Project 2019-072

Multiple – Before After Control Impact

analysis of the effect of a 3D marine seismic survey

on Danish Seine catch rates

Preliminary M-BACI Results - Phase I (31/07/20)

Background

Multiple Before–After, Control–Impact (M-BACI) experimental designs[1] allow for robust tests of environmental impacts in real world situations. M-BACI designs involve environmental measurements taken from multiple **Impact Sites** (subjected to the disturbance and potentially affected by it) and multiple **Control Sites**, which are similar to the impact sites but not subject to the disturbance. Each site is then sampled multiple times before and after the disturbance event to ensure appropriate temporal replication. M-BACI designs are a robust impact assessment tool because (i) they account for natural spatial and temporal variation, (ii) they provide strong evidence for the disturbance event as the cause of impact, and (iii) they allow for the estimation of the magnitude of environmental change caused by the disturbance. Given this, an M-BACI experimental design was used to test the hypothesis that the catch rates of key target species (i.e. flathead and whiting) in the Danish seine commercial fishery off Lakes Entrance are impacted by marine seismic surveys (MSS).

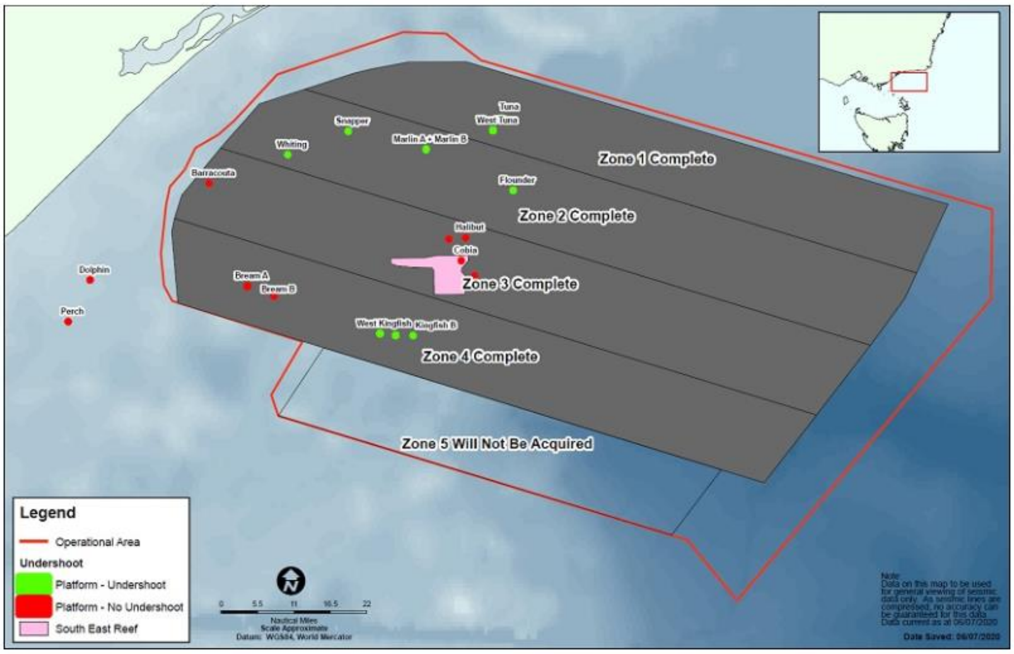

Figure 1. Region off Lakes Entrance where the CGG 3-D seismic acquisition occurred during January – July 2020 [2].

---

[1] Adapted from http://www.waterquality.gov.au/anz-guidelines/monitoring/study-design/study-type

[2] https://www.cgg.com/en/Media-and-Events/Media-Releases/2018/06/Gippsland-3D-marine-seismic-survey-information

Survey Design

Danish seine fishing

The Danish seine fleet is one of the primary commercial fishing fleets operating across (inside and outside) the area of the proposed CGG MSS. They have remained basically unchanged and have used the same method of fishing over the last half century. Vessels are typically 15–20 m long, and powered by 250–300 HP engines. Their nets are conical in shape with two long wings, a bag where fish collect and warps that connect the net to the vessel and to surround an area fished (Figure 2). They are set in a circle over relatively flat sea beds and hauled slowly back to the vessel, only moving a distance of about 1 nm while it surrounds a large, pear shaped area.

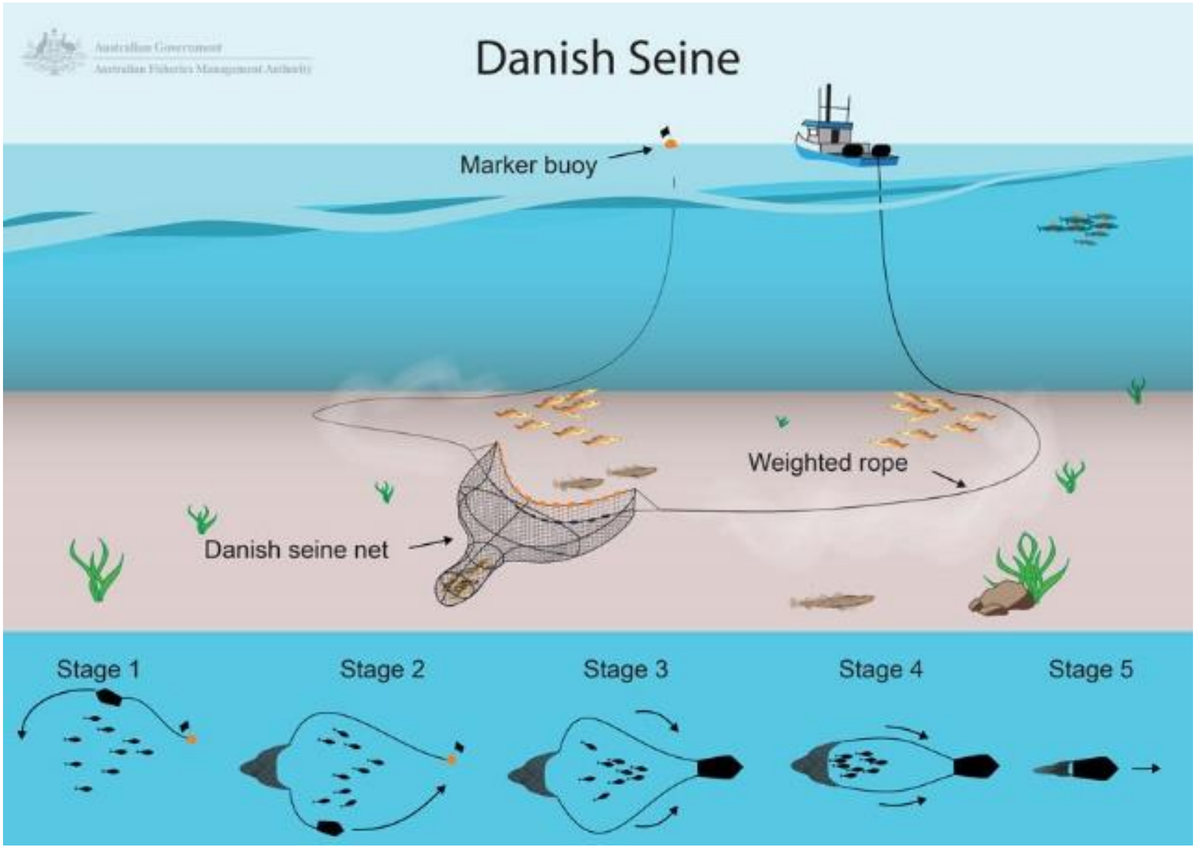

Figure 2. Schematic diagram of Danish seine fishing (AFMA).

Since 1986, it has been a requirement for Danish seine operators to maintain a commercial logbook recording the position and catch composition (by weight) of each fishing “shot”. As a result, there is extensive fine-scale spatial and temporal data on Danish seine catch rates for all key commercial species. Further, because of the relatively short shots undertaken by Danish seine vessels, up to 10 shots can be completed in a day, which is an advantage for obtaining the large number of shots required to achieve adequate statistical power in an M-BACI survey design. Because of the extensive coverage of Danish seine shots required inside and outside of the proposed MSS, this information was used as the “Before” data to estimate fish abundances in Control and Impact sites prior to the commencement of the seismic survey. The “After” data of fish abundances were then obtained through planned charters of commercial fishing vessels to work in both Control and Impact sites during and after the CGG marine seismic acquisition. This approach provided the data on fish abundances required to undertake an M-BACI analysis to assess the impact of seismic surveys on commercial catch rates in the Danish seine fishery.

Identification of M-BACI sampling sites

Detailed analysis and planning were used to identify appropriate areas that could be used as Control and Impact sites in the different Zones (Z1 – Z5) of the MSS. Ultimately, it was decided that there would be more research value to sample just in Z1 and Z2 during the period of acquisition (Phase I) and at multiple periods in the same Zones after the MSS was completed (Phase II – IV).

In general, the Impact and Control sites had similar environmental conditions, although M-BACI designs are relatively robust to site-to-site variation. Eastern School Whiting are generally caught in shallower water than flathead, so separate survey sites were required for each of these species, although it turned out that the whiting sites also provided good information on flathead catches. Control and Impact sites had relatively similar mean depths, despite the MSS coming very close inshore through the whiting grounds. Given the large variation in whiting compared to flathead catches, more whiting sites were required to achieve the same statistical power for detecting a significant impact interaction. The final experimental design included two Control and two Impact sites for flathead only, and four Control and four Impact whiting sites that also acted as flathead sites. At each site, between 10–20 fishing "shots" were carried out in a 5 km radius (Figure 3).

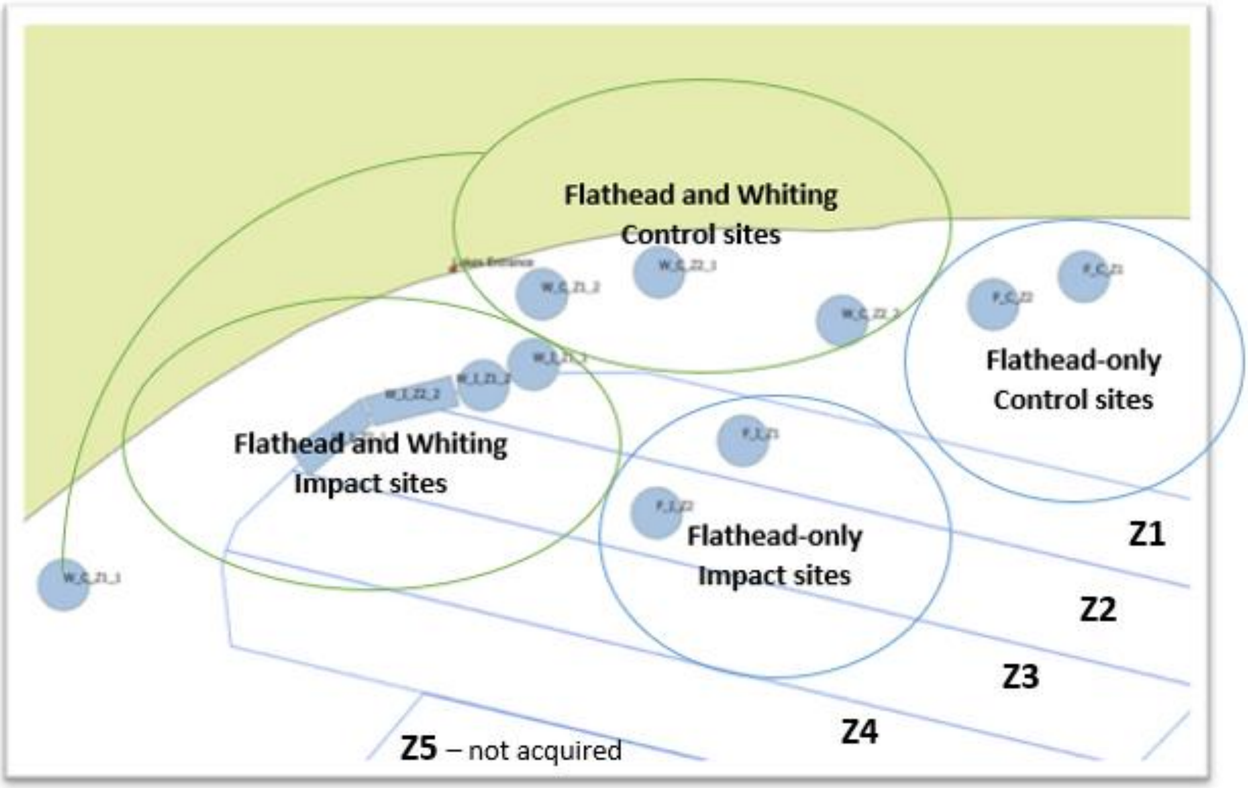

Figure 3. Sites surveyed during Phase 1 M-BACI indicating Control and Impact Sites for flathead and whiting.

Scientific observers were onboard during each M-BACI shot undertaken by chartered Danish seine vessels to monitor the validity of each shot with respect to the experimental design and record the catch composition of species in each shot and the length-frequency of whiting and flathead in the catch.

To complete the work, the FRDC and CGG, with the agreement of the CGG Scientific Advisory Committee (SAC), established the project timeline shown in Figure 4. This timeline allowed for the time required to complete each round of sampling, an appropriate interval between times of sampling, and the capacity to detect any potential recovery in the years following the completion of the seismic surveys.

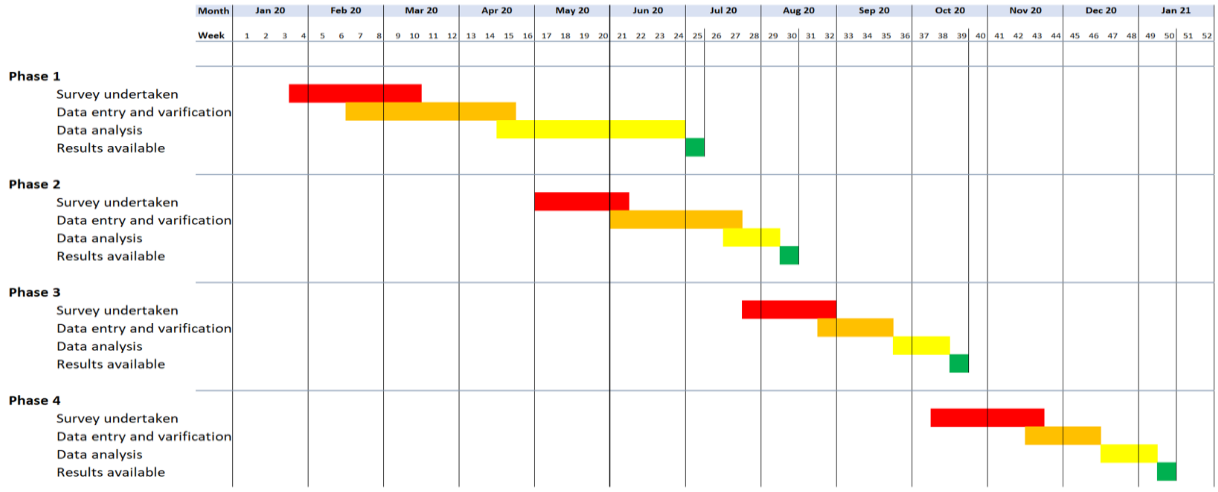

Figure 4. Project timelines indicating survey period, data entry and verification, data analysis and reporting for each Phase of the M-BACI survey.

Preliminary M-BACI Results - Phase I

Whiting

- The catch frequency (per shot) of whiting was heavily skewed, with small catches being the most common (Figure 5) and a lot of zero-catch shots being recorded.
- Transforming the data using a *log +1* function changed the distribution to approximately normal, but highlighted that it remained "zero-inflated".
- This, and other diagnostic tests revealed that analysis of these data required the use of a "zero-inflated gaussian model" for the M-BACI analysis. Basically, this method compares not only the average whiting catch rate achieved in the Control and Impact Sites from before to after the seismic survey, but also the relative proportion of zero-catch shots.

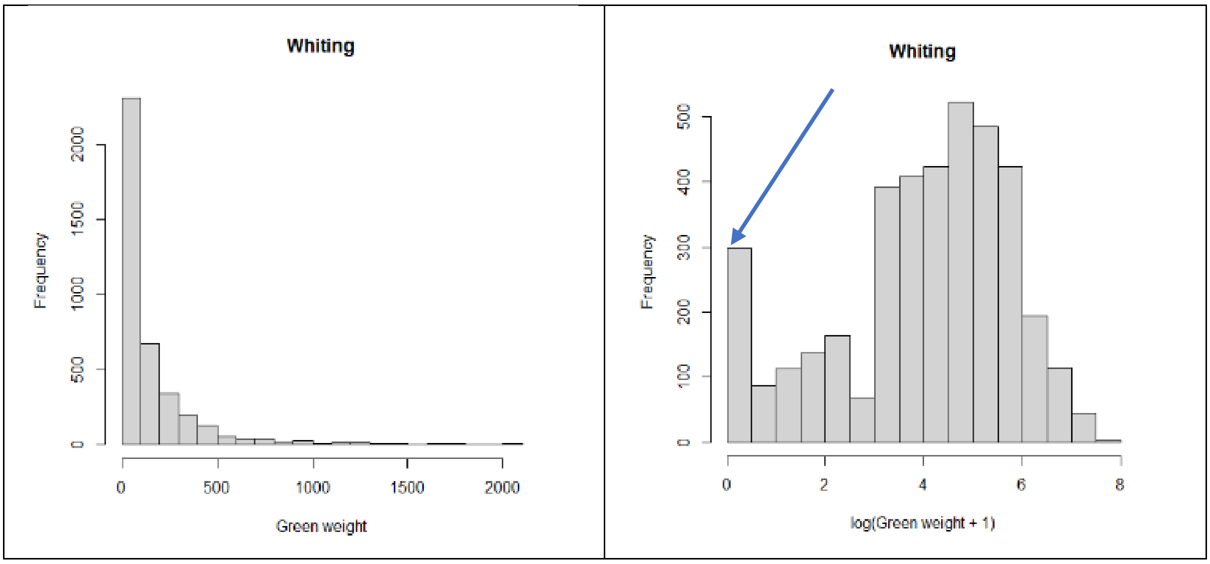

Figure 5. Histogram of frequency of raw (left) and logged (right) catch weights from survey areas targeting whiting.

- Prior to 2014 it appears that management arrangements were such that logbook reporting did not include shots with zero commercial catch. As a consequence, we restricted the time series of "Before" data from logbooks to records from 2014 onwards (Figure 6).
- When targeting whiting, Danish seine shots with zero catches of whiting generally comprised 5–10% of catch records.
- During the 2020 M-BACI survey, zero catches comprised 4% of records in Control sites and 95% of records in Impact sites.

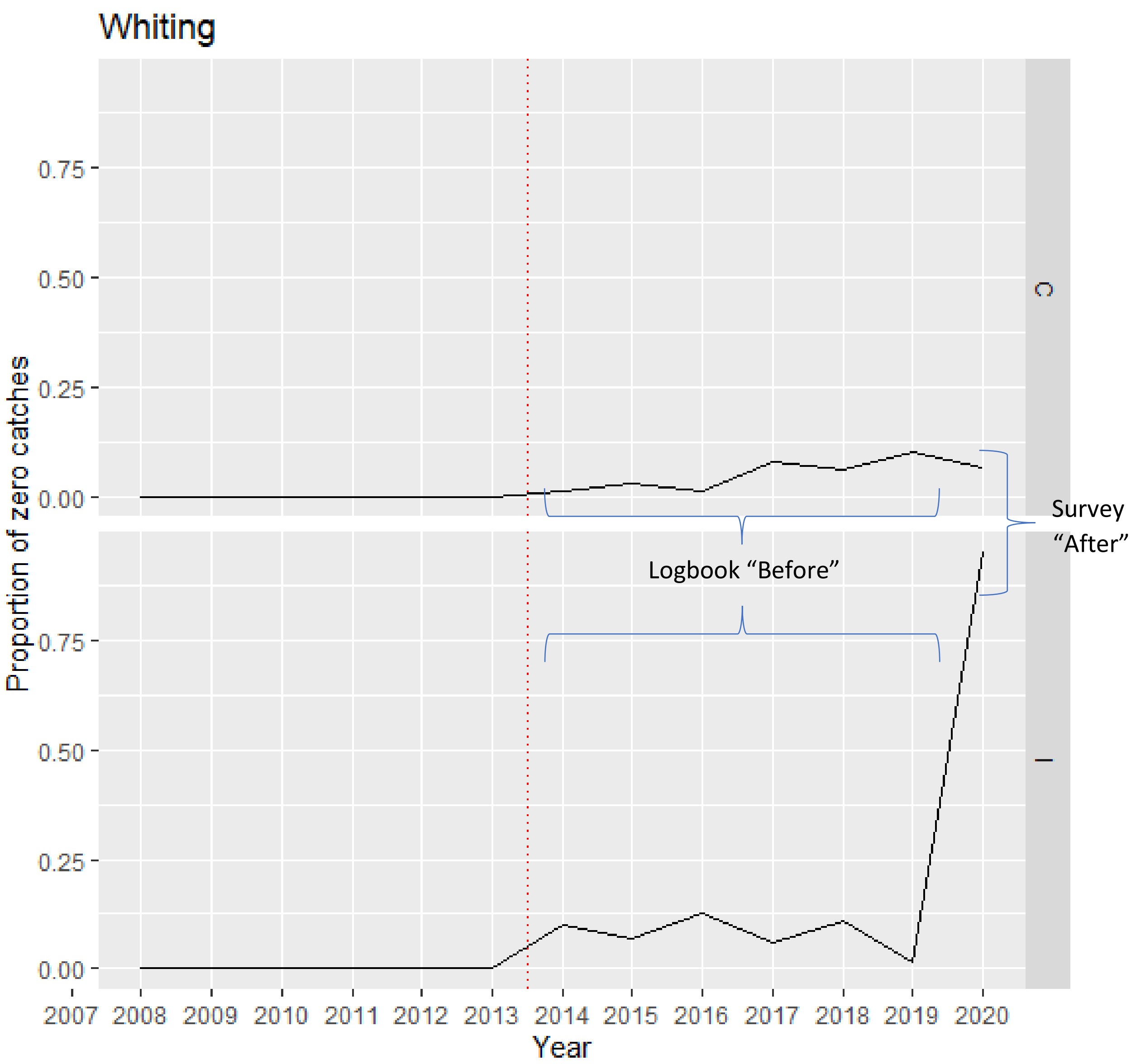

Figure 6. Proportion of catch records with 0 kg catches of Eastern School Whiting in control (top) and impact (bottom) sites.

- Commercial catches of whiting (from logbook data) exhibit substantial year-to-year variation (Figure 7).
- During the M-BACI survey, average catches of whiting at Impact Sites were 0.5% of those from Control Sites.
- Analyses showed statistically significant impact interactions for whiting catch rates and the number of zero catches of whiting. These interactions were driven by relatively lower catches and increased numbers of zero catches of whiting in Impact sites relative to Control

sites. This provided robust evidence for a negative impact of seismic surveys on whiting catches in the Danish Seine Fishery.

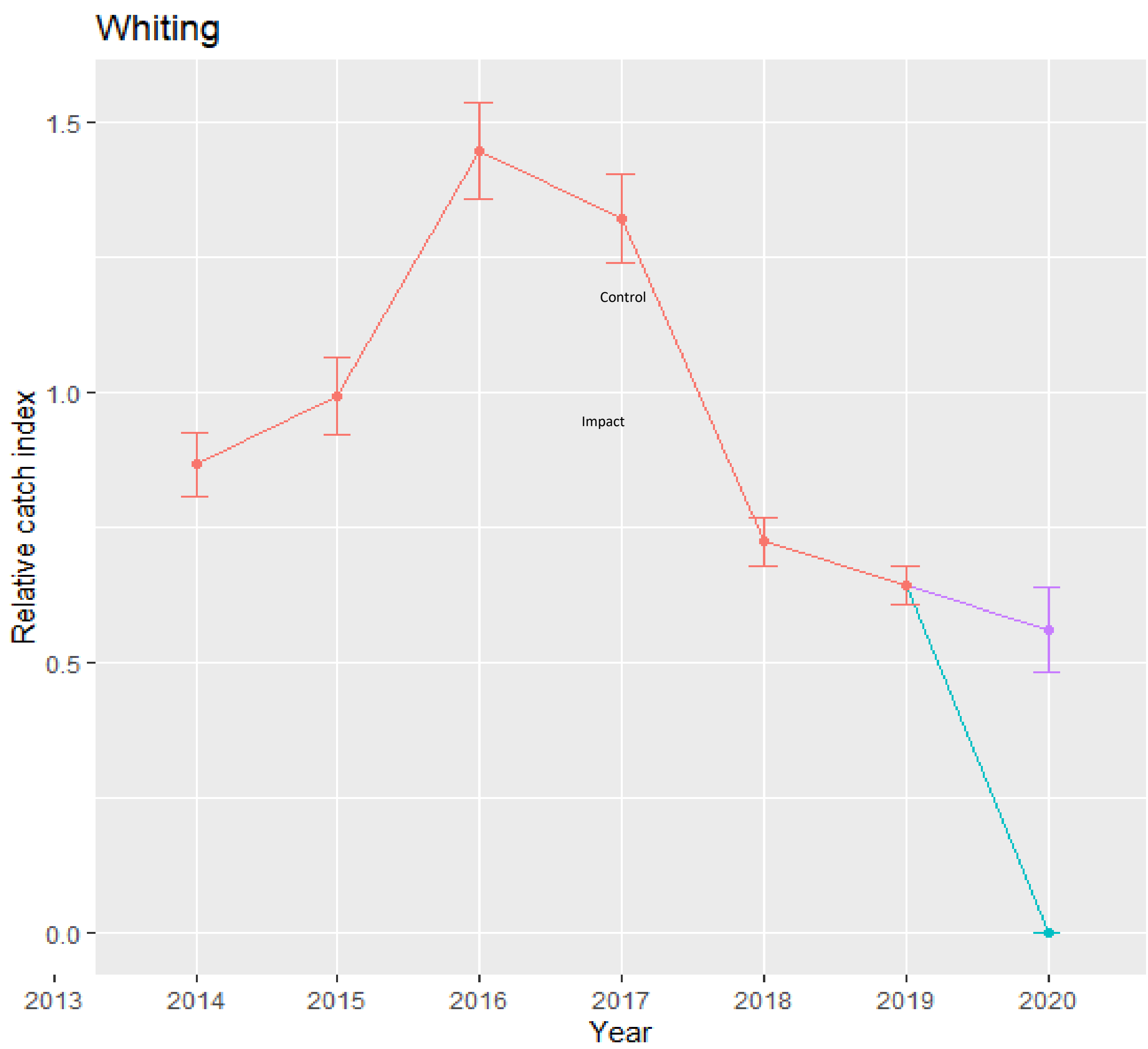

Figure 7. Relative catch index at survey sites for commercial whiting shots from 2014 to 2019 and 2020 survey shots

Flathead

- The catch frequency of flathead (per shot) was heavily skewed, with small catches being the most common (Figure 8).
- Transforming the data using a *log +1* function changed the distribution to approximately normal, meeting the requirements of a parametric statistical analysis.
- Diagnostics indicated that the flathead data were not zero-inflated, as there were very few zero catches in the commercial flathead data (Figure 9).
- During the 2020 M-BACI survey, zero catches comprised 2% of records in Control Sites and 22% of records in Impact Sites.

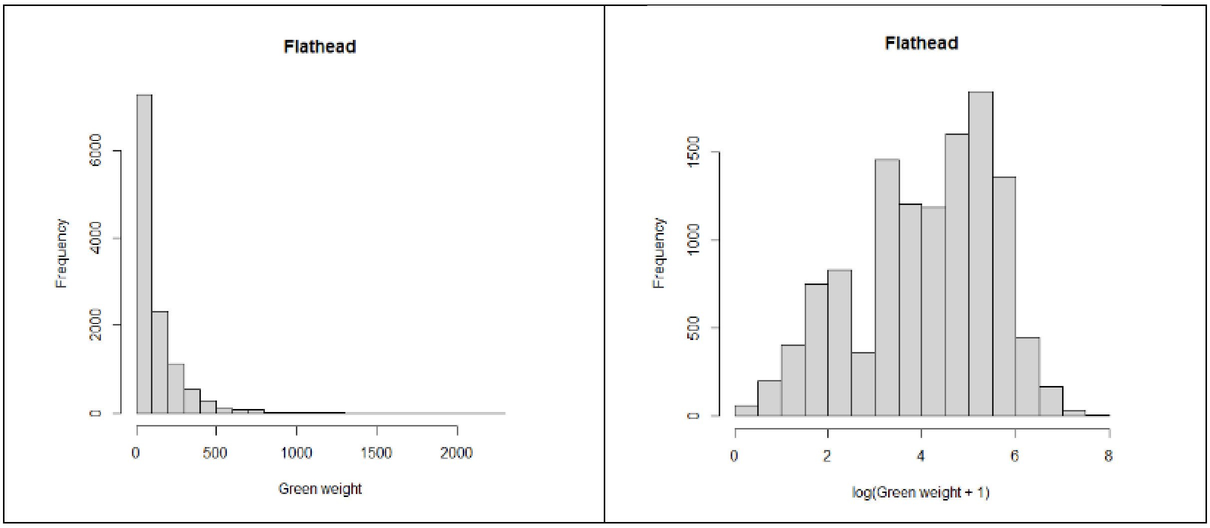

Figure 8. Histogram of frequency of raw (left) and logged (right) catch weights from survey areas targeting flathead.

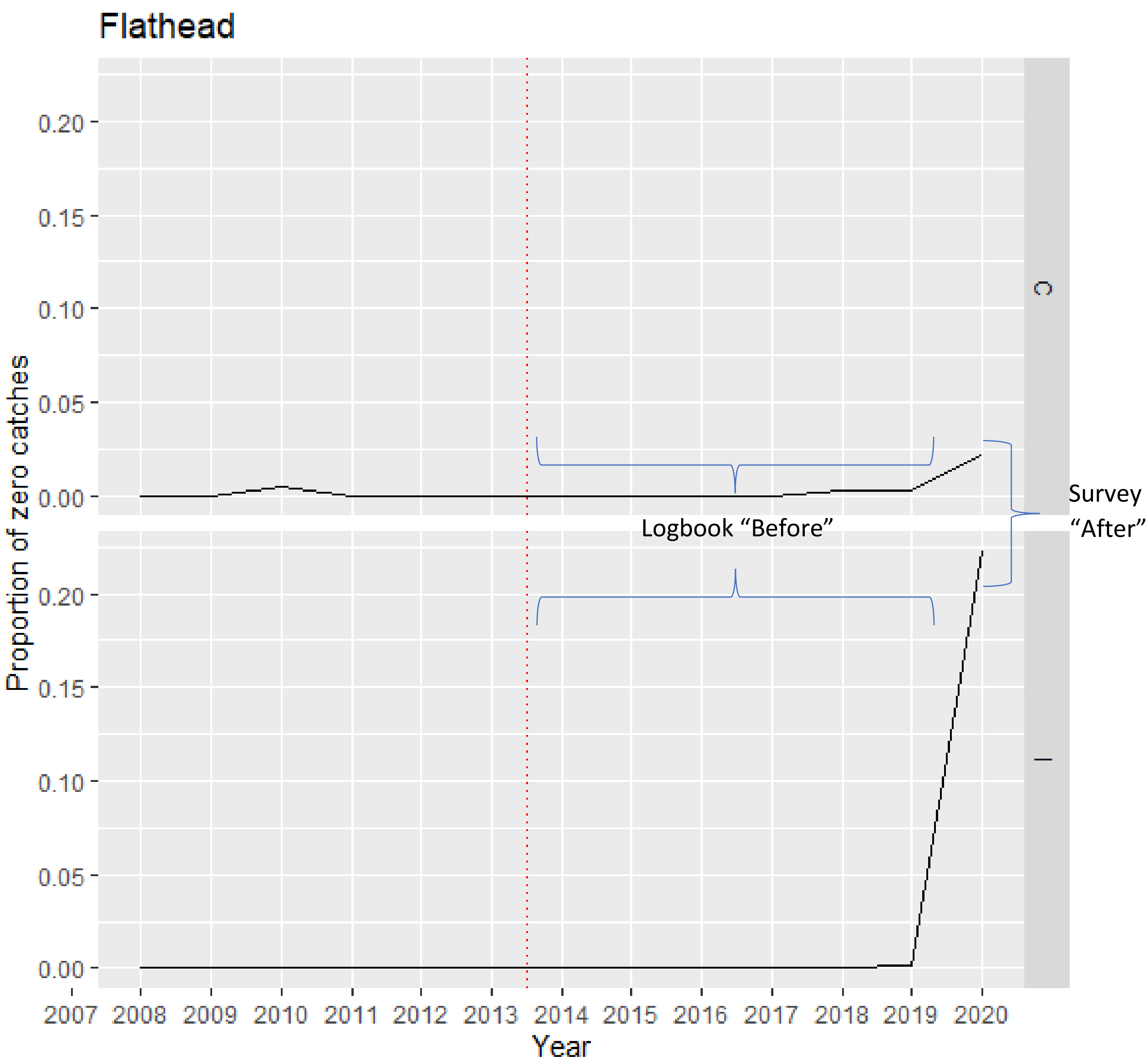

Figure 9. Proportion of catch records with 0 kg catches of flathead in control (top) and impact (bottom) sites.

- In general, commercial flathead catches (from logbook data) declined over 2015 to 2019 (Figure 10).
- During the M-BACI survey, the average catch of flathead at Impact Sites was 29% of those recorded at Control Sites, which underpinned a significant impact interaction.
- These results indicate that seismic surveys had a negative impact on flathead catches in the Danish Seine Fishery.

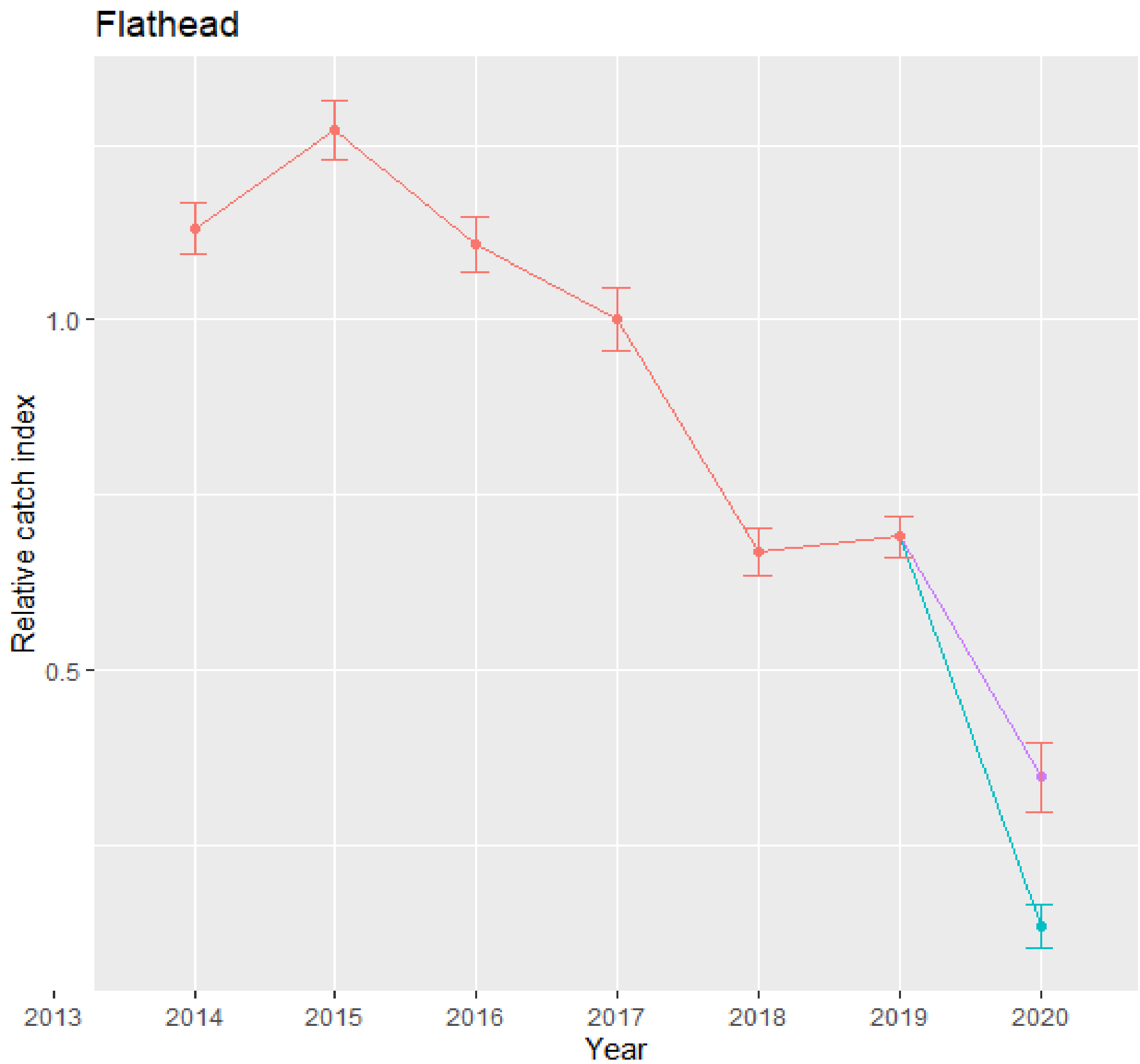

Figure 10. Relative catch index at survey sites for commercial flathead shots from 2014 to 2019 and 2020 survey shots.