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Short Communication

No evidence that the Atlantic jackknife clam *Ensis leei* benefits from shrimp fisheries

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ABSTRACT

Few experimental studies have been performed on the impact of shrimp fisheries on benthic life. One recent study observed an increase in densities of the Atlantic jackknife clam in hydraulic dredge samples at heavily fished plots and hypothesized that individuals may have been attracted by and immigrated into the disturbed areas (Tulp et al., 2020). We analysed additional box core data taken in the same experiment, and the results could not support this hypothesis. An alternative hypothesis that high densities of clams were coincidentally present in the heavily fished areas already before fishing, but were then too small to be included in the dredge, could neither be confirmed. Additional experiments are required to shed more light on the possible impact of shrimp fisheries on clam abundance and distribution.

1. Introduction

The impact of beam trawl fisheries on benthic communities has been intensively studied (Hiddink et al., 2017; Rijnsdorp et al., 2018; Sciberras et al., 2018; Pitcher et al., 2022), but most attention has been paid to fisheries targeting flatfish, where the gear is equipped with heavy tickler chains penetrating the upper layer (about 3 cm) of the sediment (Hiddink et al., 2017). Only few studies focused on the impact of the much lighter beam trawl used in shrimp fisheries, which has a rope with light rubber bobbins instead of heavy tickler chains (Riesen and Reise, 1982; Berghahn and Vorberg, 1998; Vorberg, 2000; Tulp et al., 2020). The first shrimp fishery studies were performed in relatively undisturbed areas, and concentrated on the short term effect on biogenic structures such as reefs of *Sabellaria spinulosa*, fields of *Lanice conchilega*, or beds of *Sertularia cupressina* (Riesen and Reise, 1982; Berghahn and Vorberg, 1998; Vorberg, 2000). A more recent study was performed in a shallow area of the western Wadden Sea, which is not only characterized by high physical stress, but has also been used for shrimp fishing for already a long time (Tulp et al., 2020). Experimental fishing at five different intensities, ranging from no fishing to four times within a single week, enabled the estimation of dose-response relationships between fishing intensity and short-term changes in various benthic community characteristics (Tulp et al., 2020). Originally, the study also aimed to include 15 paired plots (single fishing event versus a no fishing control) spread out over a large variety of areas and habitats across the Dutch coastal zone and Wadden Sea, but that part of the study was disturbed by unplanned fishing in the control parts, thereby disrupting the combined setup of the study. In the dose-response experiment a negative linear correlation was observed between fishing intensity (from zero to four times) and Pielou's species evenness, which could mainly be attributed to a positive correlation between fishing intensity and changes in the density of the Atlantic jackknife clam *Ensis leei*, also known as the American razor clam. In their discussion Tulp et al. (2020) suggested that the fisheries removed or killed many original inhabitants of the community, such as the cockle *Cerastoderma edule*, and that the vacant space became quickly colonized by the opportunistic jackknife clam, which is highly mobile and can even swim short distances (Drew, 1907; Swennen et al., 1985). The idea was also put forward that the animals might have been attracted to organic material resuspended by the experimental fishing.

Yet, an alternative explanation is that the observed increase in density is not real, but a consequence of the sampling procedure. The period between the first sampling in early to mid-July (T0) and the second sampling in late August to mid-September (T1) coincides with the growing season of the jackknife clam. The sampling gear was a trawled hydraulic dredge and all samples were sieved through a 5-mm

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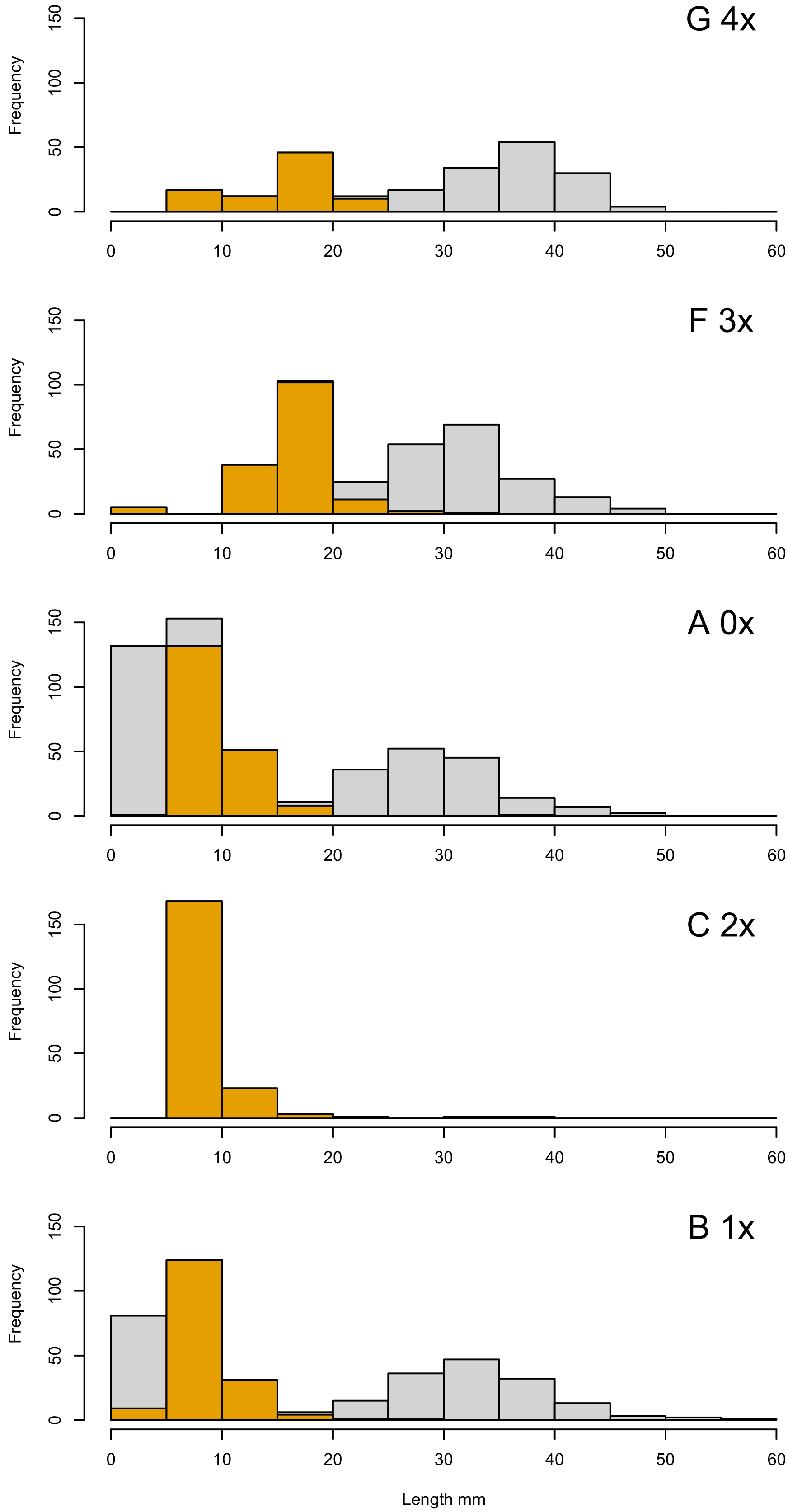

Fig. 1. Length-frequency distribution of all individual clams sampled with the box core for each of the five experimental plots. Orange-brown part refers to T0, grey represents the animals sampled at T1. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

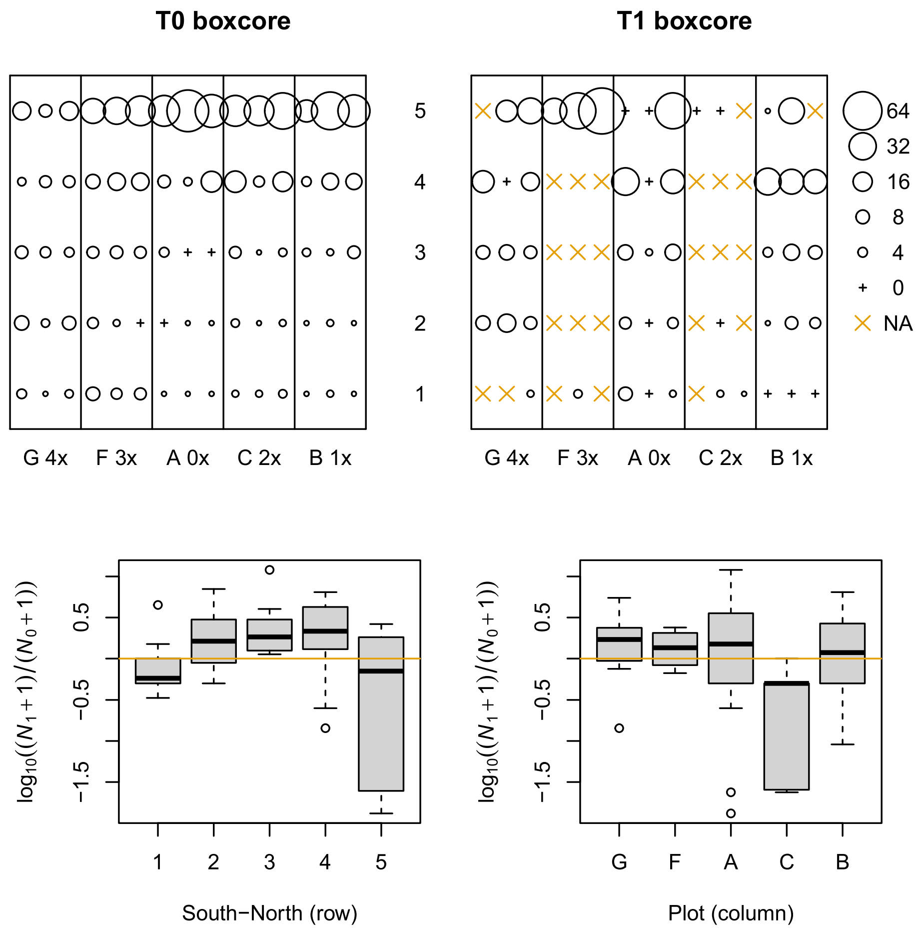

Fig. 2. Map of the sampling area, where the size of the circle is proportional to the number of individual clams within each sampled box core at T0 (upper left panel) and at T1 (upper right panel). Fishing intensity within each of the five experimental plots ranges from 0 fishing events (plot A) to 4 events (plot G). Orange-brown crosses indicate that no box core has been analysed (NA). A plus sign means that zero animals were present. The lower panels give the log-ratio between the number of individual clams per box core at T0 and at T1 for each row (left) and each column or plot (right). New recruits, i.e. clams with a length smaller than 10 mm at T1, are excluded. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

sieve, implying that clams with a width smaller than 5 mm, which is more or less equivalent with a length shorter than 30 mm (V. Escaravage, pers. comm.), had a lower chance of being caught. Animals sampled at T1 may have already been present at T0, but were at that time simply too small to be included in the sampling gear. The observed increase in density may thus be the consequence of growth. Recruitment of marine bivalves is spatially very heterogeneous, and since the five areas with different fishing intensity were not replicated, the larger increase in clam density at higher fishing intensity could easily be a coincidence, related to a specific spatial recruitment pattern.

In addition to the hydraulic dredge sampling, 15 box cores were taken in each of the five experimental plots, both at T0 and at T1, and all cores were washed through a 1-mm sieve, which implies that smaller individuals that could not be sampled with the dredge were also included. In this study we examine the density data of *E. leei* based on the box core sampling data to explore the alternative hypothesis that the positive correlation between fishing intensity and changes in the density of the Atlantic jackknife clam, as observed on the basis of the hydraulic dredge sampling, is solely a sampling artifact and was not caused by an invasion of animals into the intensely dredged areas.

2. Methods

A shallow subtidal and species-rich area of 500 by 1500 m within the western Wadden Sea, which was normally fished about two times per year, was subdivided in five adjacent plots of 500 by 300 m each. Trawling intensity during the experiment was (from the most westerly to the most easterly plot) four (plot G), three (F), zero (A), two (C), and one (B) fishing event within a single week (6–10 August 2012). In each of the five plots five parallel hydraulic dredge samples were taken, effectively excising a 7 cm deep strip of sediment with a width of 10 cm and a length of 150 m, resulting in a total sampled surface of approximately 15 m^2. Additionally, three box cores, each with a diameter of 30 cm and a surface area of 0.07 m^2, were taken as close as possible alongside each strip, i.e. 15 cores per experimental plot. Penetration depth was mostly between 30 and 35 cm (range 24–40 cm). Sampling occurred before (T0, boxcores 3, 4 and 12 July 2012, dredge 12–13 July 2012) and after (T1, boxcore 28–29 August 2012, boxcore 12–13 September 2012) the experimental fishing. All box core samples were sieved through a 1-mm mesh, and fixed in 6 % formaldehyde. In the laboratory, organisms were counted and identified to the lowest possible taxonomic level. At T1 only 50 out of the planned 75 cores were actually analysed in the laboratory, due to lack of financial project resources. For all further details we refer to Tulp et al. (2020).

3. Results

The length-frequency plots are in agreement with the notion that clams grew considerable longer in the period between early July (T0) and late August (T1). During the first sampling period most individuals are below 20 mm in length, whereas in the second period a bimodal distribution is observed, the larger individuals are almost all longer than

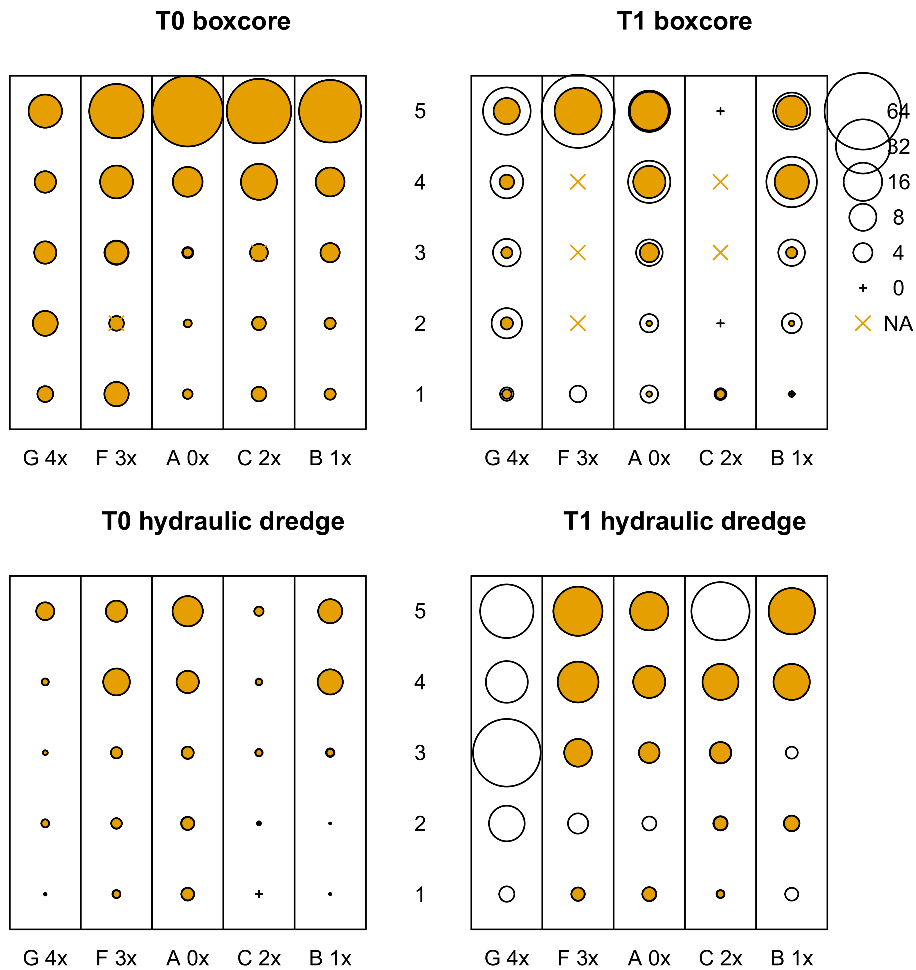

Fig. 3. Map of the sampling area, where the size of the circle is proportional to the average number of clams within each sampled box core at T0 (upper left panel) and at T1 (upper right panel), and within the hydraulic dredge at T0 and T1 (adjusted for area, i.e. numbers per 0.07 m^2). The orange-brown part refers to animals with a length less than 30 mm (in the box cores) or a width less than 5 mm (in the hydraulic dredge). Orange-brown crosses indicate that no box core has been analysed (NA). A plus sign means that zero animals were present. New recruits, i.e. clams with a length smaller than 10 mm at T1, are excluded. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

20 mm, but a new recruitment cohort with a length below 10 mm is also present in plots A and B (Fig. 1). These newly settled small individuals at T1 are left out from all further analysis, which aims to explore whether the increase in abundance in the hydraulic dredge samples between T0 and T1 could be the result of growth into the appropriate size-classes or whether immigration of larger individuals has played a role too. At both sampling occasions, the animals in plots G and F are larger than those in the other three plots. In all plots animals have grown by about 20–25 mm in eight weeks.

At T0 the spatial distribution appears very heterogeneous with a high density area in the northern part of the study area, and very low densities in the southern part (Fig. 2, upper panels). In most plots numbers increased from T0 to T1 (Fig. 2, lower right panel), indicated by positive log-ratios between the numbers in the box cores at T1 and at T0. Only plot C shows a decrease in clam density, but the number of cores analysed in plot C at T1 is limited to five (Fig. 2, lower right panel). The log-ratios do not reveal any indication of a stronger increase in numbers in the more intensely fished areas. The increase in numbers merely occurred in the middle area in rows 2–4 (Fig. 2, lower left panel). The most northern and southern parts (rows 5 and 1) showed a decrease in numbers. Overall, clam density increased between T0 and T1 at 29 sites, and decreased at 18 sites.

Tulp et al. (2020) applied a linear mixed model (library lme4 in R) with fishing intensity as a fixed factor, plot as a random factor, and the difference between T1 and T0 in the fourth-root transformed densities of the clam in the hydraulic dredge as the response variable, and reported a significant positive effect ($p = 0.028$). A similar analysis using the box core data revealed no indication of an effect of fishing intensity ($p = 0.98$).

Maps of clam densities based on the hydraulic dredge sampling confirm the relatively large increase in density in plot G, the most westerly and most intensely fished area, and to a lesser extent in plots F and C (Fig. 3).

In the first period (T0), the box core reveals much higher densities than the hydraulic dredge (Fig. 4), whereas there is no systematic difference in the second period (T1). The variation is much higher in the second period and plot C and G reveal much higher densities in the hydraulic dredge compared to the box cores, whereas the opposite is true for the plots A and F.

4. Discussion

The box core data did not confirm the relatively large increase from T0 to T1 in clam densities in the more intensely fished areas, as appeared from the hydraulic dredge data. No dose-response relationship between fishing intensity and change in clam density could be detected ($p = 0.98$). Yet, the box core data did neither support the alternative hypothesis that the more intensely fished areas (in particular plot G) already had a large number of small individuals at T0, which could not have been be sampled by the hydraulic dredge, and which would explain

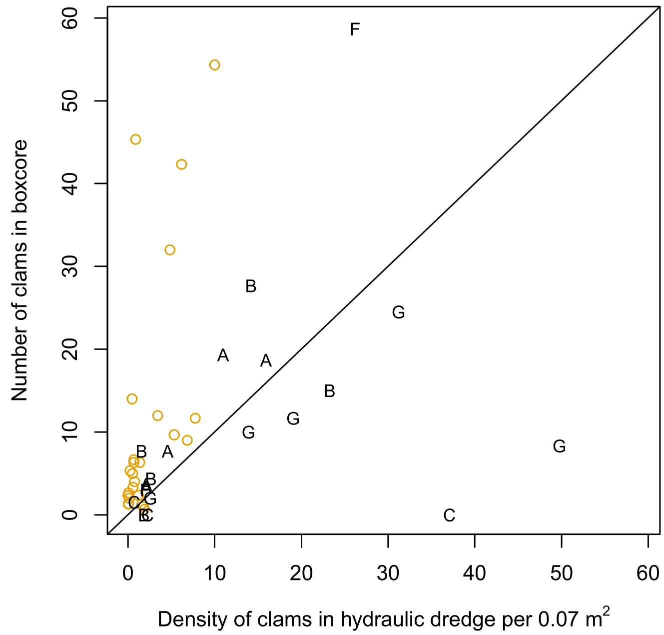

Fig. 4. Densities (per 0.07 m^2) in the hydraulic dredge versus average number of clams within a box core (surface area 0.07 m^2) at T0 (orange-brown dots) and at T1 (black letters). New recruits, i.e. clams with a length smaller than 10 mm at T1, are excluded. Line $y = x$ shows all points of equal density at both sampling occasions. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

the observed increase in the number of animals sampled by the dredge in the most heavily fished area. The box core data did point to an increase in clam density between T0 and T1 at many sites. Such increase could not be attributed to a new recruitment wave, but might point to an immigration of older animals into the area, both in the none, less and more heavily fished areas. The maps suggest an extension of the original high density area in the north into a southern direction.

The length frequency data showed that the animals grew considerably in the period between the two sampling occasions, and the observed length growth of approximately 2–2.5 cm is in accordance with earlier Wadden Sea observations (Cardoso et al., 2013) and model predictions (Wijsman, 2011). Wijsman (2011) predicts a maximum daily growth of about 0.5 mm in the first growing season. At T0 most animals were indeed too small to be accurately sampled by the hydraulic dredge, i.e., due to low efficiency of the dredge method at catching small clams, and the much higher clam densities at T0 in the box core than in the dredge could be explained by the small size of the clams at that time of the year. The fact that at T1 clams had grown into a size that can be sampled by the dredge (apart from a small number of newly recruited individuals) also explains that at T1 no overall difference in sampling density occurred between the box core and the dredge. The huge systematic variation (higher relative densities in the dredge in plots C and G, and lower densities in plots A and F) remains, however, unexplained.

So, neither the original suggestion of much stronger immigration into the heavily fished areas nor the alternative explanation that the animals were already there before experimental fishing were supported by the box core data. The unexplained discrepancy between the two types of data and the large spatial variability in clam densities require additional field experiments, with replicated randomised plots, a wider spatial coverage of the study area, and sufficient power, to shed more light on the idea that the Atlantic jackknife clam could possibly benefit from the shrimp fisheries. Conclusions on the effect of disturbance on clam densities cannot be drawn from the experimental data presented here and in Tulp et al. (2020).

CRediT authorship contribution statement

Jaap van der Meer: Writing – original draft, Formal analysis, Conceptualization. **Johan Craeymeersch:** Writing – review & editing, Formal analysis. **Sander Glorius:** Writing – review & editing, Data curation, Conceptualization. **Ingrid Tulp:** Writing – review & editing, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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References

Berghahn, R., Vorberg, R., 1998. Shrimp Fisheries and Nature Conservation in the National Park Wadden Sea of Schleswig-Holstein: Impact, Possible Conflicts of Interest and Their Prevention. Umweltbundesamt, Berlin.

Cardoso, J.F.M.F., Nieuwland, G., Witbaard, R., van der Veer, H.W., Machado, J.P., 2013. Growth increment periodicity in the shell of the razor clam *Ensis directus* using stable isotopes as a method to validate age. Biogeosciences 10 (7), 4741–4750.

Drew, G.A., 1907. The habits and movements of the razorshell clam, *Ensis directus*, Con. The Biological Bulletin 12 (3), 127–140.

Hiddink, J.G., Jennings, S., Sciberras, M., Szostek, C.L., Hughes, K.M., Ellis, N., Rijnsdorp, A.D., McConnaughey, R.A., Mazor, T., Hilborn, R., Collie, J.S., Pitcher, C. R., Amoroso, R.O., Parma, A.M., Suuronen, P., Kaiser, M.J., 2017. Global analysis of depletion and recovery of seabed biota after bottom trawling disturbance. Proc. Natl. Acad. Sci. 114 (31), 8301–8306.

Pitcher, C.R., Hiddink, J.G., Jennings, S., Collie, J., Parma, A.M., Amoroso, R., Mazor, T., Sciberras, M., McConnaughey, R.A., Rijnsdorp, A.D., Kaiser, M.J., Suuronen, P., Hilborn, R., 2022. Trawl impacts on the relative status of biotic communities of seabed sedimentary habitats in 24 regions worldwide. Proc. Natl. Acad. Sci. 119 (2), e2109449119.

Riesen, W., Reise, K., 1982. Macrobenthos of the subtidal Wadden Sea - revisited after 55 years. Helgoländer Meeresuntersuchungen 35 (4), 409–423.

Rijnsdorp, A.D., Bolam, S.G., Garcia, C., Hiddink, J.G., Hintzen, N.T., van Denderen, P. D., van Kooten, T., 2018. Estimating sensitivity of seabed habitats to disturbance by bottom trawling based on the longevity of benthic fauna. Ecol. Appl. 28 (5), 1302–1312.

Sciberras, M., Hiddink, J., Jennings, S., Szostek, C., Hughes, K., Kneafsey, B., Clarke, L., Ellis, N., Rijnsdorp, A., McConnaughey, R., Hilborn, R., Collie, J., Pitcher, C., Amoroso, R., Parma, A., Suuronen, P., Kaiser, M., 2018. Response of benthic fauna to experimental bottom fishing: a global meta-analysis. Fish Fish. 19 (4), 698–715.

Swennen, C., Leopold, M.F., Stock, M., 1985. Notes on growth and behaviour of the American razor clam *Ensis directus* in the Wadden Sea and the predation on it by birds. Helgoländer Meeresuntersuchungen 39 (3), 255–261.

Tulp, I., Glorius, S., Rippen, A., Looije, D., Craeymeersch, J., 2020. Dose-response relationship between shrimp trawl fishery and the macrobenthic fauna community in the coastal zone and Wadden Sea. J. Sea Res. 156, 101829.

Vorberg, R., 2000. Effects of shrimp fisheries on reefs of *Sabellaria spinulosa* (Polychaeta). ICES J. Mar. Sci. 57 (5), 1416–1420.

Wijsman, J.W.M., 2011. Dynamic Energy Budget (DEB) Parameters for *Ensis directus*. Technical Report C116/11. IMARES, Wageningen.