MIT2022-05: Large vessel trawl warp mitigation

Presentation to DOC CSP Technical Working Group
9 March 2023

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DRAGONFLY
Data Science

Project context

- Mandatory mitigation in large vessel trawl fisheries were introduced in the early 2000s, but mitigation requirements have remained largely unchanged for several years.

- Whilst substantial reductions in seabird bycatch estimates were documented in the 2000s, there has been little evidence for further bycatch rate reduction in more recent years.

- Since the introduction of mandatory mitigation, substantial new data on bycatch between vessels and across sectors of the fleet is available from relatively high levels of observer coverage.

- Of particular note, some mitigation used, i.e., bird bafflers, are not currently recognised as best practice globally.

Project context

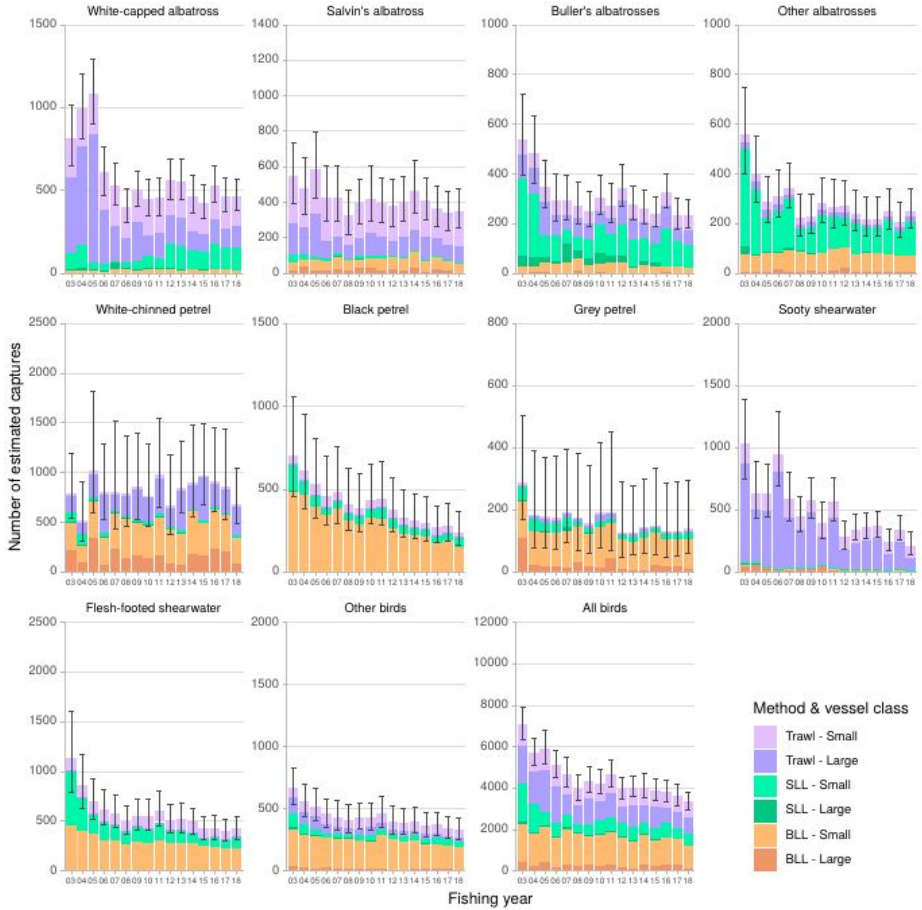


Figure 6 from Abraham and Richards (2020)

- Time series of the number of estimated captures for the seabird species groups and for all birds for the 2002–03 to 2017–18 fishing years.
- Estimates are shown by fishing method and vessel size class.
- Cut-off lengths for small and large vessel size classes were 45 m, 34 m, and 28 m, for surface-longline (SLL), bottom- longline (BLL), and trawl fishing, respectively.
- Coloured bars indicate the mean number of captures, error bars are the 95% credible interval in the total number of estimated captures within each fishing year.
- Note different y-axis scales.

Approach

Investigate whether the recorded designs of the mitigation devices are impacting their effectiveness.

- Determine whether modelling can identify optimal device combinations or configurations based on available data (Part1)

- Characterise and summarise the mitigation device data, which includes device measurements (Part 2)

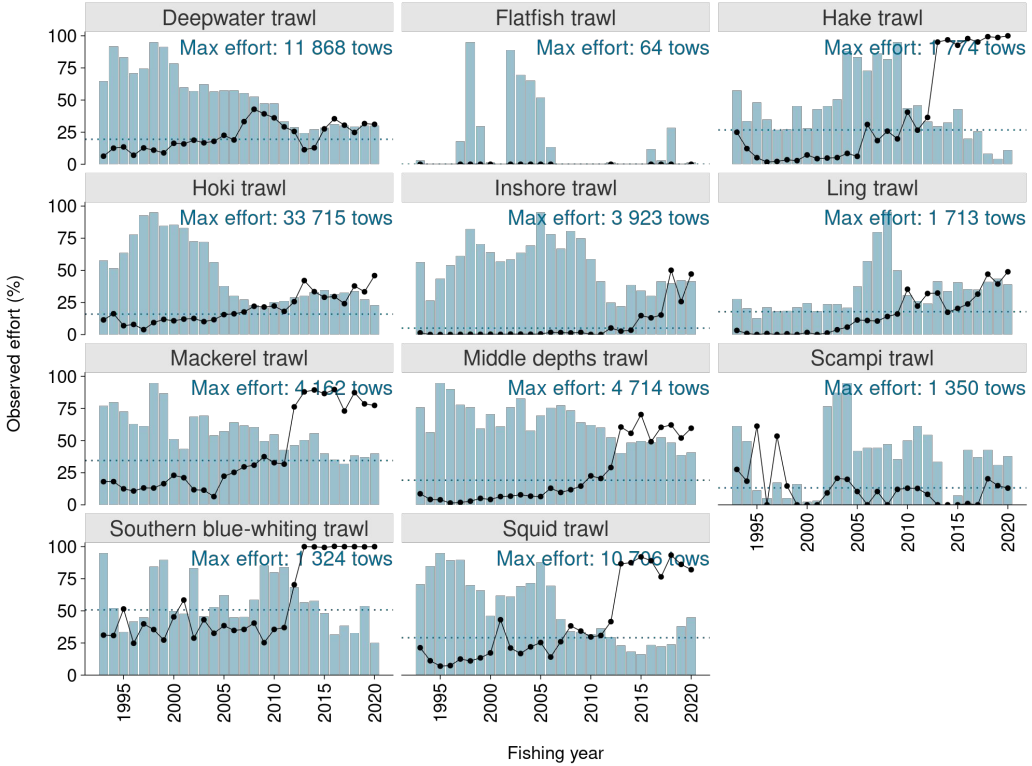
    - Using the device data characterisation, liaise with stakeholders to determine:
        i. ideal device design and deployment;
        ii. whether device design details are evident in the data;
        iii. how the data could best be summarised to inform mitigation effectiveness; and,
        iv. how the data collection and reporting can be improved to better inform mitigation effectiveness.

Data

Observed large vessel trawl effort

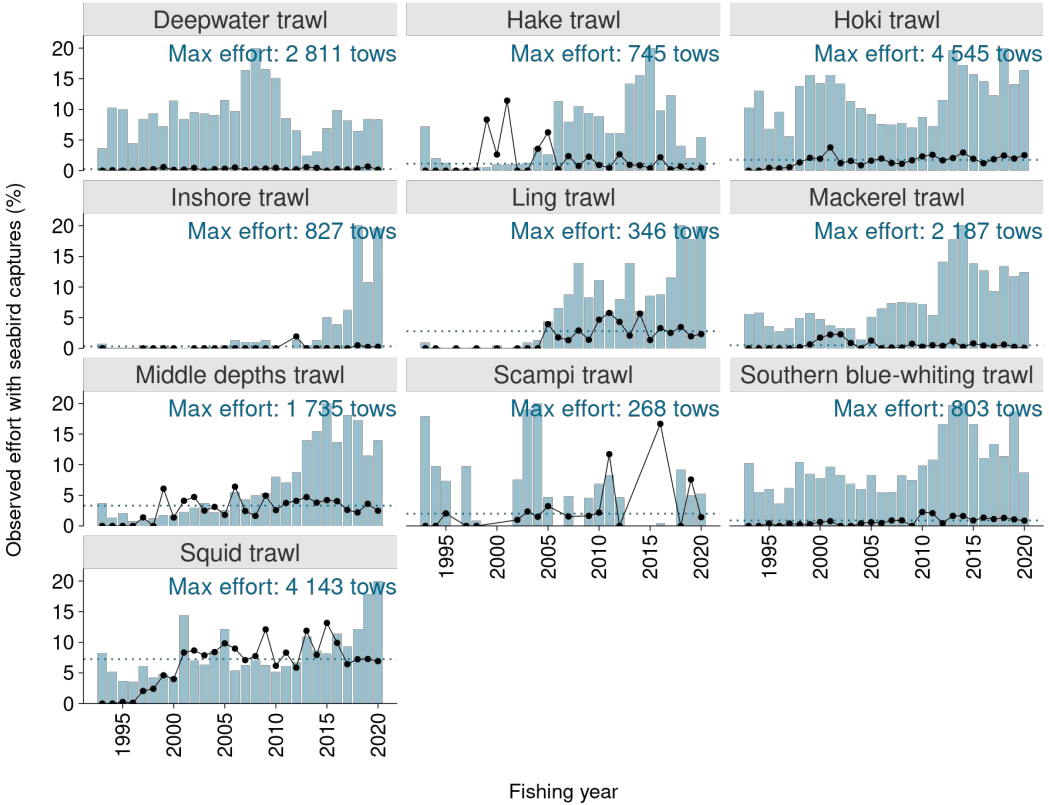
Number of observed tows (green), with seabird captures (grey), and with warp captures (pink), by fishery group, 1993-2020

Data



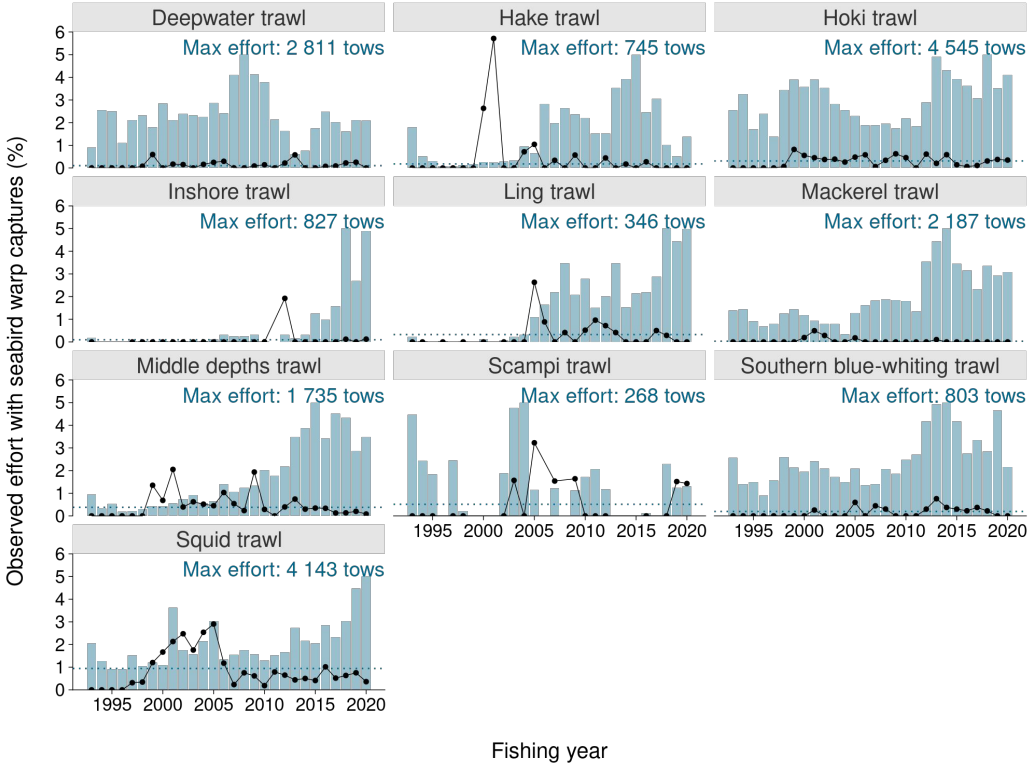
- Proportion of large vessel trawls that were observed (black line).
- Total effort (blue bars)
- By fishery and fishing year

Data



- Proportion of observed effort with observed seabird captures (black line).
- Observed effort (blue bars)

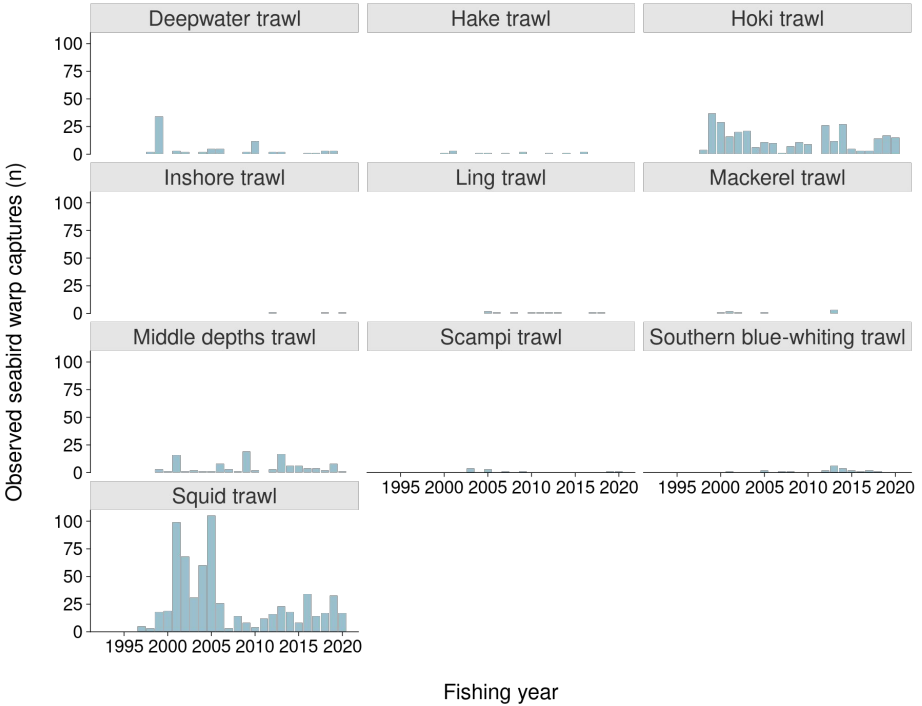
Data

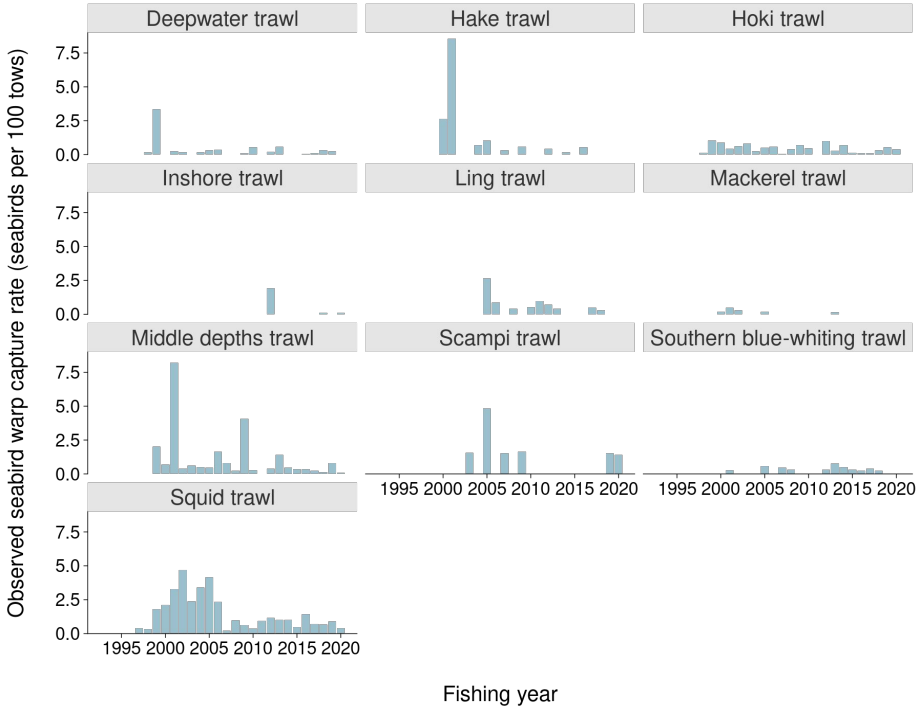


- Proportion of observed effort with seabird warp captures (back line)
- Observed effort (blue bars)

Data

- Observed warp captures (left) and warp capture rates (right) in observed large vessel trawls





Data

Number of tows with warp mitigation use recorded

B = baffler only
T = tori only
W = warp scarer only
BT = baffler and tori line
BS = baffler and warp scarer
TS = tori line and warp scarer
BTS = baffler, tori line and warp scarer

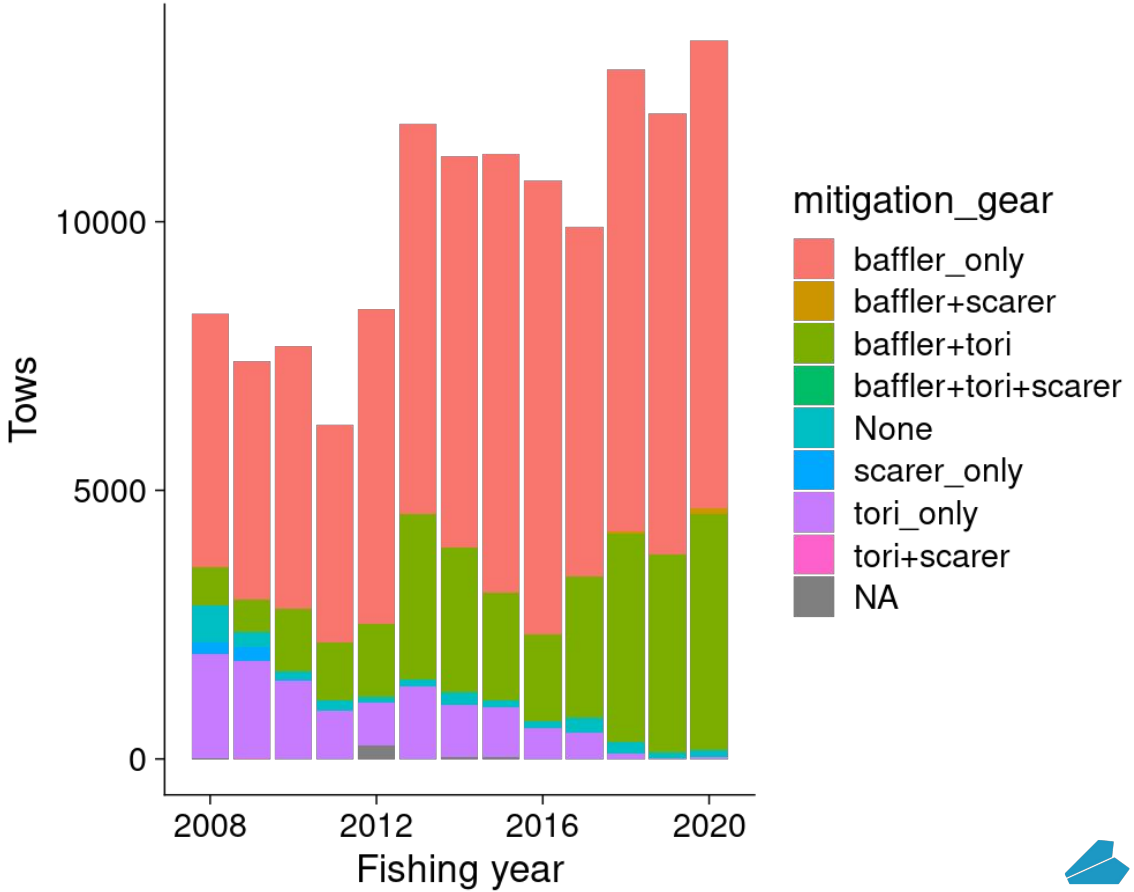
- Reliable recorded since 2008
- Not recorded an None records are probably misreported and not true “nones”.

fyear	Not_recorded	None	B	T	S	BT	BS	TS	BTS
1993	6429	-	-	-		-			
1994	6657	-	-	-		-			
1995	4676	-	-	-		-			
1996	4052	-	-	-		-			
1997	4534	-	-	-		-			
1998	6418	-	-	-		-			
1999	6695	-	-	-		-			
2000	6779	-	-	-		-			
2001	8753	-	-	-		-			
2002	7103	-	-	-		-			
2003	6453	-	-	-		-			
2004	6364	-	-	-		-			
2005	7587	-	-	-		-			
2006	6183	-	-	-		-			
2007	4817	377	993	870	55	133			
2008	5	697	4738	1941	207	696		12	
2009	-	277	4447	1803	259	605		15	
2010	-	152	4878	1458	12	1176	1		
2011	-	189	4043	904		1077			
2012	245	104	5874	803		1354			
2013	-	127	7265	1350	1	3073	1		
2014	37	250	7281	959		2695			
2015	29	134	8178	929		1993			
2016	-	127	8436	574		1619			
2017	1	286	6508	477		2628			
2018	1	225	8595	92		3866	58		
2019	-	124	8211	4		3679			1
2020	-	137	8720	25		4406	90		2

Data

Recorded warp mitigation use for observed trawls

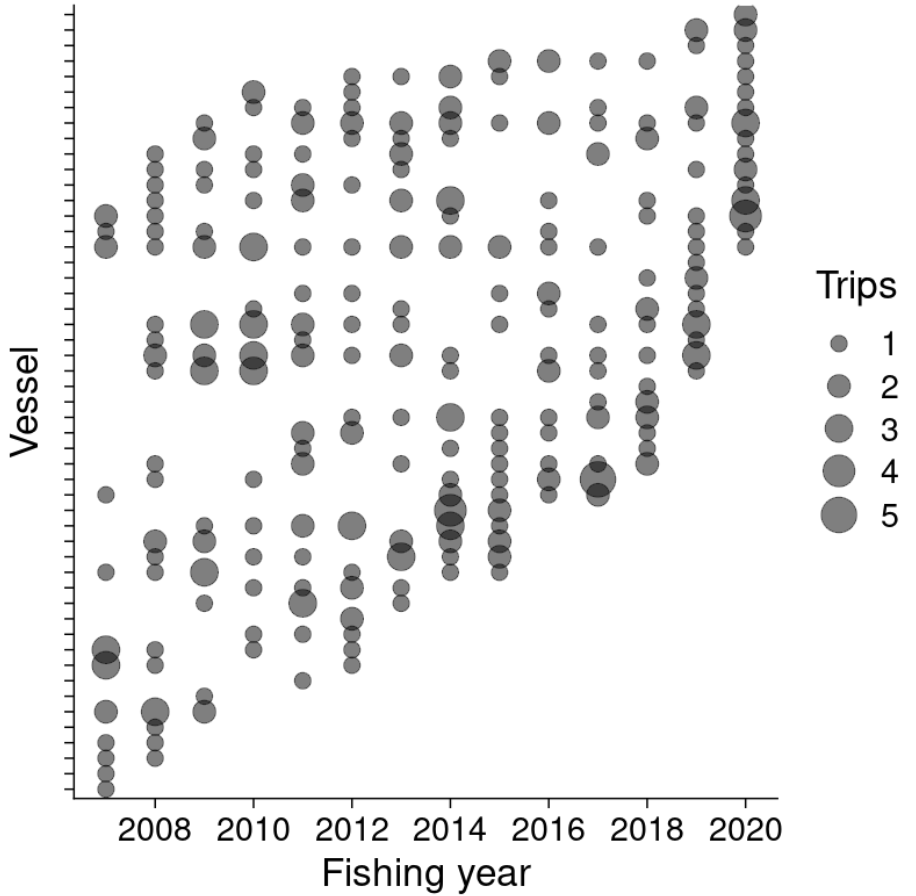
- 2008 to 2020
- Use of baffler only the most prevalent form of mitigation gear
- Use of tori line only has decreased with the increase in tori lines used in conjunction with bafflers



Data

Recorded warp mitigation use for observed trawls, 2007 to 2020

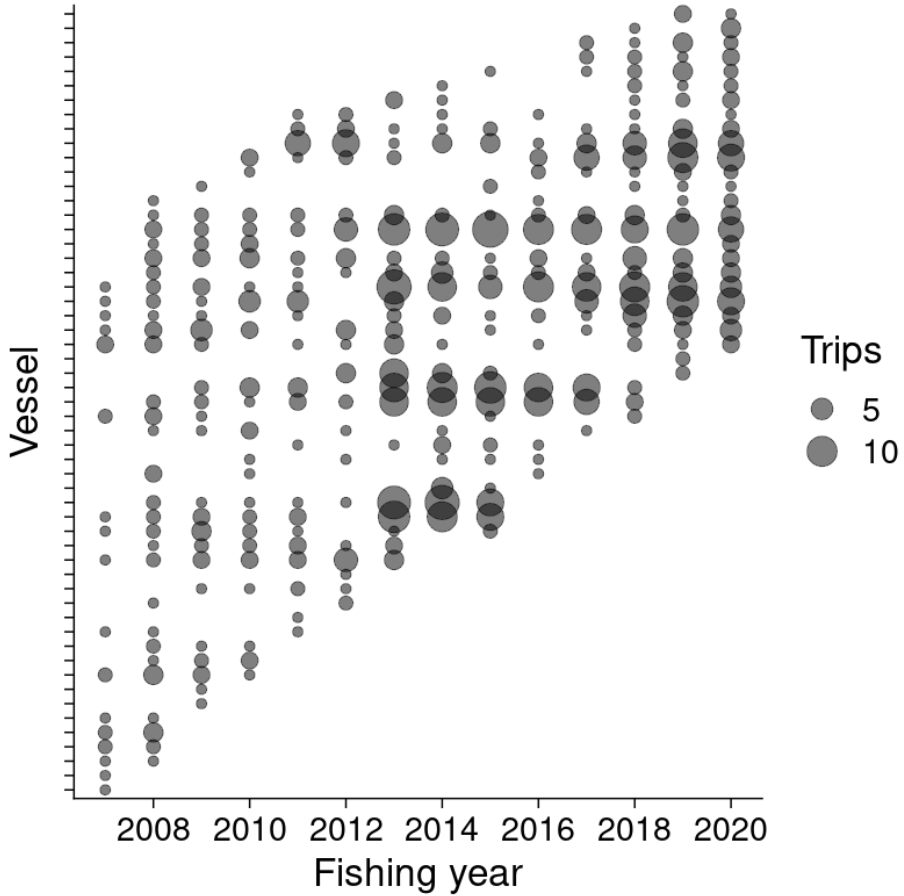
- Baffler use by vessel and year
- Good coverage across years and fleet



Data

Recorded warp mitigation use for observed trawls, 2007 to 2020

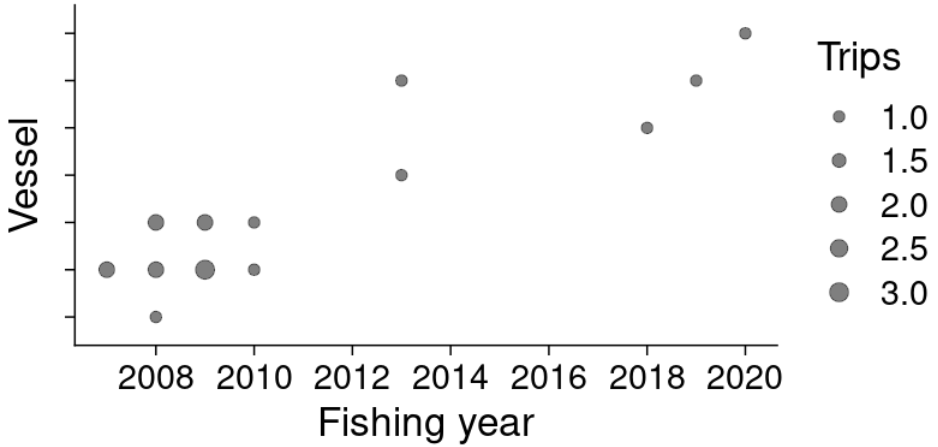
- Tori line use by vessel and year
- Good coverage across years and fleet



Data

Recorded warp mitigation use for observed trawls, 2007 to 2020

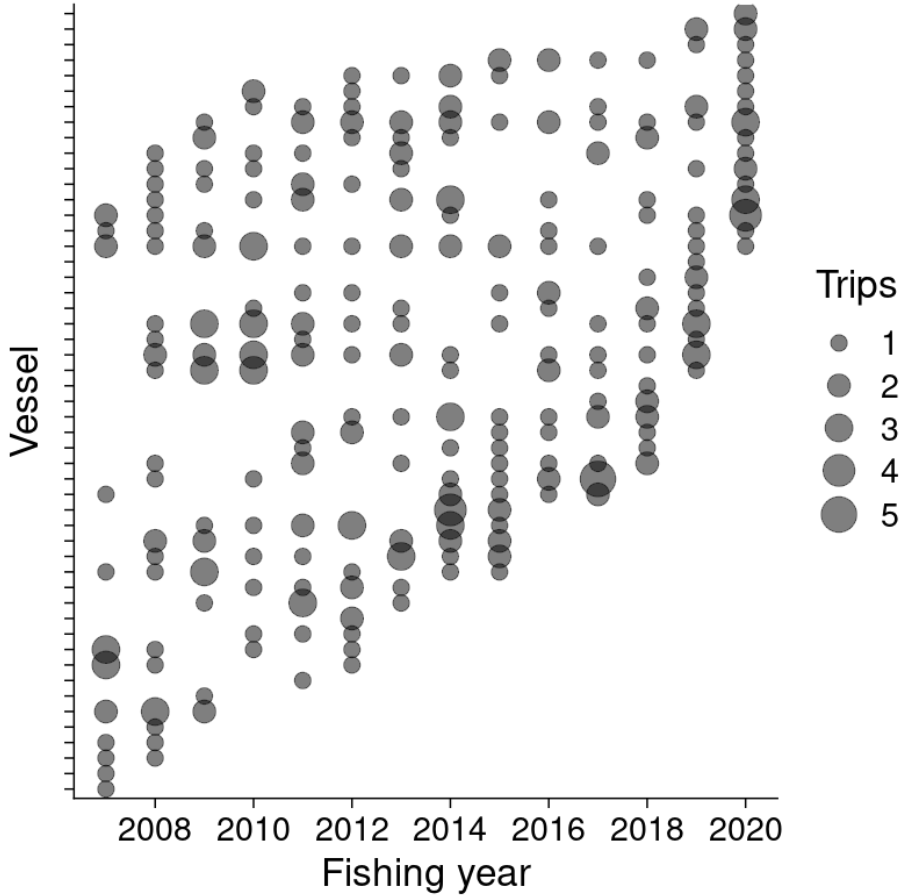
- Warp scarer use by vessel and year
- No coverage across years and fleet



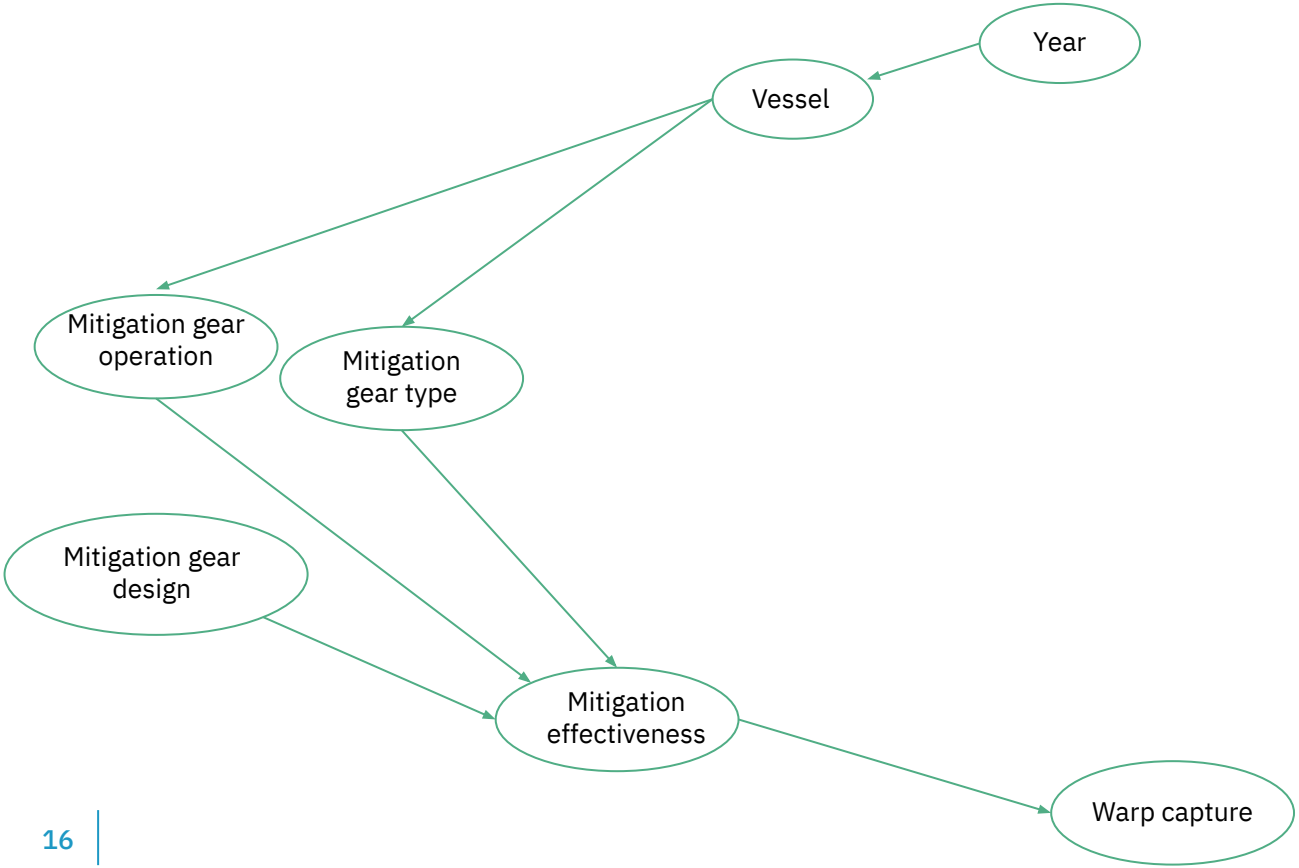
Data

Recorded warp mitigation use for observed trawls, 2007 to 2020

- Mitigation gear not recorded
- More work required to reconcile these records



Approach - relating use of mitigation gear to seabird warp captures



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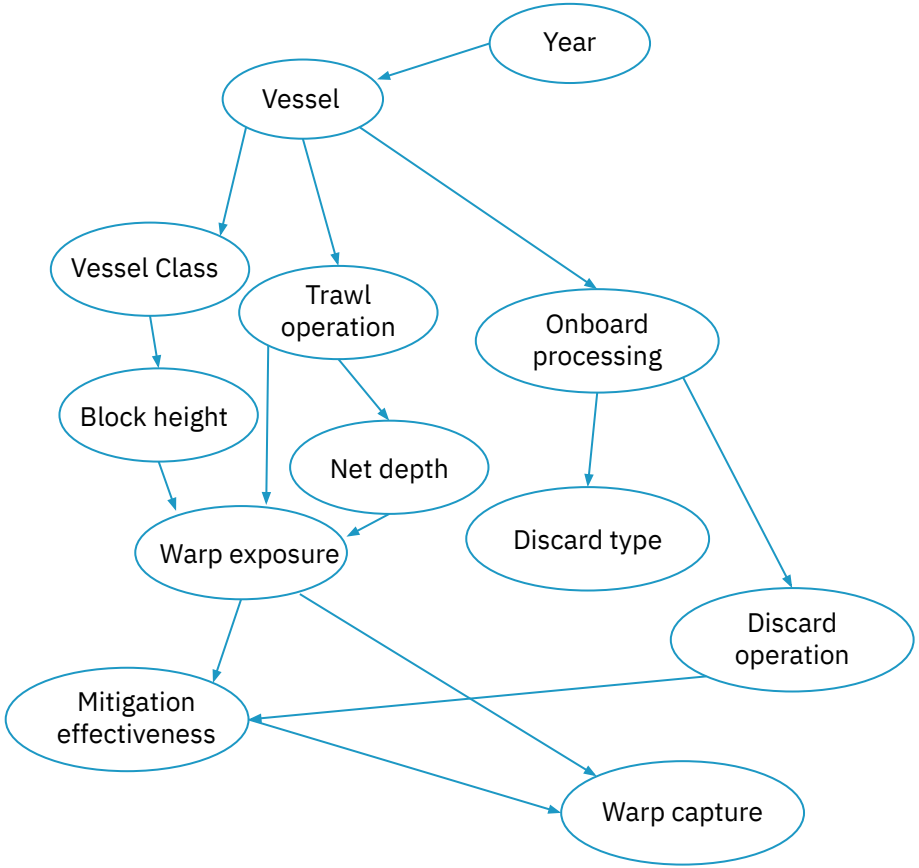

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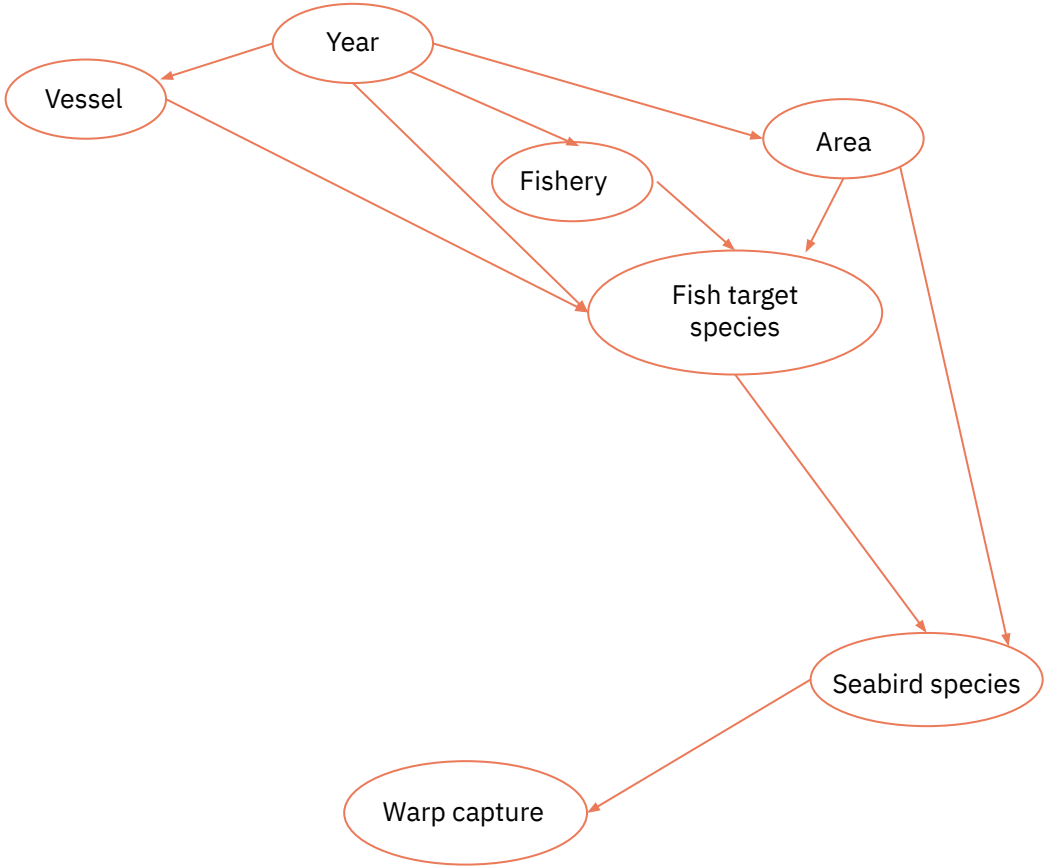
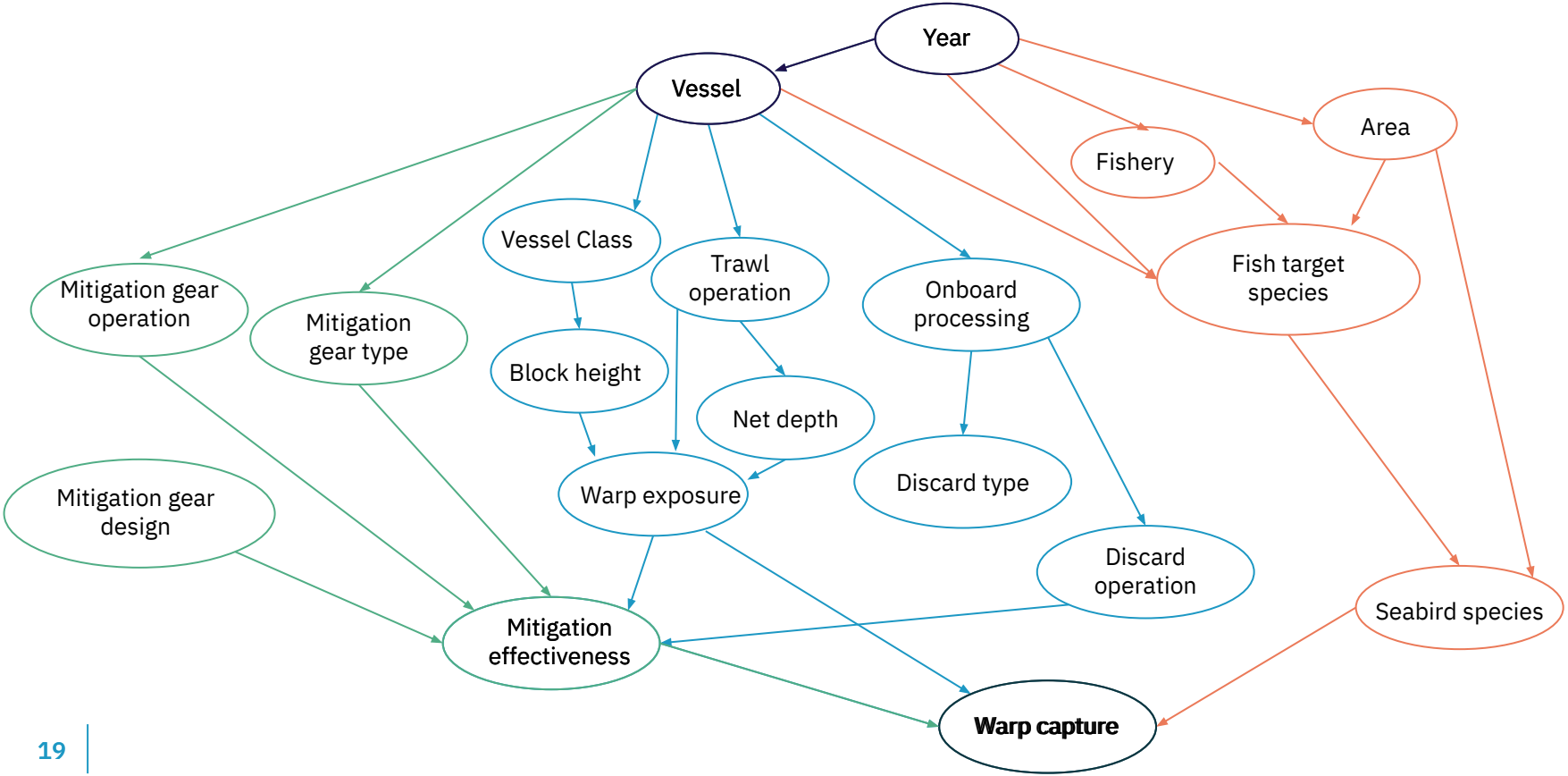
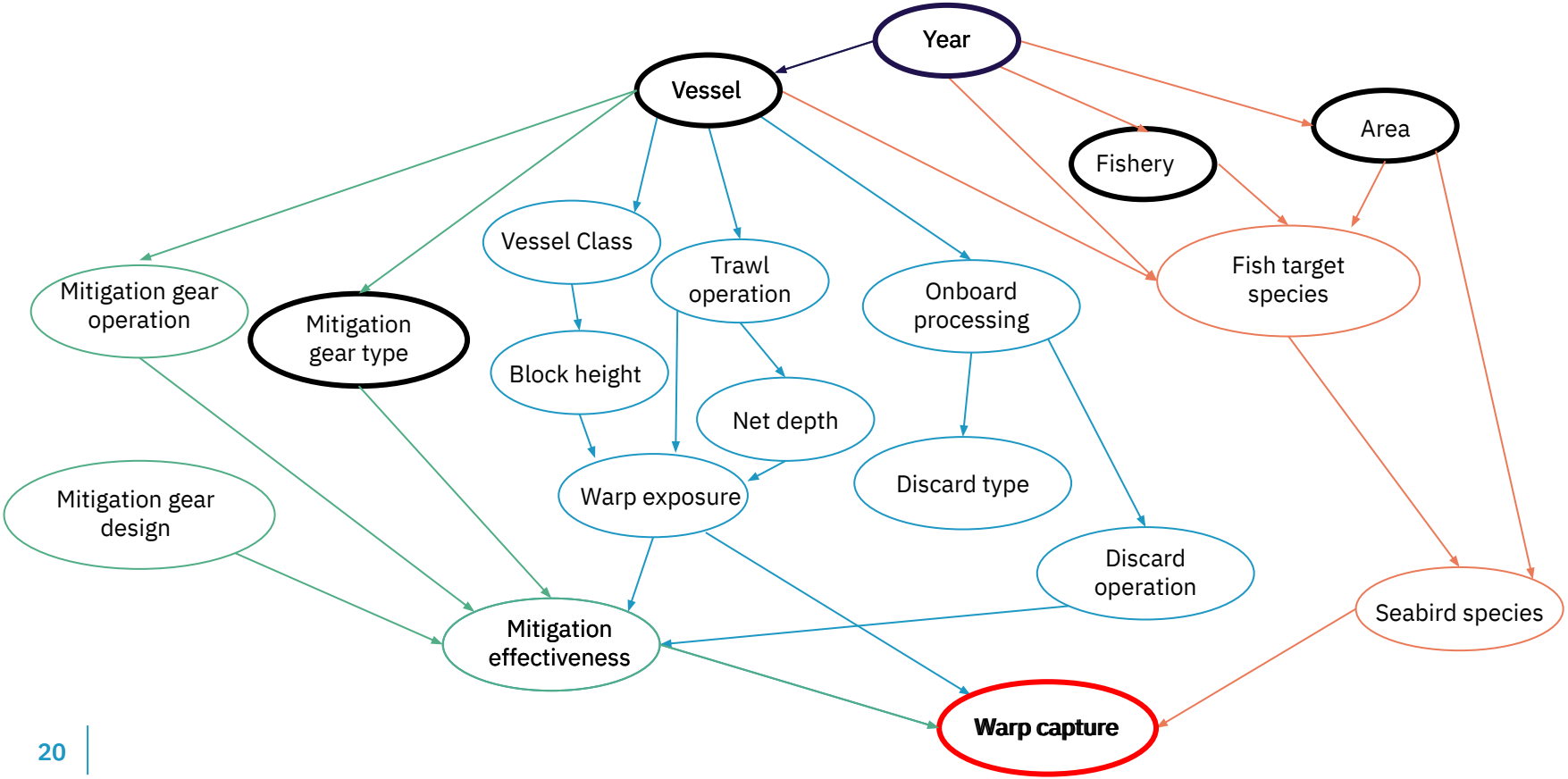


Approach - relating use of mitigation gear to seabird warp captures



Approach - relating use of mitigation gear to seabird warp captures



Approach

Using modelling to identify optimal device combinations or configurations based on available data - Part 1

Captures were estimated from observer catch rates using a generalised linear mixed model:

- covariates included fishing year, fishery, area and vessel as random effects, with mitigation gear included as a categorical fixed effect (at levels baffler-only, tori-only, baffler+tori)
- models were run with data aggregated to year, area, fishery and mitigation gear
- data included for fishing years 2008 to 2020, and excluding data where warp mitigation gear was not recorded

Approach

Captures were estimated from observer catch rates using a generalised linear mixed model:

- estimated within a general Bayesian linear model framework “brms”
- used a negative binomial model (often preferred for highly skewed distributions with large amounts of zeros)
- models were fitted with eight separate Markov Chain Monte Carlo chains with 3000 iterations, including a 1000 iteration burn-in period that was discarded from posterior samples
- convergence was judged by marginal and multivariate scale reduction factors (SRF) across the eight chains (at convergence of MCMC runs, the MSFR (or Rhat) is one)
- Model fit was evaluated by posterior predictive checks and leave-one-out information criterion (loo-ic) comparisons

Approach

Model sets/hypotheses (using NB response):

Fleet (area, fishery, vessel, fishing year) vs mitigation gear

mod 1 *captures | tows ~ mitigation_type*

mod 2 *captures | tows ~ (1|area) + mitigation_type*

mod 3 *captures | tows ~ (1|Fishery Group) + (1|area) + mitigation_type*

mod 4 *captures | tows ~ (1|vessel) + (1|Fishery Group) + (1|area) + mitigation_type*

mod 5 *captures | tows ~ (1|fyear) + (1|Fishery Group) + (1|area) + mitigation_type*

mod 6 *captures | tows ~ (1|fyear) + (1|vessel) + (1|Fishery Group) + (1|area) + mitigation_type*

Fleet (area, fishery, vessel, fishing year) vs interaction of mitigation gear and fishing year or vessel

mod 7 *captures | tows ~ (1|fyear) + (1|vessel) + (1|Fishery Group) + (1|area) + mitigation type + (1|vessel:mitigation_type)*

mod 8 *captures | tows ~ (1|fyear) + (1|vessel) + (1|Fishery Group) + (1|area) + mitigation type + (1|fyear:mitigation_type)*

mod 9 *captures | tows ~ (1|fyear) + (1|vessel) + (1|Fishery Group) + (1|area) + mitigation type + (1|fyear:mitigation_type) + (1|vessel:mitigation_type)*

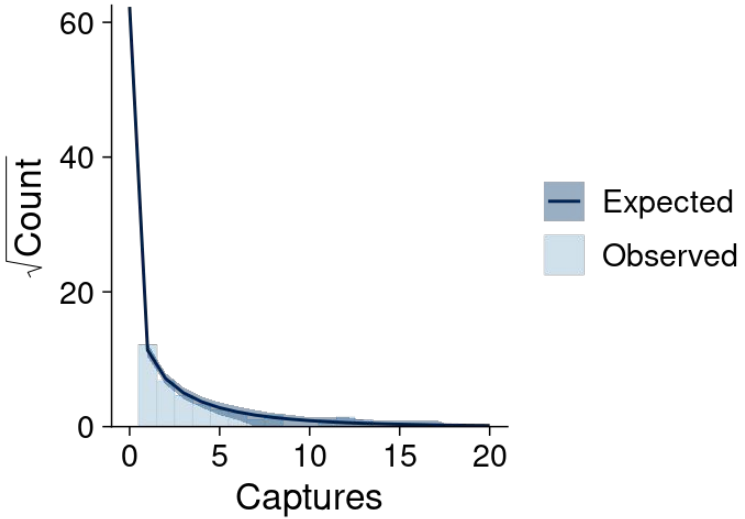
Model fit

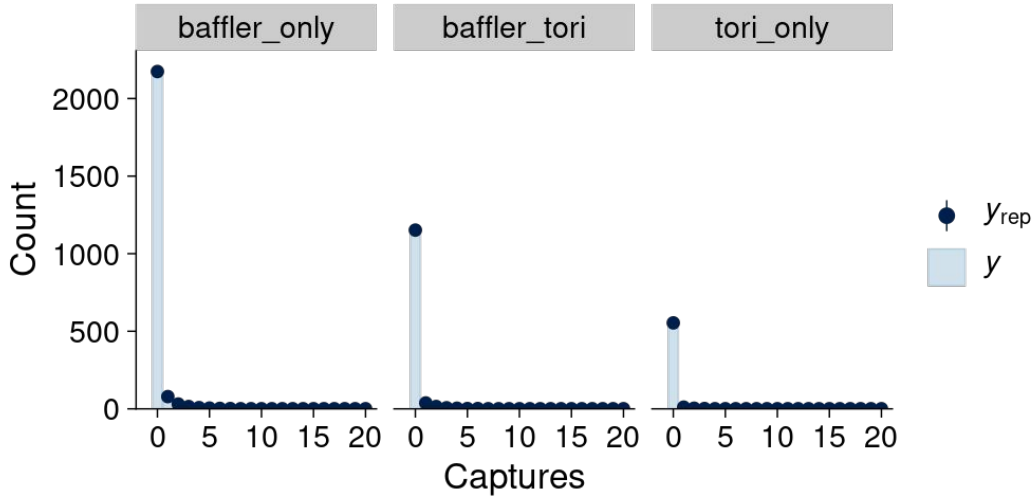
- models 8 and 9 provided the best fit to the data
- these models included random effects for year and vessel, whereas the other models did not

Model	elpd_loo	se_elpd_loo	elpd_diff	se_diff	right side of formula
bmod8	-1,072.42	58.45	0.00	0.00	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear + (1 | fyear:mitigation_gear)
bmod9	-1,072.86	58.44	-0.43	2.53	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear + (1 | vessel_key:mitigation_gear) + (1 | fyear:mitigation_gear)
bmod7	-1,075.22	58.63	-2.80	3.94	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear + (1 | vessel_key:mitigation_gear)
bmod6	-1,075.32	58.67	-2.90	2.75	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod4	-1,078.68	58.83	-6.26	4.74	(1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod3	-1,106.11	60.11	-33.69	9.63	(1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod5	-1,106.20	60.46	-33.78	9.73	(1 | fyear) + (1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod2	-1,112.91	60.04	-40.49	11.02	(1 | area) + mitigation_gear
bmod1	-1,168.01	63.19	-95.59	15.74	mitigation_gear

Model fit

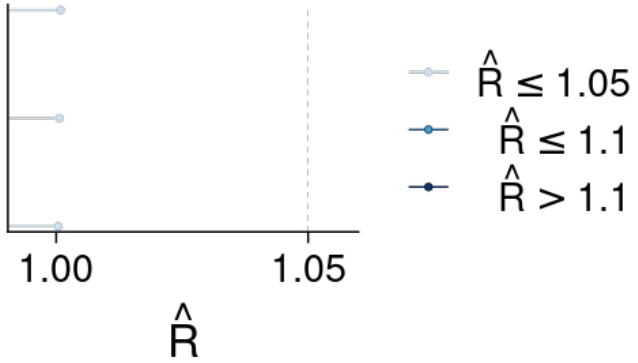
Posterior predictive checks for Model 8 shows the model fits the data well overall (left) and for each of the mitigation gear categories (right)





Model diagnostics

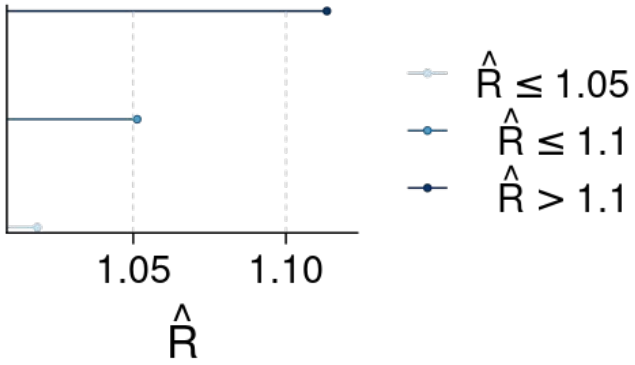
Models 2-8



Rhat values were at or close to 1 for all variables in Models 2 to 8, indicating convergence

- Rhat values shown for the mitigation categories in Model 8

Model 1

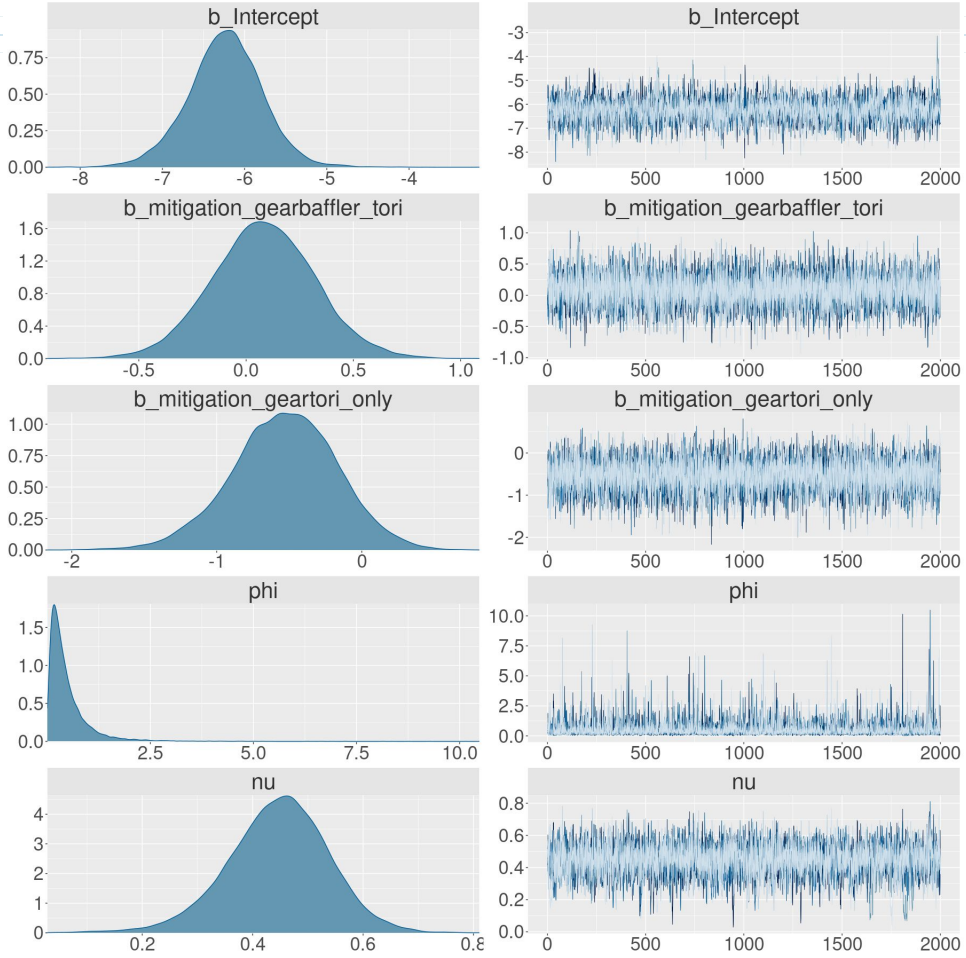


Rhat values were >1.05 for most variables in Model 1, indicating non-convergence for this model.

Model diagnostics

Model 8:

- Distribution and trace plots of the estimated values for the models main variables at each iteration
- Reasonably well mixing MCMC chains indicating convergence



Model results

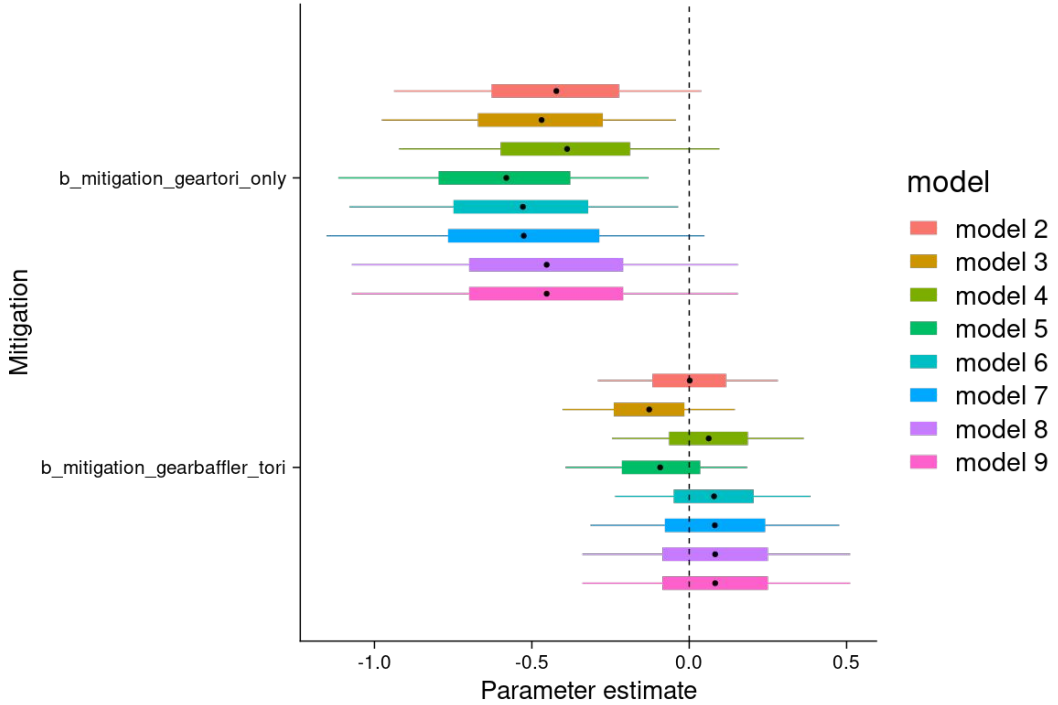
- Model estimates and 95% credible intervals (in brackets) for the levels of mitigation gear
- Best performing models (8, 9, 7, 6) have consistent results, and all include an effect for vessel and for fishing year

mods	baffler & tori	tori only	right side of forumla
bmod8	0.08 (-0.34 , 0.51)	-0.45 (-1.07 , 0.15)	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear + (1 | fyear:mitigation_gear)
bmod9	0.09 (-0.41 , 0.59)	-0.47 (-1.17 , 0.2)	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear + (1 | vessel_key:mitigation_gear) + (1 | fyear:mitigation_gear)
bmod7	0.08 (-0.31 , 0.48)	-0.53 (-1.15 , 0.05)	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear + (1 | vessel_key:mitigation_gear)
bmod6	0.08 (-0.24 , 0.39)	-0.53 (-1.08 , -0.03)	(1 | fyear) + (1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod4	0.06 (-0.25 , 0.36)	-0.39 (-0.92 , 0.1)	(1 | vessel_key) + (1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod3	-0.13 (-0.4 , 0.15)	-0.47 (-0.98 , -0.04)	(1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod5	-0.09 (-0.39 , 0.18)	-0.58 (-1.12 , -0.13)	(1 | fyear) + (1 | fisheryGroup) + (1 | area) + mitigation_gear
bmod2	0 (-0.29 , 0.28)	-0.42 (-0.94 , 0.04)	(1 | area) + mitigation_gear
bmod1	0.36 (0.09 , 0.68)	-0.35 (-0.79 , 0.19)	mitigation_gear

Model results

Model estimates and 95% credible intervals for the levels of mitigation gear, by model

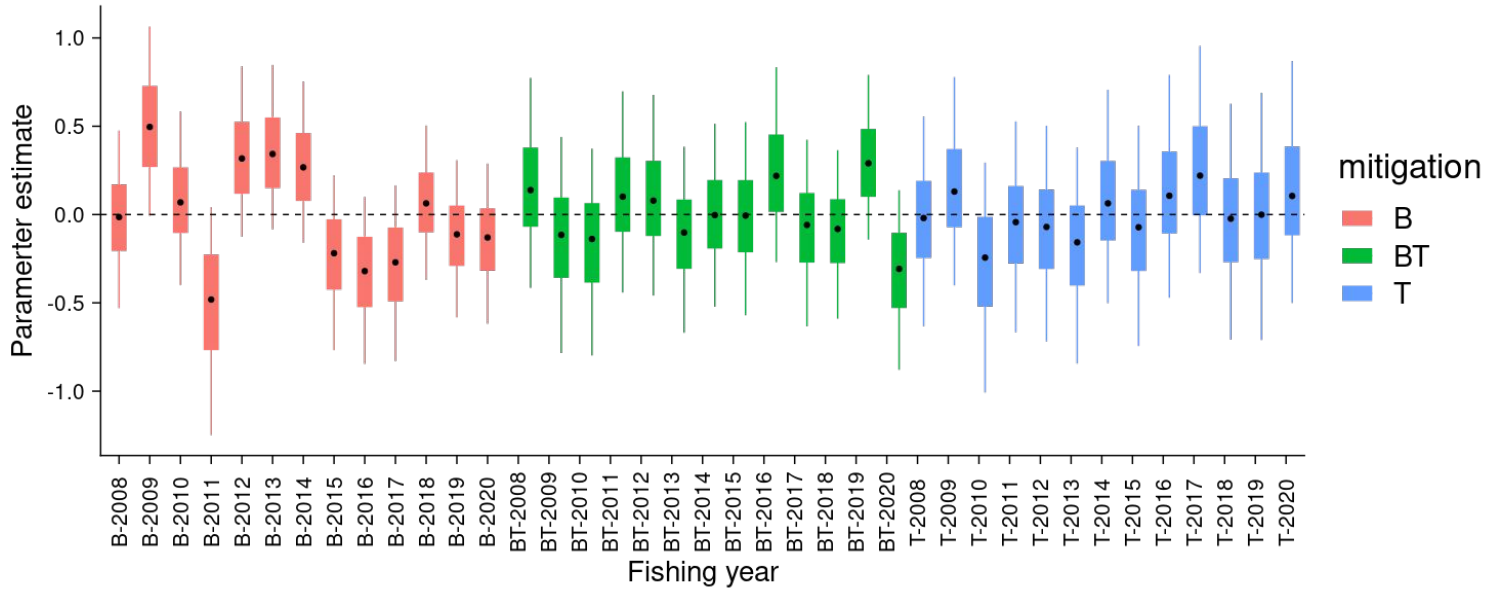
- In general, compared to baffler use only, the use of tori lines is more effective
- The combination of bafflers and tori lines are slightly less effective than baffler use only
- Models 2, 3 and 5 did not include a vessel effect
- Model 4 did not include a year effect
- Model 1 did not converge



Results

Model 9 estimates and 95% credible intervals for the levels of mitigation gear by year

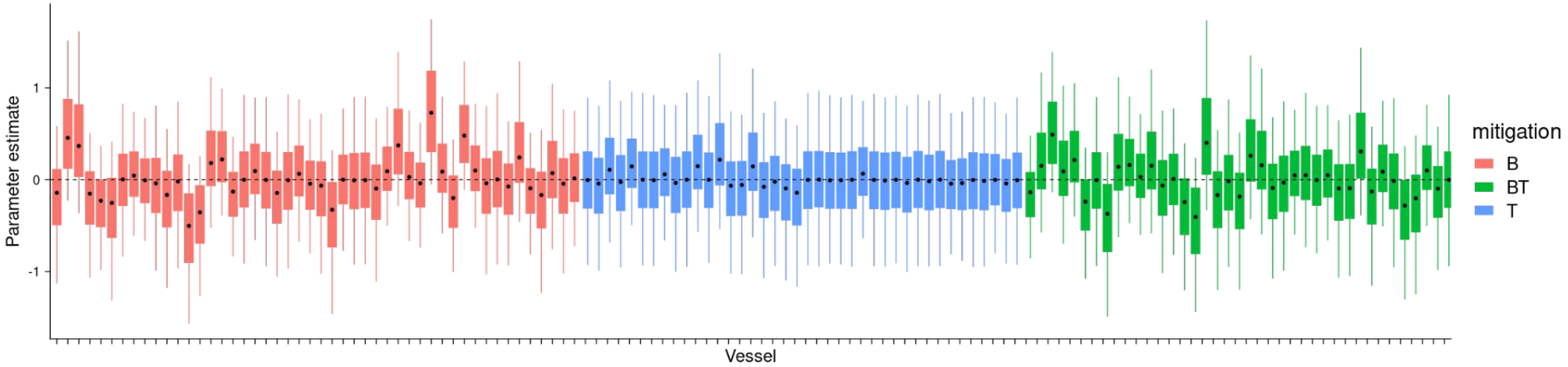
- Effectiveness of bafflers has improved, especially after 2015
- Effectiveness of tori lines (and tori lines used with bafflers) is less variable than that of bafflers only over time



Results

Model 9 estimates and 95% credible intervals for the levels of mitigation gear by vessel

- Effectiveness of tori lines is relatively consistent among vessels
- Effectiveness of bafflers is highly variable amongst vessels



Discussion

- Modelling of catch rates in response to warp mitigation gear use, taking into account variability in fishery operations and species populations, shows a difference in effectiveness between the use of bafflers and tori lines

- These trends are highly variable by year, especially for baffler use, but less so since the mid 2010s, and perhaps indicate an increasing effectiveness of baffler gear in recent years

- The effectiveness of the introduction of mitigation gear is not modelled due to the lack of data available prior to 2008

- Investigation of mitigation device data may:
  1. provide information to inform the patterns in effectiveness indicated in Part 1; and
  2. enable more complex modelling of mitigation effectiveness.

Thanks to:

Richard Wells
John Cleal
Ben Steele Mortimer
David Middleton
Phil Neubauer
Yvan Richards
Ed Abraham
CSP Technical Working Group

Additional model diagnostics

Model 8, pairs plot

- Good, no evidence of correlated variables