Project 2019-072
Multiple – Before After Control Impact analysis of the effect of a 3D marine seismic survey on Danish Seine catch rates

Summary Results: Phase I, II & III

15 October 2020

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 that 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. An M-BACI experimental design was used to test whether catch rates of key target species (i.e. flathead (*Platycephalus spp*.) and whiting (*Sillago flindersi*)) in the Danish seine commercial fishery off Lakes Entrance are impacted by marine seismic surveys (MSS).

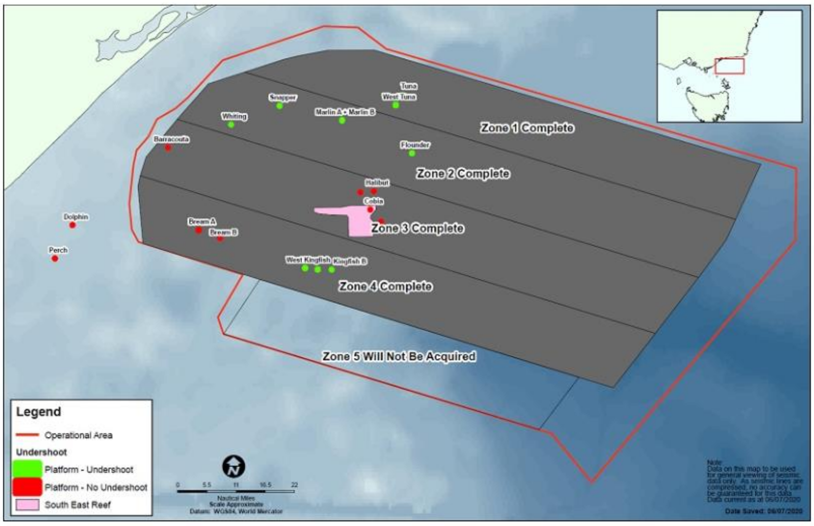

Figure 1. Region off Lakes Entrance where the CGG 3-D seismic acquisition occurred during January – July 2020 [2].

[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 data

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 generate 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 catch rates in Control and Impact sites prior to the commencement of the seismic survey. The “After” data of catch rates were then obtained through charters of commercial fishing vessels to work in both Control and Impact sites during and after the CGG marine seismic acquisition.

Identification of M-BACI sampling sites

Appropriate areas to be used as Control and Impact sites in the different Zones (Z1 – Z5) of the MSS were chosen. In general, the Impact and Control sites were similar, although M-BACI designs are relatively robust to site-to-site variation. 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 catches compared to those of flathead, 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, 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 2).

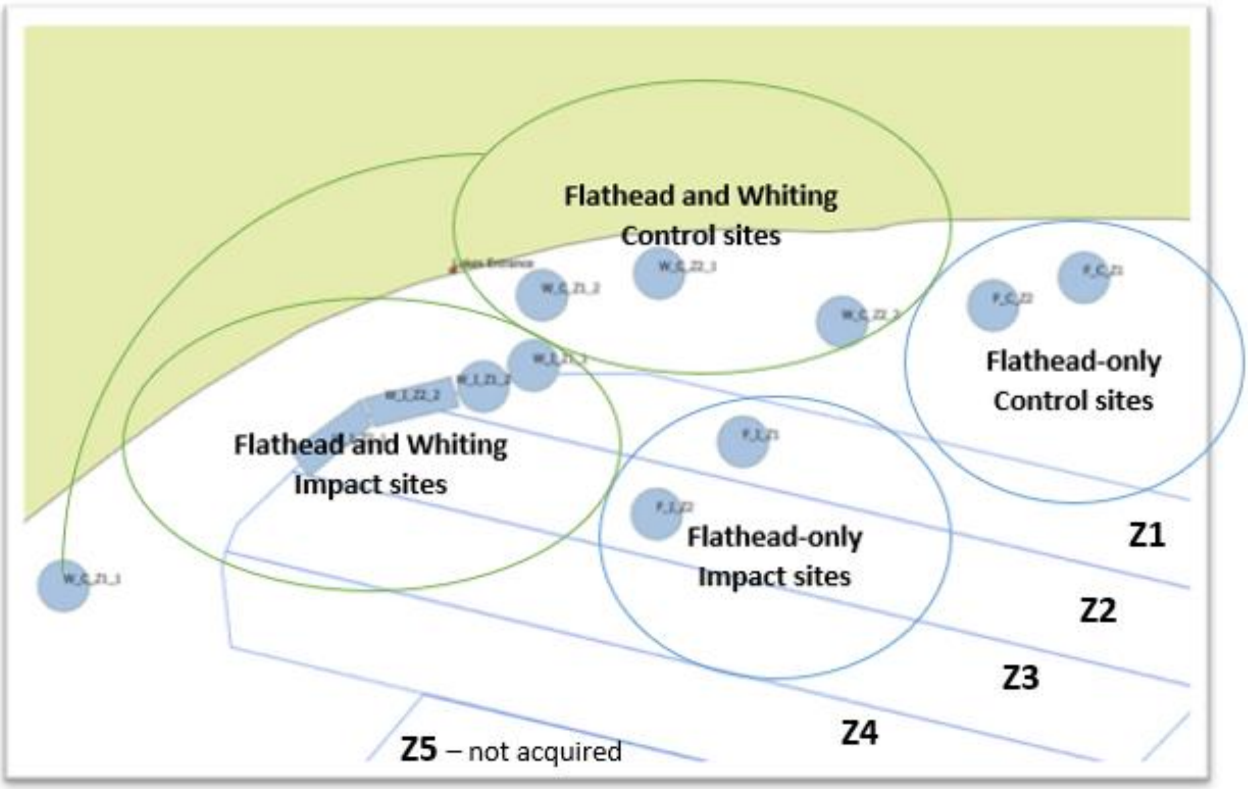

Figure 2. Sites surveyed during Phase 1 M-BACI indicating Control and Impact Sites for flathead and whiting.

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.

Ultimately, it was decided that it would be of more research value to sample just in Z1 and Z2 during the first period of data acquisition (Phase I) and in the same Zones at multiple periods following the MSS acquisition (Phase II – IV) as shown below:

	M-BACI				Z2 & Z1 MSS		
Phase	Start	Mid	End	Duration (days)	Start 2/01/20	Mid 15/02/20	End 30/03/20
					MSS -> M-BACI Interval (days)		
I	25/01/20	17/02/20	12/03/20	48	23	2	-18
II	5/05/20	18/05/20	1/06/20	28	124	93	63
III	3/08/20	21/08/20	10/09/20	39	214	189	164
IV (yet to start)	5/11/20	19/11/20	5/12/20	31	308	279	250

Preliminary M-BACI Results: Phase I – III

M-BACI Model

During Phase I it was noted that there were a lot of "zero shots" occurring (targeted shots that did not catch whiting or flathead). This resulted in the catch frequency (per shot) being skewed, with zero or small catches being the most common, particularly for whiting (Figure 3). This type of "zero-inflated" data is problematic to analyse, so the data were log-transformed and a Tweedie distribution[3] was used in the M-BACI model to deal with the zero inflation.

Prior to 2014, management arrangements were such that logbook reporting did not include shots with zero commercial catches of particular species. As a consequence, we restricted the time series of "Before" data from logbooks to records from 2014 onwards (Figure 6).

The analysis used the data from all Phases of the study. The before/after impact variable was given four categories. That is, "Before", "After1", "After2" and "After3" corresponding to pre-MSS (2014-2019), Phase I, Phase II, and Phase III, respectively. This enabled the impact effect at all Phases to be quantified. The analysis also considered a linear effect of year, and quarter (of the year) as a factor, but for whiting these were not significant and hence were removed.

The Tweedie model was fitted to the Phase I to III whiting data.

For flathead, the GLMM model was identical to that fitted to whiting, except that the effect of year and quarter were both significant and hence are included in the model.

[3] See simple description of a Tweedie distribution at https://en.wikipedia.org/wiki/Tweedie_distribution

Whiting

Analysis of catch distribution and zero shots

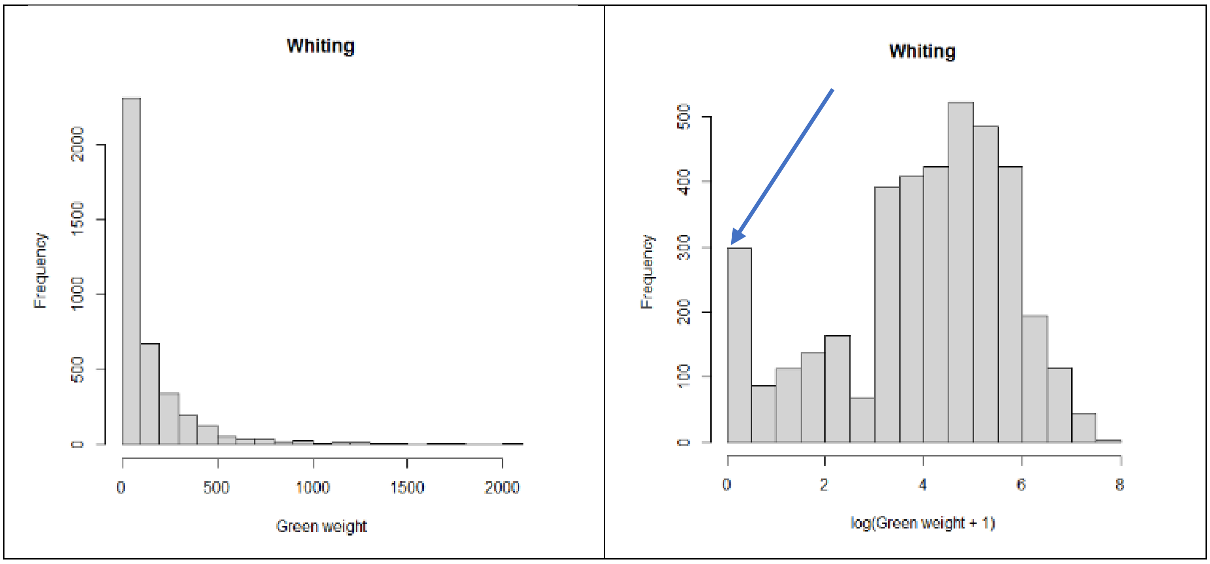

Figure 3. Histogram of frequency of raw (left) and logged (right) catch weights from Phase I M-BACI shots targeting whiting (arrow points to the zero inflation).

- When targeting whiting, commercial Danish seine shots with zero catches of whiting generally comprised 5–10% of catch records.
- During Phase I, zero catches comprised 7% of records in Control sites and 95% of records in Impact sites.
- During Phase II, zero catches comprised 14% of records in Control sites and 23% of records in Impact sites.
- During Phase III, zero catches comprised 16% of records in Control sites and 33% of records in Impact sites.

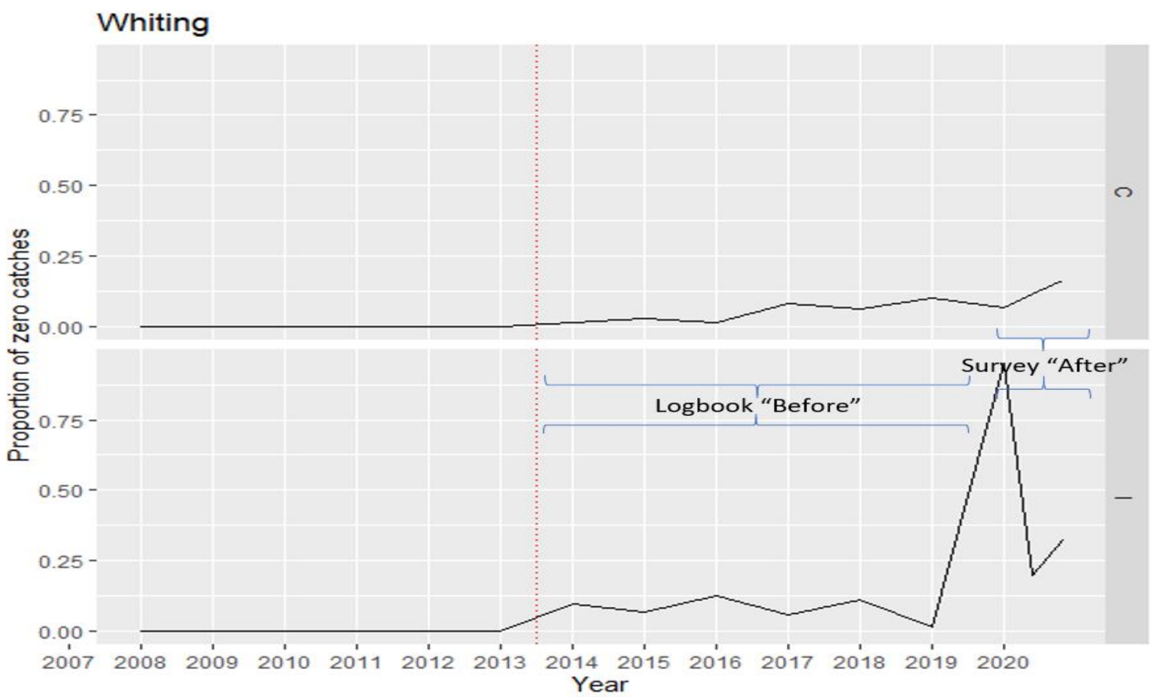

Figure 4. Proportion of catch records with 0 kg catches of Eastern School Whiting in control (top) and impact (bottom) sites.

Analysis of catch rates

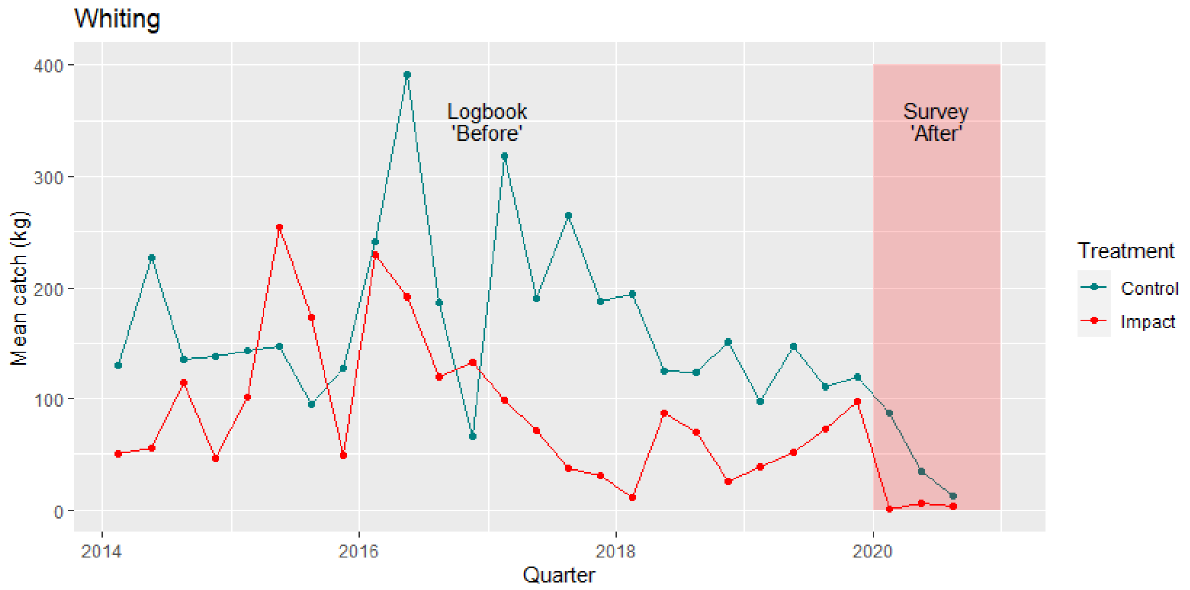

Figure 5. Relative catch index at survey sites for commercial whiting shots from 2014 to 2019 and 2020 Phase I to Phase III survey shots.

- Commercial catches of whiting (from logbook data) exhibited substantial year-to-year variation (Figure 5).

- During Phase I, the impact effect on whiting was estimated to be a 99.7% reduction in catch rates relative to Control Sites This is statistically significant.

- During Phase II, the impact effect on whiting was estimated to be a 42.7% reduction in catch rates relative to Control Sites. This is statistically significant.

- During Phase III, the impact effect on whiting was between 79.5% less and 60.1% more than those from Control Sites. This is not statistically significant.

Overall, the M-BACI analyses provide robust evidence for a negative impact of seismic acquisition on whiting catch rates in the Danish Seine Fishery up to ~100 days following the MSS.

Flathead

Analysis of catch distribution and zero shots

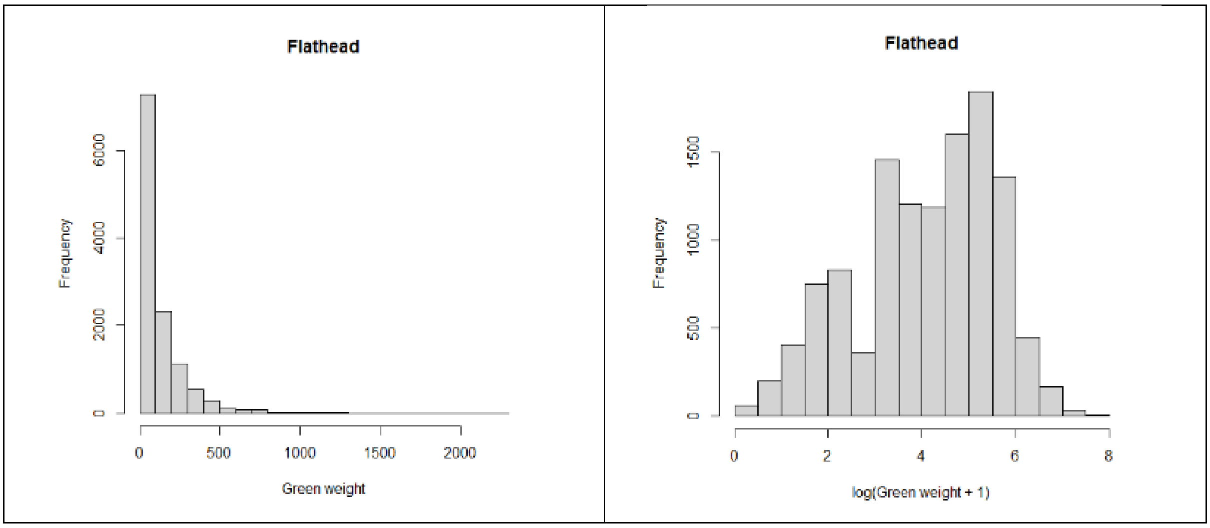

Figure 6. Histogram of frequency of raw (left) and logged (right) catch weights from survey areas targeting flathead.

- The catch frequency of flathead (per shot) was heavily skewed, with small catches being the most common (Figure 6).
- Diagnostics indicated that the commercial flathead data were not zero-inflated (Figure 6). However, zero inflation was observed following MSS (Figure 7).
- During Phase I, zero catches comprised 2% of records in Control Sites and 22% of records in Impact Sites.
- During Phase II, zero catches comprised 9% of records in Control Sites and 5% of records in Impact Sites.
- During Phase III, zero catches comprised 20% of records in Control Sites and 25% of records in Impact Sites.

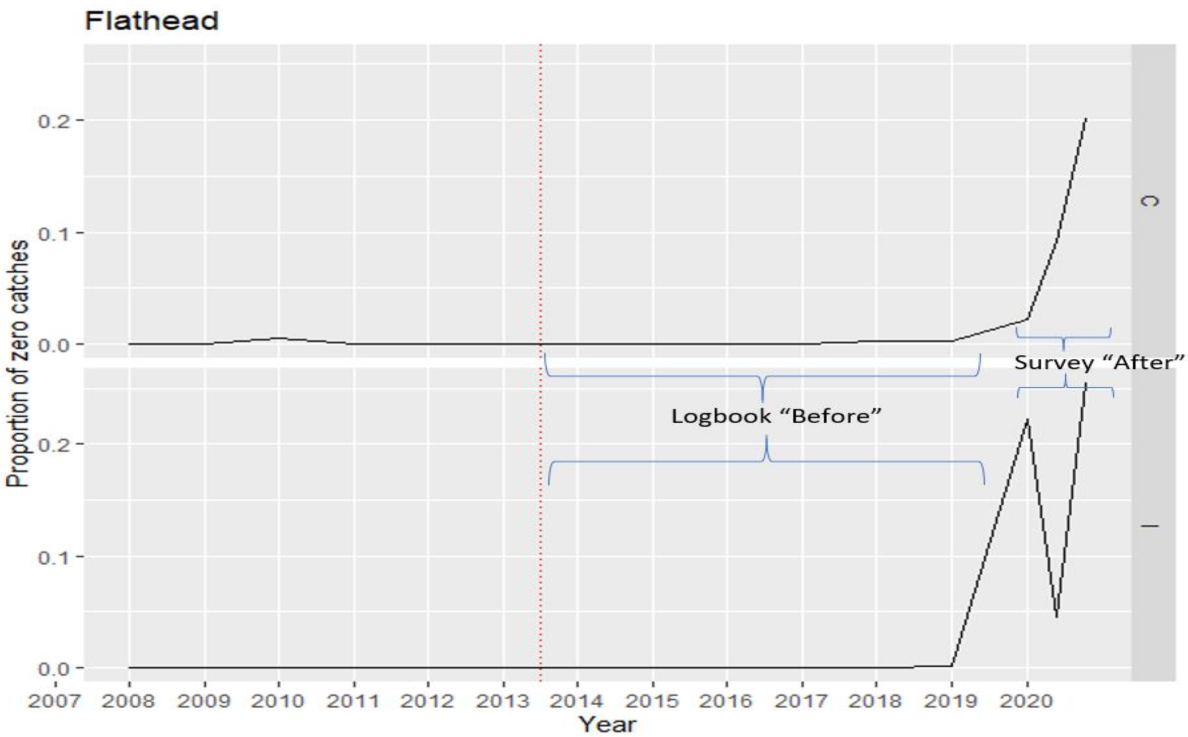

Figure 7. Proportion of catch records with 0 kg catches of flathead in control (top) and impact (bottom) sites.

Analysis of catch rates

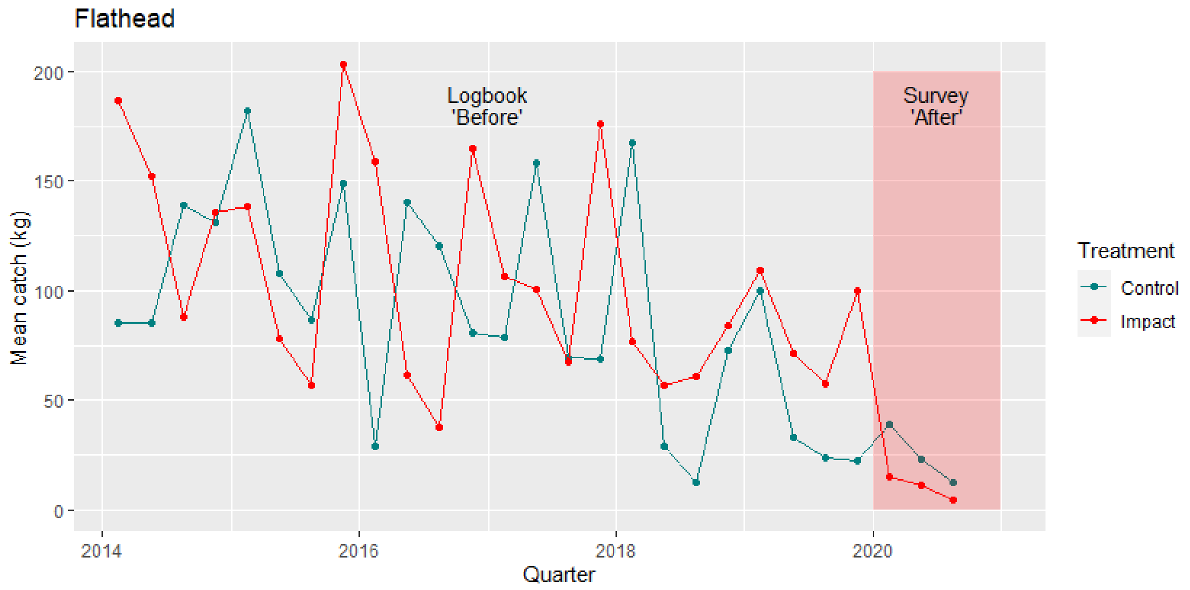

Figure 8. Relative catch index at survey sites for commercial flathead shots from 2014 to 2019 and 2020 survey shots.

- In general, commercial flathead catches (from logbook data) declined over 2015 to 2019 (Figure 8). The decline continued during 2020.
- During Phase I, the impact effect on flathead was estimated to be a 78.1% reduction in catch rates relative to Control Sites. This was statistically significant.
- During Phase II, the impact effect on flathead was estimated to be a 58.0% reduction in catch rates relative to Control Sites. This was statistically significant.
- During Phase III, the impact effect on flathead was estimated to be a 65.5% reduction in catch rates relative to Control Sites. This remained statistically significant.

Overall, the M-BACI analyses provide robust evidence for a negative impact of the seismic acquisition on flathead catch rates in the Danish Seine Fishery up to ~200 days following the MSS.