small, generally up to 1 km but sometimes ranging to 10 km (Smaal *et al.*, 2015). The lifecycle of the flat oyster is summed up in Figure 1.

Environmental parameters such as water temperature, dissolved oxygen, suspended matter and chlorophyll a concentration can influence the gametogenic cycle of flat oyster (Cano, Rosique and Rocamora, 1997). To make artificial production of spat as efficient as possible, these parameters and the specific effects of each of them should be known where possible. In a Spanish study of wild flat oysters, temperature seemed to be the main defining parameter, in which gametogenesis took place year round but spawning only occurred at water temperatures between 14°C and 28°C (Cano, Rosique and Rocamora, 1997). A Danish study showed a positive correlation between average summer water temperature and oyster yield 5 years later, indicating warmer water (>15-16°C) has a positive effect on reproductive output (Nielsen and Petersen, 2019).

The timing of spawning varies between years and locations (Didderen *et al.*, 2019) with water temperature generally accepted as the most important factor for inducing reproductive activity (Allison *et al.*, 2020). Using a technique called the 'temperature sum' the larval peak can be predicted for a specific location (Sas *et al.*, 2019; Maathuis *et al.*, 2020). The temperature sum, also known as growing degree-days, heat units or thermal time, is the sum of the (average) water temperature per day, if the temperature is higher than a threshold temperature (Sas *et al.*, 2019). A study in Lake Grevelingen and the Oosterschelde in the Dutch Delta showed that spawning is not only dependent on temperature sum but also on lunar cycle, chlorophyll a concentration (food abundance), day-in-year and mean temperature (Maathuis *et al.*, 2020). This can make prediction of spawning somewhat complicated. Hence, a prediction model based on local temperature sum is currently the most practical method of predicting the larval peak. Maathuis *et al.*, 2020 shows the first peak of oyster larvae in the Oosterschelde was predicted at 576-593 degreedays, in Lake Grevelingen 903 degreedays (not significant). For North Sea locations, a prediction can be made using the same methods as described in Maathuis *et al.,* 2020, however no current research can validate the predications yet as not enough data is available. The method can be validated for a location with regular (preferably weekly) larval monitoring in June and July (P.Kamermans, pers. comm. June 2020).

An oyster pilot in Dutch OWF Luchterduinen in 2018-2019 successfully used the threshold of 593 degreedays to predict the larval peak in July (Didderen, Bergsma and Kamermans, 2019). This implies that the larval peak at offshore locations will probably occur later in the season than at nearshore locations, since offhore water temperature usually lags behind nearshore temperature. Further validation of the temperature model for offshore locations is necessary. According to Sas *et al.* (2019) and unpublished research based on Didderen, Bergsma and Kamermans (2019), the best timing for placing clean settling substrate is two weeks after the larval peak (P.Kamermans, pers. comm. June 2020). The same sources indicate that shell material is probably the best settling material.

References

Airoldi, L. and Beck, M. W. (2007) 'Loss, status and trends for coastal marine habitats of Europe', *Oceanography and Marine Biology: An Annual Review*, 45, pp. 345–405. doi: 10.1201/9781420050943.ch7.

Allison, S. *et al.* (2020) 'Strongholds of Ostrea edulis populations in estuaries in Essex, SE England and their association with traditional oyster aquaculture: evidence to support a MPA designation', *Journal of the Marine Biological Association of the United Kingdom*, 100, pp. 27–36. doi: 10.1017/S0025315419001048.

Bayne, B. L. (2017) 'Reproduction', in *Biology of oysters*. Developmen. London: Academic Press, pp. 565–701. doi: 10.1016/B978-0-12-803472-9.00009-1.

Cano, J., Rosique, M. J. and Rocamora, J. (1997) 'Influence of environmental parameters on reproduction of the European flat oyster (Ostrea edulis L.) in a coastal lagoon (Mar Menor, southeastern Spain)', *Journal of molluscan studies*. Oxford University Press, 63(2), pp. 187–196. Available at: https://watermark.silverchair.com/63-2-187.pdf?token=AQECAHi208BE49Ooan9kkhW_Ercy7Dm3ZL_9Cf3qfKAc485ysgAAAnkwggJ1BgkqhkiG9w0BBwagggJmMIICYgIBADCCAlsGCSqGSIb3DQEHATAeBglghkgBZQMEAS4wEQQMIrnXqvyuDJEViDbgAgEQgIICLJeec1AadjkShDuWW88GJuQRWalJRJ-cTI55q_8LVk4FjP.

Coolen, J. W. P. (2017) *North Sea reefs : benthic biodiversity of artificial and rocky reefs in the southern North Sea*, *PhD-thesis North Sea Reefs. Benthic biodiversity of artificial and rocky reefs in the southern North Sea*. Wageningen University. doi: 10.18174/404837.

Coolen, J. W. P. *et al.* (2019) *Upscaling positive effects of scour protection in offshore wind farms Quick scan of the potential to upscale positive effects of scour protection on benthic macrofauna and associated fish species*. Den Helder. doi: 10.18174/475354.

Didderen, K. *et al.* (2019) *Shellfish bed restoration pilots Voordelta, Netherlands, Annual Report 2018*. Available at: www.haringvliet.nu (Accessed: 26 May 2020).

Didderen, K., Bergsma, J. H. and Kamermans, P. (2019) *Offshore flat oyster pilot Luchterduinen wind farm. Results campaign 2 (July 2019) and lessons learned.* Culemborg.

Drinkwaard, A. C. (1999) 'Introductions and developments of oysters in the North Sea area: A review', *Helgolander Meeresuntersuchungen*, 52(3–4), pp. 301–308. doi: 10.1007/BF02908904.

Henshaw, J. M. (2018) 'Protandrous Hermaphroditism', *Encyclopedia of Animal Cognition and Behavior*. doi: 10.1007/978-3-319-47829-6.

Kamermans, P. *et al.* (2018) 'Offshore wind farms as potential locations for flat Oyster (Ostrea edulis) restoration in the Dutch North Sea', *Sustainability*. Multidisciplinary Digital Publishing Institute, 10(11), p. 3942.

Lapègue, S. *et al.* (2006) 'European flat oyster-Ostrea edulis', in *GENINPACT-Evaluation of genetic impact of aquaculture activies on native population. A European network, WP1 workshop Genetics of domestication, breeding and enhancement of performance of fish and shellfish.*

Maathuis, M. A. M. *et al.* (2020) 'Factors determining the timing of swarming of European flat oyster (Ostrea edulis L.) larvae in the Dutch Delta area: Implications for flat oyster restoration', *Journal of Sea Research*, 156. doi: 10.1016/j.seares.2019.101828.

Nielsen, P. and Petersen, J. K. (2019) 'Flat oyster fishery management during a time with fluctuating population size', *Aquatic Living Resources*, 32, p. 22. doi: 10.1051/alr/2019020.

Pogoda, B. *et al.* (2019) 'The Native Oyster Restoration Alliance (NORA) and the Berlin Oyster Recommendation: Bringing back a key ecosystem engineer by developing and supporting best practice in Europe', *Aquatic Living Resources*, 32(13), pp. 1–9. doi: 10.1051/alr/2019012.

Sas, H. *et al.* (2019) *Recommendations for flat oyster restoration in the North Sea Synthesis of lessons learned from the Dutch Voordelta experiments, with additional observations from flat oyster pilots in Borkum Reef and Gemini wind farm, modelling exercises and literature*.

Smaal, A. *et al.* (2016) *Flat oysters on offshore wind farms: Opportunities for the development of flat oyster populations on existing and planned wind farms in the Dutch section of the North Sea*. Yerseke. doi: 10.18174/418092.

Smaal, A. C. *et al.* (2015) *Feasibility of flat oyster (Ostrea edulis L.) restoration in the Dutch part of the North Sea*, *Imares Report for the Ministry of Economic Affairs*. Available at: www.imares.wur.nl (Accessed: 9 March 2020).