Fisheries New Zealand
Tini a Tangaroa

Longline observer data coverage in ling fisheries and their use in stock assessments

New Zealand Fisheries Assessment Report 2024/85

S. Mormede;
A. Dunn;
D. Webber

ISSN 1179-5352 (online)
ISBN 978-1-991330-33-8 (online)

November 2024

Te Kāwanatanga o Aotearoa
New Zealand Government

Requests for further copies should be directed to:

Fisheries Science Editor
Fisheries New Zealand
Ministry for Primary Industries
PO Box 2526
Wellington 6140
NEW ZEALAND

Email: Fisheries-Science.Editor@mpi.govt.nz
Telephone: 0800 00 83 33

This publication is also available on the Ministry for Primary Industries websites at:
http://www.mpi.govt.nz/news-and-resources/publications
http://fs.fish.govt.nz go to Document library/Research reports

Please cite this report as:
Mormede, S. Dunn, A.; Webber, D. (2024). Longline observer data coverage in ling fisheries and their use in stock assessments. *New Zealand Fisheries Assessment Report 2024/85.* 30 p.

TABLE OF CONTENTS

PLAIN LANGUAGE SUMMARY

Ling (*Genypterus blacodes*) is an important commercial fish species in New Zealand middle depths waters and is caught mainly by bottom trawls, bottom longlines, and increasingly by potting.

On board cameras will be rolled out on all bottom longline vessels in December 2024, which is expected to lead to a reduction in the collection of biological samples that are used in ling stock assessments. This report investigates the observer coverage of the ling fisheries to date and the potential effect of the loss of longline observer data on the stock assessments.

Observer coverage has typically been lower for bottom longline vessels than trawl vessels, and less representative of the fishery. The bottom longline observer data was the most influential for the stock assessment of LIN 3&4 Removing bottom longline data in the assessment model of this stock resulted in a different estimate of biomass and status of the stock, highlighting the importance of these data to inform the stock assessment.

For the other ling stocks, the removal of the bottom longline data from the model did not result in a marked changed, possibly due to a lack of adequate observer coverage of these stocks. An increase in observer coverage may lead to a better-informed stock assessment and potentially different understanding of the status of these stocks.

The Deepwater Working Group recommended that observer coverage should be increased in bottom longline fisheries to inform the stock assessments better and that scientific research programmes using both observers and on-board cameras should be developed to leverage the most benefit from both systems.

EXECUTIVE SUMMARY

Mormede, S.[1]; Dunn, A.[2]; Webber, D.[3] (2024). Longline observer data coverage in ling fisheries and their use in stock assessments.

***New Zealand Fisheries Assessment Report 2024/85*. 30 p.**

Ling (*Genypterus blacodes*) is an important commercial species with adults found throughout the middle depths of the New Zealand Exclusive Economic Zone (EEZ) typically in depths of 100 m to 800 m. Ling are caught mainly by deepwater trawlers, demersal longliners, and more recently by potting. Stock assessments are carried out regularly for the three main ling stocks: the Chatham Rise (LIN 3&4), the Sub-Antarctic (LIN 5&6 and LIN 6B), and the west coast South Island (LIN 7WC). These assessments are informed by fisheries-independent survey data, observer data, and commercial catch and effort data.

On board cameras (OBC) will be rolled out on all bottom longline (BLL) vessels in December 2024. This will have the effect of reducing observer coverage on large BLL vessels and impact the collection of biological samples which are used in ling stock assessments. Between 15% and 50% of the total annual catch in the three main ling stocks was caught by bottom longliners between 2020 and 2023. The observer coverage of the ling fisheries to date and the potential effect of the loss of longline observer data on the stock assessments was investigated.

Observer coverage has typically been lower for bottom longline vessels than trawl vessels, possibly due partly to smaller vessel sizes and/or longer trip durations. LIN 3&4 had the highest proportional total ling catch by bottom longline yet on average half the bottom longline catch annually came from 0.5° cells with no observer data in that year, and about 30% of the catch came from 0.5° cells where no bottom trawl was operating in that year. LIN 7WC also has a high ling catch by bottom longline; its observer coverage has been improving since 2015. LIN 6B is an almost exclusively bottom longline fishery, with such low observer coverage that a stock assessment for that area was not deemed feasible.

The bottom longline observer data was the most influential for the model of LIN 3&4. Removing bottom longline data in the assessment model of this stock resulted in a different estimate of biomass and status of the stock, highlighting the importance of these data to inform the stock assessment. For the other two stocks, the bottom longline age composition data did not seem to contain information on initial spawning stock biomass. This could be due to the already low and variable spatial coverage of this fishery: the bottom longline age composition for those two fisheries was highly variable between years. If observer coverage was adequate, the data may contain information on initial biomass and the outcomes of the stock assessments, and our understanding of ling stocks may well change. This could only be determined by an increase in and more representative observer coverage in the ling bottom longline fisheries to better inform the stock assessments.

The Deepwater Working Group recommended that observer coverage should be increased in bottom longline fisheries to inform the stock assessments better and that scientific research programmes using both observers and on-board cameras should be developed to leverage the most benefit from both systems.

[1] soFish Consulting Ltd.
[2] Ocean Environmental Ltd.
[3] Quantifish Ltd.

1. INTRODUCTION

Ling (*Genypterus blacodes*) is an important commercial species with adults found throughout the middle depths of the New Zealand Exclusive Economic Zone (EEZ) typically in depths of 100 m to 800 m (Hurst et al. 2000). Ling are managed within eight administrative Quota Management Areas (QMAs, Figure 1), with five of these (LIN 3, 4, 5, 6, and 7) reporting about 95% of landings.

Ling are caught mainly by deepwater trawlers, often as bycatch in hoki (*Macruronus novaezelandiae*) target fisheries, by demersal longliners (Mormede et al. 2021, 2022, 2023a), and more recently by potting (Mormede et al. 2024b). LIN 5&6 has the highest ling catches, followed by LIN 3&4 then LIN 7WC. Between 15% and 50% of the total annual catch in each stock has been caught by bottom longliners between 2020 and 2023. There has been a recent move for bottom longliners to convert to potting, particularly in LIN 3&4 where the proportion of catch from bottom longliners dropped from about 63% of total ling catches in 2013 to 53% in 2022 and 26% in 2023 (Figure 2).

There are at least five major biological stocks of ling in New Zealand waters (Horn 2005)—the Chatham Rise, the Sub-Antarctic (including the Stewart-Snares shelf and Puysegur Bank), the Bounty Platform, the west coast of the South Island, and the Cook Strait. Recent analyses have indicated that the Bounty Platform might be an offshoot of the Sub-Antarctic stock (Mormede et al. 2024c), and these two areas were assessed as a single stock in 2024 (Mormede et al. 2024d). The ling biological stocks were defined using statistical areas as described in Figure 1.

Stock assessments are carried out regularly for the three main ling stocks, and were last updated in 2022 for the Chatham Rise (LIN 3&4, Mormede et al. 2023b), in 2023 for the west coast South Island (LIN 7WC, Mormede et al. 2024a), and in 2024 for the Sub-Antarctic (LIN 5&6 and LIN 6B, Mormede et al. 2024d). These age structured stock assessments were done using the general-purpose stock assessment program CASAL (Bull et al. 2012) or Casal2 (Doonan et al. 2016; Casal2 Development Team 2023). Estimated levels of stock status at the latest assessment were 56%, 66%, and 55% of the initial spawning stock biomass for LIN 3&4, LIN 5&6 and LIN 6B, and LIN 7WC respectively. A management strategy evaluation was done in 2024 for those three stocks (Mormede 2024). Assessments for other stocks were last updated in 2007 (LIN 6B when assumed a stand-alone stock, Bounty Platform, with a CPUE update in 2014), and 2010 (LIN 7CK, Cook Strait, with an assessment in 2013 rejected). These are not considered further in the present analysis. The status of ling stocks are summarised annually by Fisheries New Zealand (2024).

The three main ling stock assessment models are structured with separate longline and trawl fisheries. The models are informed by the following data which the models fit to:

- Regular fisheries-independent survey biomass indices and age compositions.
- Annual bottom longline age compositions, informed from observer length data and otolith collection.
- Annual bottom trawl age compositions, informed from observer length data and otolith collection.
- Annual longline fishery standardised catch per unit effort (CPUE) for LIN 7WC only, informed from commercial catch and effort data.

Additional data which inform the models include, for example, the weight and maturity status of fish at length, collected by observers or during fisheries-independent surveys. These contribute to the development of the general understanding of ling biology including growth and maturity curves and stock structure hypotheses but are inputs to the models rather than annual data fitted to by the model.

On board cameras (OBC) will be rolled out on all bottom longline (BLL) vessels in December 2024. This is likely to lead to a reduction in observer coverage on large BLL vessels and impact the collection of biological samples that are used in ling stock assessments. Whilst cameras can capture a range of information, they cannot sample otoliths for ageing purposes, and are not currently designed to sample fish length information.

This report summarises the results of project SEA2023-17, funded by Fisheries New Zealand. The aim of the project was ‘to analyse the observer coverage for ling trawl and bottom longline fisheries to understand the impact of onboard cameras and consequent reduction of observer data collected from bottom longline vessels.’ The aim of Objective 1 was ‘to re-run ling stock assessment models for LIN 3&4, 5&6, and 7WC without the inclusion of BLL observer data and report differences.’ The aim of Objective 2 was ‘to analyse the spatial coverage of the ling BLL and trawl observer coverage and identify areas where BLL observer coverage is needed to maintain adequate biological sampling of ling fisheries.’ Both objectives are reported herein.

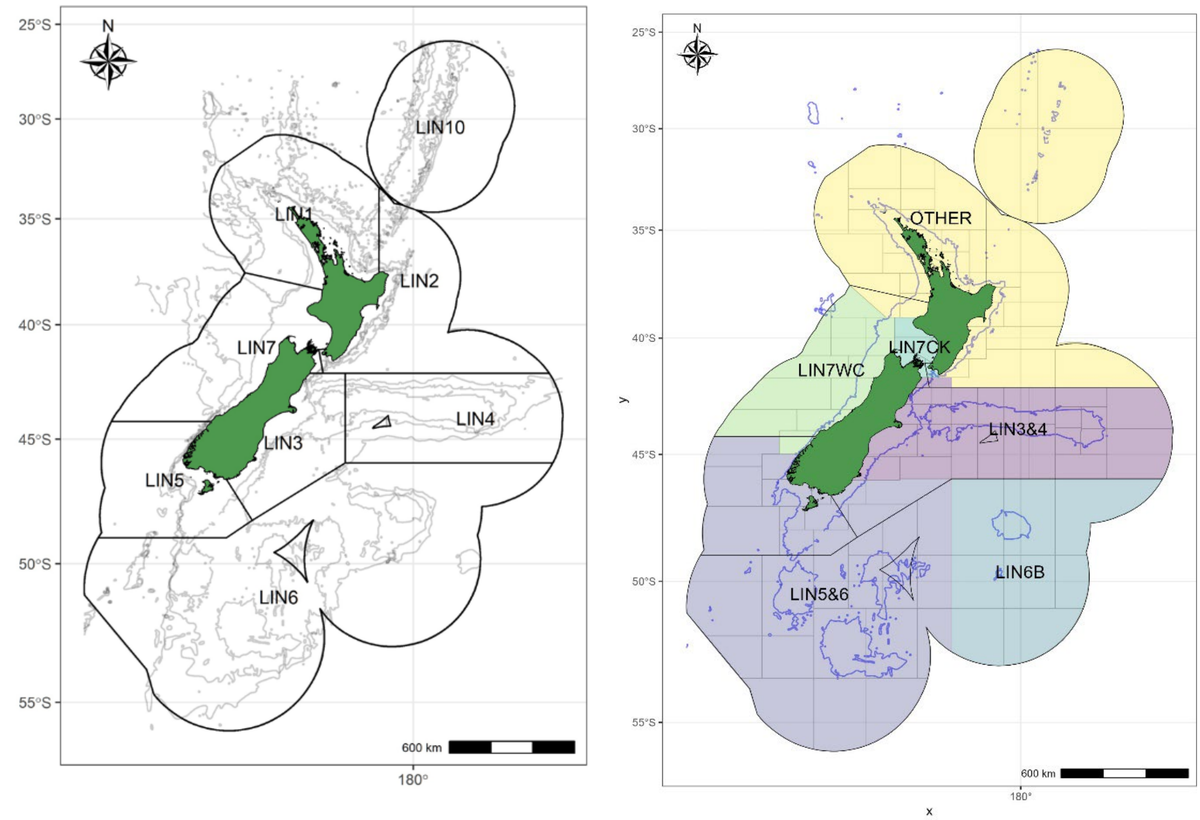

Figure 1: Quota Management Areas (QMAs, left) and biological stock boundaries (right) for ling, as used in this analysis. In 2024, LIN 5&6 and LIN 6B were assessed as a single stock.

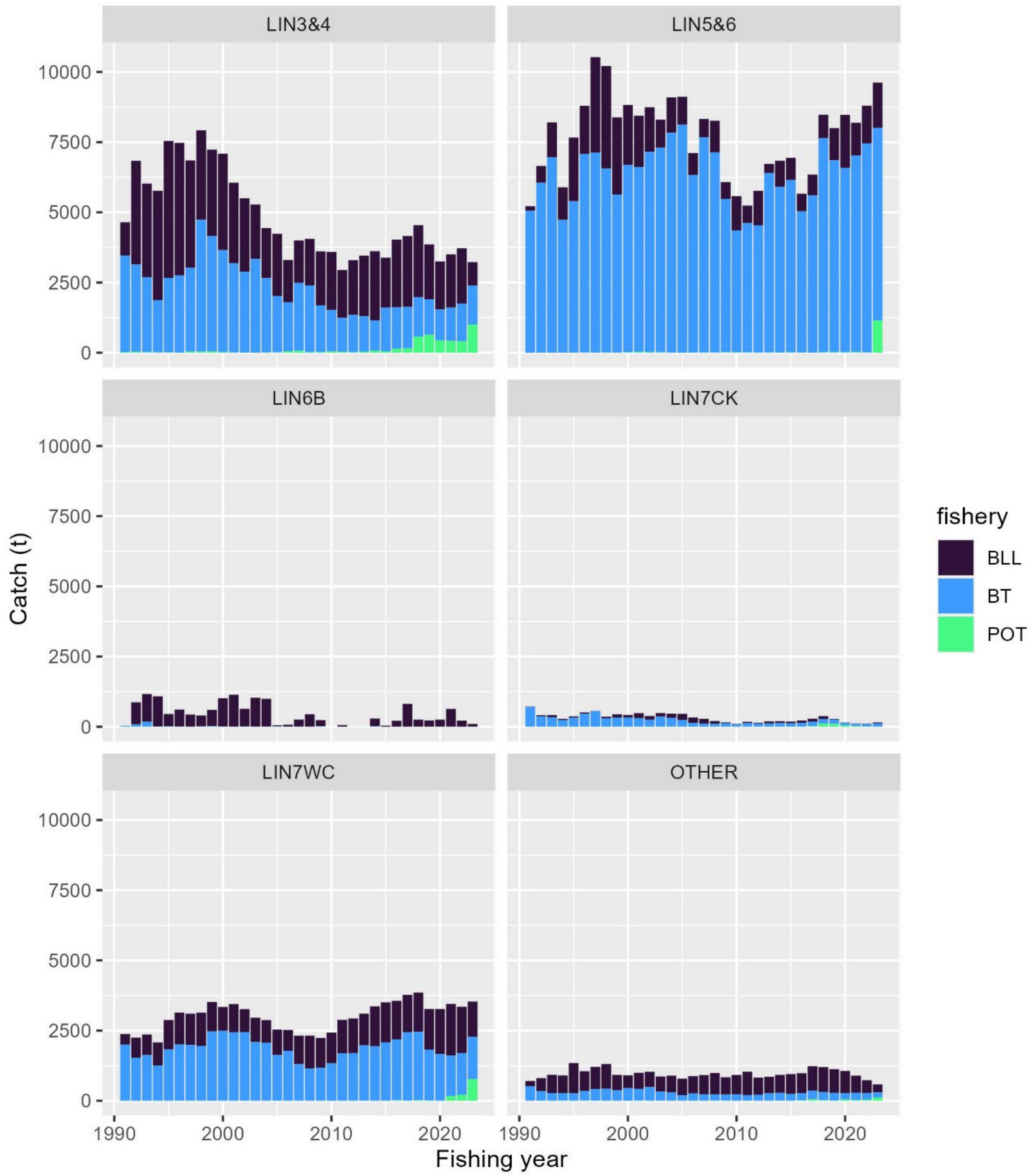

Figure 2: Ling catch (t) by stock and fishery: bottom longline (BLL), potting (POT), and all other methods (BT, dominated by bottom trawl).

2. METHODS

2.1 Observer representativeness

The data used for this analysis included the commercial catch and effort data and the observer data from observed trips. The data were extracted and checked as part of project LIN2023-01 (Mormede et al. 2024b).

This analysis concentrated on the period from 2008 to 2023 as prior to 2008 there were few data with fishing location recorded for bottom longline sets. The representativeness of observer coverage of the commercial fishery was investigated for both bottom longline and bottom trawl fisheries separately, by stock, both spatially and temporally. The spatial overlap between bottom longline and bottom trawl was also investigated.

The analyses were carried out in terms of calendar year rather than fishing year because the stock assessment models are run in calendar year.

2.2 Stock assessment investigations

The base case population models used for management purposes were used as the basis for this analysis (Mormede et al. 2023b, 2024a, 2024d; Fisheries New Zealand 2024). These were carried out using CASAL (Bull et al. 2012) for LIN 3&4, and Casal2 (Doonan et al. 2016; Casal2 Development Team 2023) for LIN 5&6 and LIN 6B and for LIN 7WC as per the approved stock assessment models.

In summary, the base case population model for each stock was rerun after excluding data collected by observers onboard bottom longline vessels. Specifically, the following process was carried out for the three main stocks:

1. select the base case population model,
2. remove the annual bottom longline age composition data from the model,
3. fix the bottom longline fishery selectivity to the median of the base case Markov chain Monte Carlo (MCMC) value,
4. rerun the model at MCMC level, and
5. compare results with the base case model.

The bottom longline fishery selectivity was fixed at its estimated value because it is currently deemed constant with time in the models and historic data exist to inform it, even if observer coverage stops in the future. Should time-varying selectivity need to be estimated in future models, the impact of having no future observer longline data might be greater than discussed here.

3. RESULTS

3.1 Observer representativeness

The temporal coverage of the bottom longline fishery by observers has been historically poor for all ling stocks (Figure A.1 shows the coverage from 2018 to 2023). On the other hand, it has been mostly adequate for the trawl fishery (Figure A.2 for 2018 to 2023). Observer coverage has typically been lower for bottom longline vessels, possibly because of smaller vessel sizes, longer trip durations, and / or competing management requirements for observer coverage.

The spatial representativeness of observer coverage was investigated by calculating the proportion of catch by stock, method, and year that was caught in 0.5° cells where observer data was also collected Table A.1 to Table A.6, Figure A.3 to Figure A.5). This proportion was high (over 80%) for the trawl fishery in all main ling stocks. On the other hand, it was either low or highly variable for the bottom longline fishery: between 2014 and 2023 it varied between 0% and 95% by stock and year. On average, about half of the longline catches in LIN 3&4 and in LIN 5&6 were in 0.5° cells with no observer information whilst coverage in LIN 7WC improved between 2015 and 2023 and coverage of LIN 6B was very patchy. In terms of actual catch, the strongest effects are likely to be for LIN 3&4, LIN 6B and LIN 7WC where the catch of ling by bottom longline is an important part of the total fishery yet coverage is inadequate spatially (Figure 3) and temporally.

In terms of spatial overlap between bottom longline and bottom trawl catches, LIN 6B was mostly pursued by bottom longliners, up to 33% of the catch in LIN 3&4 was caught in 0.5° cells where no trawling occurred, and up to 12% in LIN 5&6 and LIN 7WC. Therefore, observer coverage of longline fisheries has been sparse and mostly unrepresentative, and a non-negligible portion of the ling catch has been caught by bottom longliners in areas where no trawling occurred in that year (Table A.7, Figure A.6, and Figure A.7).

When investigated in terms of longitude and latitude, the spatial coverage of the bottom longline and bottom trawl fisheries by observers followed the same pattern as that by 0.5° cells: a much lower representativeness for the bottom longline fishery than the bottom trawl fishery (Figure A.8 to Figure A.11).

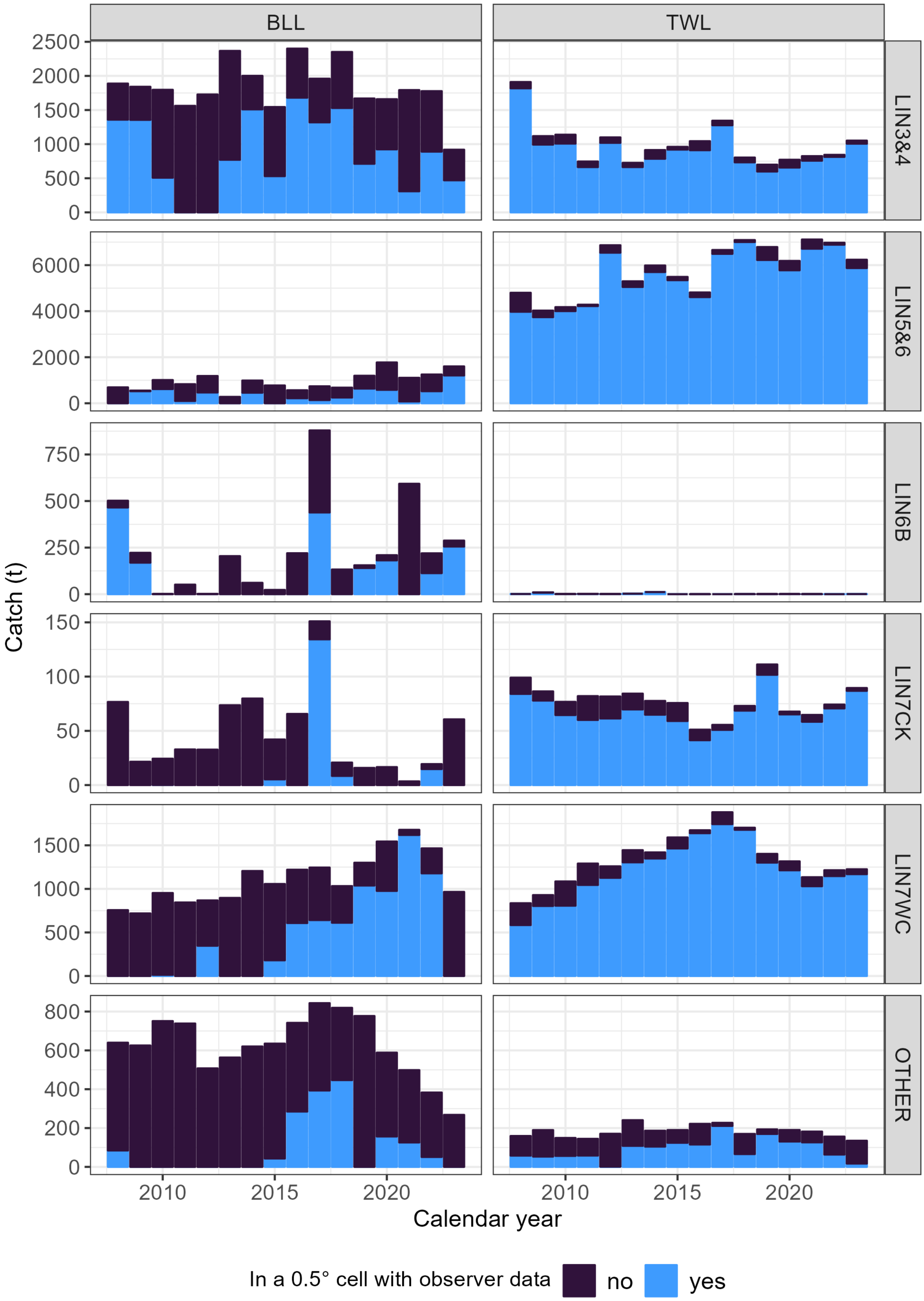

Figure 3: Annual catch of ling from the 2008 to the 2023 calendar years by stock, method, and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Method is bottom longline (BLL) or bottom or midwater trawl (TWL). Only catches from returns with location data are included in this plot.

3.2 Stock assessment investigations

Removing bottom longline age compositions from the stock assessment model was most influential for LIN 3&4. It resulted in an increase in the estimated initial spawning stock biomass (B_0) and in the estimated average natural mortality M_{av} (Table B. 1, Figure B.1), a reduction in the estimated survey catchability and a change in the estimated trawl fishery and survey selectivities, but no change in the estimated recruitment strength. A maximum posterior density (MPD) profile of initial spawning stock biomass and average natural mortality indicated that the bottom longline age composition contained some information on the value of B_0 and to a lesser extent on M_{av} (Figure B.2). This model was relatively well informed in terms of both B_0 and natural mortality although the different data sources point to slightly different values, hence the changes in the estimation of those two parameters when the bottom longline age composition information was removed from the model.

For the LIN 5&6 and LIN 6B stock, removing the bottom longline age composition resulted in a slight increase in B_0 (Table B. 2 and Figure B.3) and a small decrease in both survey catchabilities. The improvement in fits was marginal: the fits to the summer survey data improved by two negative log likelihood (NLL) points, and the fits to the autumn survey data reduced by one NLL point. The Maximum Posterior Density (MPD) profile on B_0 showed that the bottom longline age composition data contained very little information on B_0, which explains why removing these data resulted in little change (Figure B.4). Moreover, this model contained very limited information on the potential maximum value for B_0: the MPD were very flat on the right-hand side.

For LIN 7WC, removing the bottom longline age composition data had virtually no effect on any of the parameters estimated in the model (Table B. 3 and Figure B.5). This is not surprising given that the bottom longline age composition contained very little information on B_0 (Figure B.6).

4. DISCUSSION

Observer coverage has typically been lower for bottom longline vessels than trawl vessels, possibly because of smaller vessel sizes and/or longer trip durations. On average, 50% or more of the ling caught by longlines was caught in 0.5° cells with no equivalent observer coverage. Furthermore, a non-negligible portion of the ling catch has been caught by bottom longliners in 0.5° cells where no trawling occurred. Not only is the observer coverage of bottom longline often inadequate, but this also results in some areas of the stocks potentially not being monitored at all.

LIN 3&4 has the highest proportional ling catch by bottom longline yet on average half the bottom longline catch annually came from 0.5° cells with no observer data in that year, and about 30% of the catch came from 0.5° cells where no bottom trawl was operating in that year. LIN 7WC also has a high ling catch by bottom longline; its observer coverage has been improving since 2015. And LIN 6B is an almost exclusively bottom longline fishery, with such low observer coverage that a stock assessment for that area was not deemed feasible (Fisheries New Zealand 2024).

The bottom longline observer data from LIN 3&4 was the most influential of all three stocks. These data seemed to contain information on the initial biomass and natural mortality of importance to the model, and not in complete agreement with other data sources. This is interesting considering that LIN 3&4 also had the highest proportion of longline catch of all three stocks, as well as the most under-representation of observer coverage spatially and the least overlap with bottom trawl. There is a risk that a portion of the stock might not be represented by the data, and that even though the bottom longline age composition was influential in the model, it might not be representative of the entire stock. It is reassuring that the different data sources were still broadly consistent (Figure B.2).

In the other two stocks, bottom longline age composition data in the model did not seem to contain information on initial stock biomass. This could be due to the already low and variable spatial coverage of this fishery: the bottom longline age composition for those two fisheries was highly variable between years (Mormede et al. 2024a, 2024b), which is likely to be due to insufficiently representative observer coverage and highly variable spatial coverage leading to variable age compositions over time. If coverage was adequate, the data might indeed contain information on initial biomass, and possibly even on natural mortality. For ling stocks, natural mortality could only be estimated for LIN 3&4; the other stocks had too little data to inform this parameter (Mormede et al. 2023b, 2024a, 2024d).

This analysis has shown that the removal of observer data from bottom longliners from population models did not affect two of the three main ling stock assessments. However, this does not imply that these data are not needed but rather that they are likely to be currently of insufficient quality to be informative. Should data of better quality be collected, the outcomes of the stock assessment models and our understanding of ling stocks may well change. This could only be determined by an increase in and more representative observer coverage in the ling bottom longline fisheries to better inform the stock assessments. Simulations could be carried out to investigate the potential usefulness of that increase in observer coverage.

Other fisheries worldwide have already gone through this process. For example, the Canadian west coast ‘Option A’ trawl fleet had a mandatory on-board observer requirement which had been in place since February 1996 in order to police and enumerate discards. This rule was eliminated in May 2020, with the advent of the Covid epidemic and was replaced over time with a camera monitoring requirement. The implementation of camera monitoring of catch, bycatch, and discards resulted in the loss of the sampling that had been done by the on-board observers as part of their duties. In late 2022, the trawl industry, in consultation with the Canadian Department of Fisheries and Oceans and Archipelago Marine Research, designed a pilot shore sampling protocol for *Sebastes* species (known as ‘rockfish’ on the west coast), endeavouring to sample one landing per week in three ports (Ucluelet, Port Hardy, and Prince Rupert). A further sampling programme for Arrowtooth Flounder (ARF: *Atheresthes stomias*) was implemented in winter 2023–2024 to sample this fishery at the level of a tow event, with the on-board crew selecting fish from specific tows that targeted ARF that were then frozen for later processing. Additional sampling programmes are now being designed to extend sampling to other species of importance, with the funding for the sampling coming directly from the trawl industry which also ensures the cooperation of participating vessels (Paul Starr, pers. comm., 4th April 2024).

On board cameras cannot entirely replace observers. But they can be used to support observers by performing routine tasks such as line observations, allowing more time for biological sampling or other observer tasks. To optimise data collection, scientific research programmes using both observers and on-board cameras can be developed to leverage the most benefit from both systems (Fenaughty 2019).

5. FULFILLMENT OF BROADER OUTCOMES

As required under Government Procurement rules[4], Fisheries New Zealand considered broader outcomes (secondary benefits such as environmental, social, economic or cultural benefits) that would be generated by this project. The following broader outcomes were delivered:

Whakapapa links all people back to the land, sea, and sky, and our obligations to respect the physical world. This research aims to ensure the long-term sustainability of ling stocks, for the good of the wider community (including stakeholders and the public) and the marine ecosystems that ling inhabit. This project supports Māori and regional businesses, diversity and inclusion, and our research is inextricably linked to the moana from the work it carries out and the tangata whenua it supports.

4 https://www.procurement.govt.nz/procurement/principles-charter-and-rules/government-procurement-rules/planning-your-procurement/broader-outcomes/

As part of this project, the team has continued to build capacity and capability in fisheries science and stock assessment, its commitment to zero waste and carbon neutrality, environmental stewardship and social responsibility.

6. ACKNOWLEDGEMENTS

We thank the Fisheries New Zealand Project Scientist Gretchen Skea for facilitating the project and reviewing this document. We thank the Fisheries New Zealand Data Management Team for the data extracts and additional information used in these analyses and their assistance in its interpretation. We also thank members of the Deepwater Fisheries Assessment Working Group for their discussions on this work. This work was funded by Fisheries New Zealand under Objectives 1 and 2 of project SEA2023-17.

7. REFERENCES

Bull, B.; Francis, R.I.C.C.; Dunn, A.; McKenzie, A.; Gilbert, D.J.; Smith, M.H.; Bian, R.; Fu, D. (2012). CASAL (C++ algorithmic stock assessment laboratory): CASAL user manual v2.30-2012/03/21. *NIWA Technical Report 135*. 280 p.

Casal2 Development Team (2023). Casal2 user manual for age-based models (using source code from https://github.com/alistairdunn1/CASAL2). *NIWA Technical Report 139*. 270 p.

Doonan, I.; Large, K.; Dunn, A.; Rasmussen, S.; Marsh, C.; Mormede, S. (2016). Casal2: New Zealand's integrated population modelling tool. *Fisheries Research 183*: 498–505. https://doi.org/10.1016/j.fishres.2016.04.024

Fenaughty, J.M. (2019). Research data collection in CCAMLR longline fisheries for toothfish using electronic monitoring on fishing vessels. WG-FSA-2019/13. CCAMLR, 14 p.

Fisheries New Zealand (2024). Fisheries Assessment Plenary, May 2024: stock assessments and stock status. Compiled by the Fisheries Science Team, Fisheries New Zealand, Wellington, New Zealand. 1941 p.

Horn, P.L. (2005). A review of the stock structure of ling (*Genypterus blacodes*) in New Zealand waters. *New Zealand Fisheries Assessment Report 2005/59*. 41 p.

Hurst, R.J.; Bagley, N.W.; Anderson, O.F.; Francis, M.P.; Griggs, L.H.; Clark, M.R.; Paul, L.J.; Taylor, P.R. (2000). Atlas of juvenile and adult fish and squid distributions from bottom and midwater trawls and tuna longlines in New Zealand waters. *NIWA Technical Report 84*. 162 p.

Mormede, S. (2024). Management strategy evaluation of New Zealand ling stocks. *New Zealand Fisheries Assessment Report 2024/86*. 33 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2021). Descriptive analysis and stock assessment model inputs of ling (*Genypterus blacodes*) in the Sub-Antarctic (LIN 5&6) for the 2020–21 fishing year. *New Zealand Fisheries Assessment Report 2021/60*. 113 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2022). Descriptive analysis of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) up to 2020–21 and inputs for the 2022 stock assessment. *New Zealand Fisheries Assessment Report 2022/64*. 85 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2023a). Descriptive analysis of ling off the west coast of the South Island (LIN 7WC) up to 2021–22 and inputs for the 2023 stock assessment. *New Zealand Fisheries Assessment Report 2023/51*. 91 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2023b). Stock assessment of ling (*Genypterus blacodes*) on the Chatham Rise (LIN 3&4) for the 2021–22 fishing year. *New Zealand Fisheries Assessment Report 2023/14*. 39 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2024a). The 2023 stock assessment of ling (*Genypterus blacodes*) off the west coast South Island (LIN 7WC). *New Zealand Fisheries Assessment Report 2024/02*. 23 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2024b). Descriptive analysis of ling in the Sub-Antarctic (LIN 5&6 and LIN 6B) up to 2023 and inputs for the 2024 stock assessment. *New Zealand Fisheries Assessment Report 2024/82*. 94 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2024c). Stock hypotheses for ling in the Sub-Antarctic (LIN 5&6 and LIN 6B). *New Zealand Fisheries Assessment Report 2024/83.* 13 p.

Mormede, S.; Dunn, A.; Webber, D.N. (2024d). The 2024 stock assessment of ling (*Genypterus blacodes*) in the Sub-Antarctic (LIN5&6 and LIN 6B). *New Zealand Fisheries Assessment Report 2024/84.* 28 p.

APPENDIX A – Representativeness of the observer data

Table A.1: Annual catch of ling in LIN 3&4 from the 2008 to the 2023 calendar years by method and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Only catches from returns with location data are included in this table.

Year	Bottom longline			Bottom and midwater trawl		
Observer data also collected?	Yes (t)	No (t)	Yes (% catch)	Yes (t)	No (t)	Yes (% catch)
2008	1 359	529	72.0	1 819	92	95.2
2009	1 356	485	73.7	993	124	88.9
2010	508	1 289	28.3	1 008	130	88.6
2011	0	1 561	0.0	664	82	89.0
2012	0	1 728	0.0	1 019	80	92.7
2013	771	1 596	32.6	664	62	91.5
2014	1 510	491	75.5	786	127	86.1
2015	531	1 012	34.4	920	39	95.9
2016	1 681	719	70.0	911	132	87.3
2017	1 319	640	67.3	1 277	66	95.1
2018	1 530	821	65.1	733	70	91.3
2019	712	957	42.7	599	100	85.7
2020	924	735	55.7	657	114	85.2
2021	309	1 484	17.2	758	66	92.0
2022	890	886	50.1	814	29	96.6
2023	470	449	51.1	1 007	45	95.7

Table A.2: Annual catch of ling in LIN 5&6 from the 2008 to the 2023 calendar years by method and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Only catches from returns with location data are included in this table.

Year	Bottom longline			Bottom and midwater trawl		
Observer data also collected?	Yes (t)	No (t)	Yes (% catch)	Yes (t)	No (t)	Yes (% catch)
2008	0	691	0.0	3 976	822	82.9
2009	524	26	95.3	3 740	283	93.0
2010	618	391	61.2	4 003	173	95.9
2011	101	727	12.2	4 222	59	98.6
2012	469	716	39.6	6 541	324	95.3
2013	0	277	0.0	5 052	246	95.4
2014	459	529	46.5	5 701	283	95.3
2015	0	773	0.0	5 347	141	97.4
2016	220	345	38.9	4 611	201	95.8
2017	140	595	19.0	6 491	165	97.5
2018	249	429	36.7	7 003	85	98.8
2019	638	557	53.4	6 223	563	91.7
2020	585	1 188	33.0	5 776	407	93.4
2021	80	1 026	7.2	6 713	399	94.4
2022	525	724	42.0	6 887	86	98.8
2023	1 209	392	75.5	5 873	361	94.2

Table A.3: Annual catch of ling in LIN 6B from the 2008 to the 2023 calendar years by method and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Only catches from returns with location data are included in this table.

Year	Bottom longline			Bottom and midwater trawl		
Observer data also collected?	Yes (t)	No (t)	Yes (% catch)	Yes (t)	No (t)	Yes (% catch)
2008	465	36	92.8	1	0	100.0
2009	169	53	76.1	9	1	90.0
2010	0	1	0.0	0	0	
2011	0	51	0.0	2	0	100.0
2012	0	1	0.0	1	0	100.0
2013	0	204	0.0	3	0	100.0
2014	0	61	0.0	11	0	100.0
2015	0	23	0.0	0	0	
2016	0	220	0.0	0	0	
2017	439	440	49.9	0	0	
2018	0	132	0.0	0	0	
2019	140	15	90.3	0	1	0.0
2020	182	28	86.7	0	0	
2021	0	593	0.0	0	0	
2022	113	106	51.6	0	0	
2023	256	32	88.9	1	0	100.0

Table A.4: Annual catch of ling in LIN 7CK from the 2008 to the 2023 calendar years by method and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Only catches from returns with location data are included in this table.

Year	Bottom longline			Bottom and midwater trawl		
Observer data also collected?	Yes (t)	No (t)	Yes (% catch)	Yes (t)	No (t)	Yes (% catch)
2008	0	77	0.0	84	15	84.8
2009	0	22	0.0	78	8	90.7
2010	0	24	0.0	65	12	84.4
2011	0	33	0.0	60	22	73.2
2012	0	33	0.0	61	20	75.3
2013	0	74	0.0	70	15	82.4
2014	0	80	0.0	65	13	83.3
2015	5	37	11.9	59	17	77.6
2016	0	66	0.0	41	10	80.4
2017	134	17	88.7	51	5	91.1
2018	8	12	40.0	69	4	94.5
2019	0	16	0.0	102	10	91.1
2020	0	17	0.0	65	3	95.6
2021	0	3	0.0	58	6	90.6
2022	15	5	75.0	71	4	94.7
2023	0	61	0.0	87	3	96.7

Table A.5: Annual catch of ling in LIN 7WC from the 2008 to the 2023 calendar years by method and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Only catches from returns with location data are included in this table.

Year	Bottom longline			Bottom and midwater trawl		
Observer data also collected?	Yes (t)	No (t)	Yes (% catch)	Yes (t)	No (t)	Yes (% catch)
2008	0	756	0.0	585	251	70.0
2009	0	718	0.0	804	125	86.5
2010	14	939	1.5	807	278	74.4
2011	0	844	0.0	1 045	245	81.0
2012	348	520	40.1	1 127	132	89.5
2013	0	896	0.0	1 305	139	90.4
2014	0	1 205	0.0	1 349	70	95.1
2015	180	876	17.0	1 464	126	92.1
2016	608	612	49.8	1 640	33	98.0
2017	642	602	51.6	1 744	136	92.8
2018	611	421	59.2	1 678	24	98.6
2019	1 039	262	79.9	1 302	100	92.9
2020	977	567	63.3	1 214	103	92.2
2021	1 619	59	96.5	1 031	103	90.9
2022	1 179	287	80.4	1 147	67	94.5
2023	0	965	0.0	1 169	56	95.4

Table A.6: Annual catch of ling in outside of the main ling stocks (referred as OTHER in further plots) from the 2008 to the 2023 calendar years by method and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Only catches from returns with location data are included in this table.

Year	Bottom longline			Bottom and midwater trawl		
Observer data also collected?	Yes (t)	No (t)	Yes (% catch)	Yes (t)	No (t)	Yes (% catch)
2008	85	555	13.3	58	101	36.5
2009	0	625	0.0	53	136	28.0
2010	0	751	0.0	57	92	38.3
2011	0	738	0.0	58	86	40.3
2012	0	507	0.0	1	169	0.6
2013	0	563	0.0	109	132	45.2
2014	0	620	0.0	105	82	56.1
2015	43	592	6.8	124	66	65.3
2016	285	457	38.4	115	106	52.0
2017	394	450	46.7	211	16	93.0
2018	447	372	54.6	66	104	38.8
2019	0	777	0.0	170	23	88.1
2020	157	432	26.7	131	59	68.9
2021	126	373	25.3	127	55	69.8
2022	51	332	13.3	64	92	41.0
2023	0	268	0.0	17	117	12.7

Table A.7: Annual catch of ling by stock from the 2008 to the 2023 calendar years and percentage of it caught in 0.5° by 0.5° cells where only bottom longlines fished in that year. Only catches from returns with location data are included in this table.

						Catch (t)
Year	LIN3&4	LIN5&6	LIN6B	LIN7CK	LIN7WC	OTHER
2008	3 798	5 489	503	176	1 592	799
2009	2 958	4 574	232	108	1 647	815
2010	2 935	5 185	1	101	2 038	900
2011	2 307	5 109	53	115	2 135	883
2012	2 827	8 049	2	114	2 127	678
2013	3 092	5 574	207	158	2 341	804
2014	2 914	6 971	72	157	2 624	806
2015	2 503	6 261	23	118	2 647	825
2016	3 443	5 377	220	117	2 893	963
2017	3 303	7 392	879	206	3 124	1 070
2018	3 154	7 767	133	94	2 734	989
2019	2 368	7 981	156	127	2 702	970
2020	2 430	7 956	210	84	2 860	778
2021	2 617	8 218	593	68	2 812	680
2022	2 619	8 222	219	94	2 680	539
2023	1 970	7 834	288	150	2 190	403
	Percentage of catch caught in cells where only bottom longlines fished in that year					
2008	3.6	4.1	72.9	0.0	2.3	4.0
2009	10.2	2.9	17.3	0.0	1.0	10.1
2010	11.7	5.8	77.7	4.1	1.6	10.0
2011	1.6	4.4	94.9	0.0	0.0	7.6
2012	16.6	5.9	69.8	0.0	1.7	12.2
2013	32.6	0.0	26.9	0.3	1.8	6.3
2014	17.3	7.3	77.6	0.0	3.5	8.0
2015	9.7	3.8	98.9	0.2	3.7	6.2
2016	12.6	4.5	100.0	0.2	12.4	9.6
2017	11.7	6.4	100.0	0.2	11.9	20.2
2018	9.0	3.0	78.6	0.0	6.3	6.5
2019	5.4	8.3	11.6	0.0	2.8	5.0
2020	32.7	12.4	61.2	0.0	8.8	7.2
2021	25.9	6.8	87.8	0.0	2.3	2.7
2022	31.3	8.3	89.1	0.0	2.8	3.2
2023	23.8	11.8	84.6	0.0	4.4	11.4

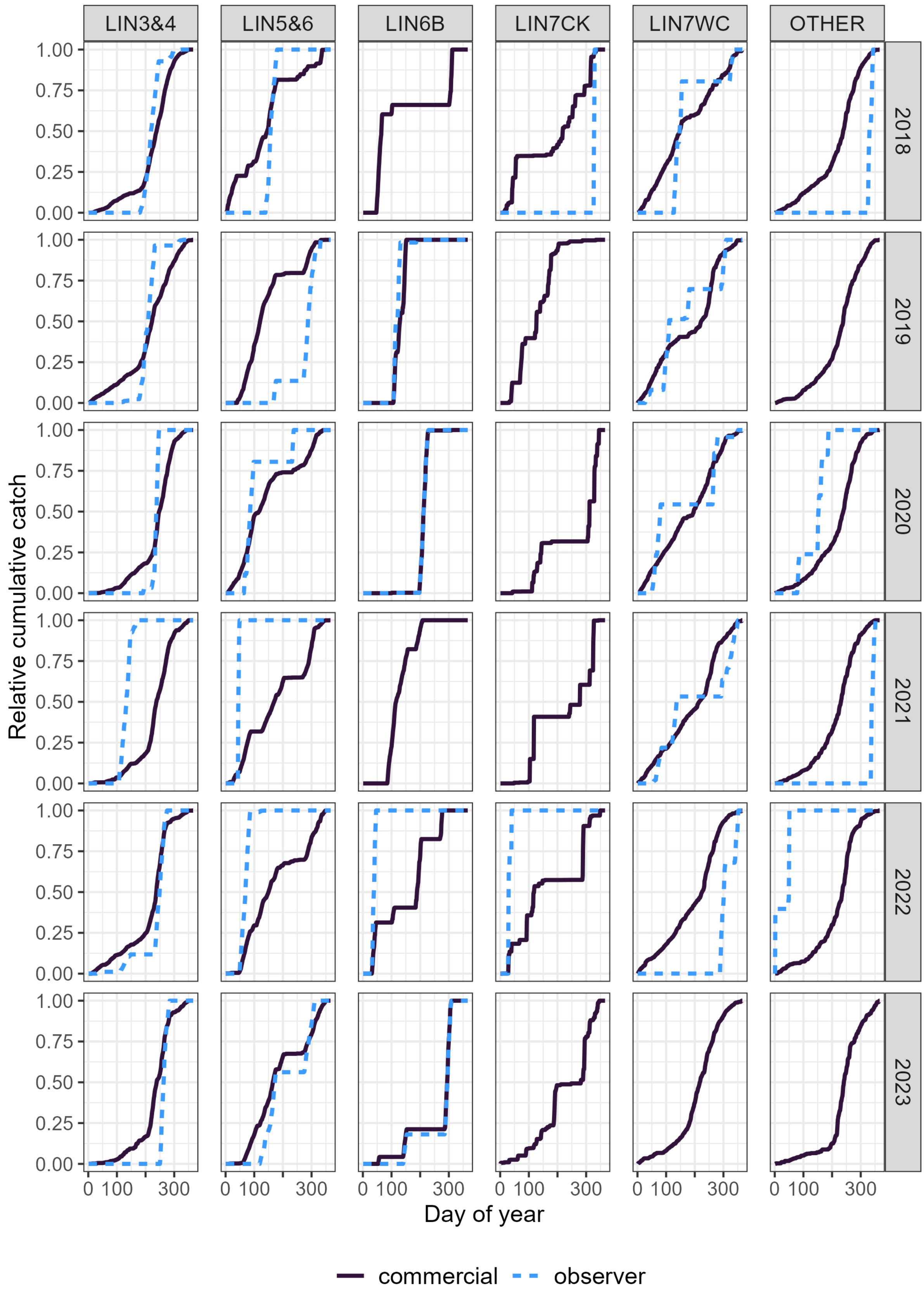

Figure A.1: Relative cumulative bottom longline ling catch from commercial and observer data by calendar year and day of year.

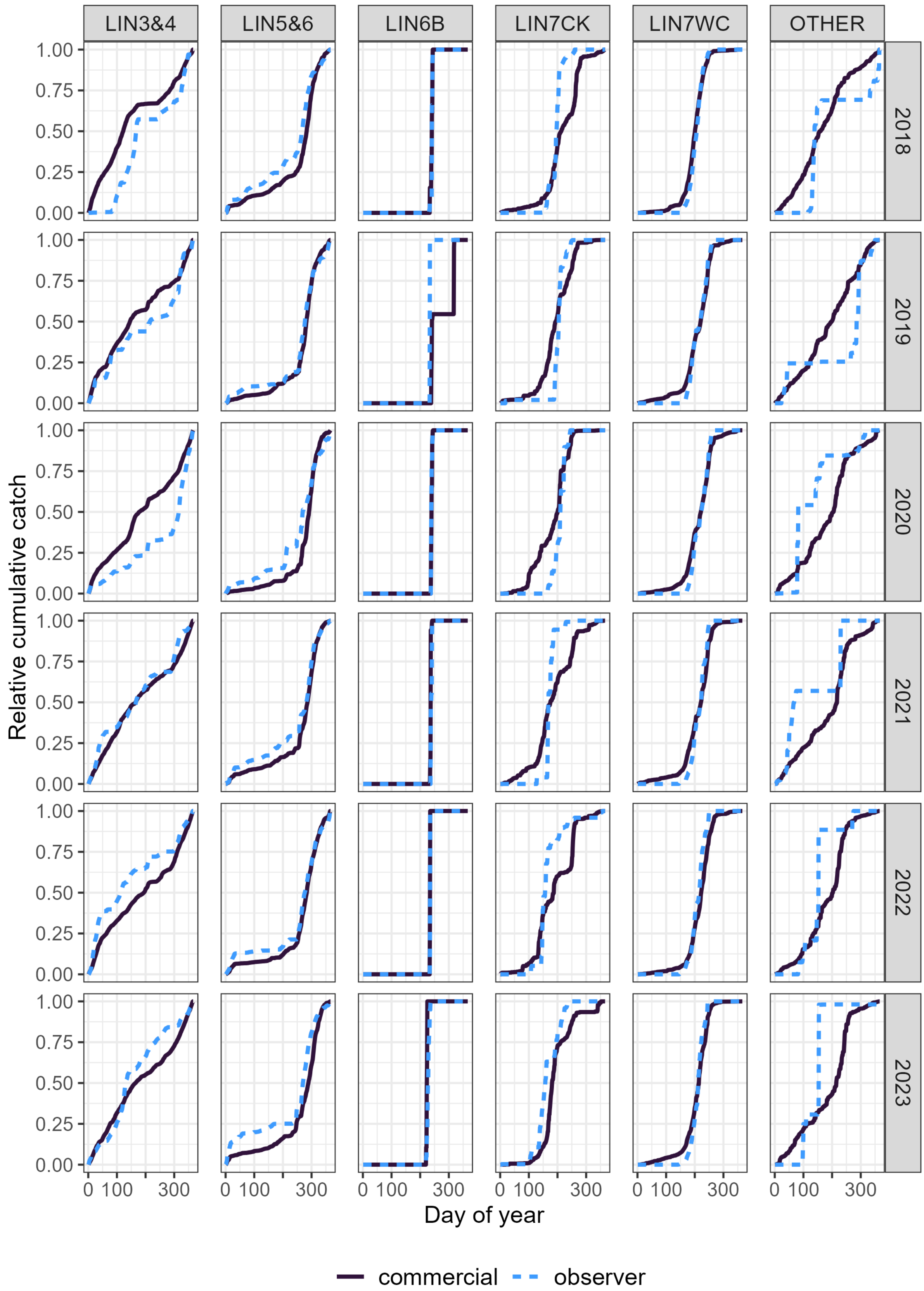

Figure A.2: Relative cumulative bottom and midwater trawl ling catch from commercial and observer data by calendar year and day of year.

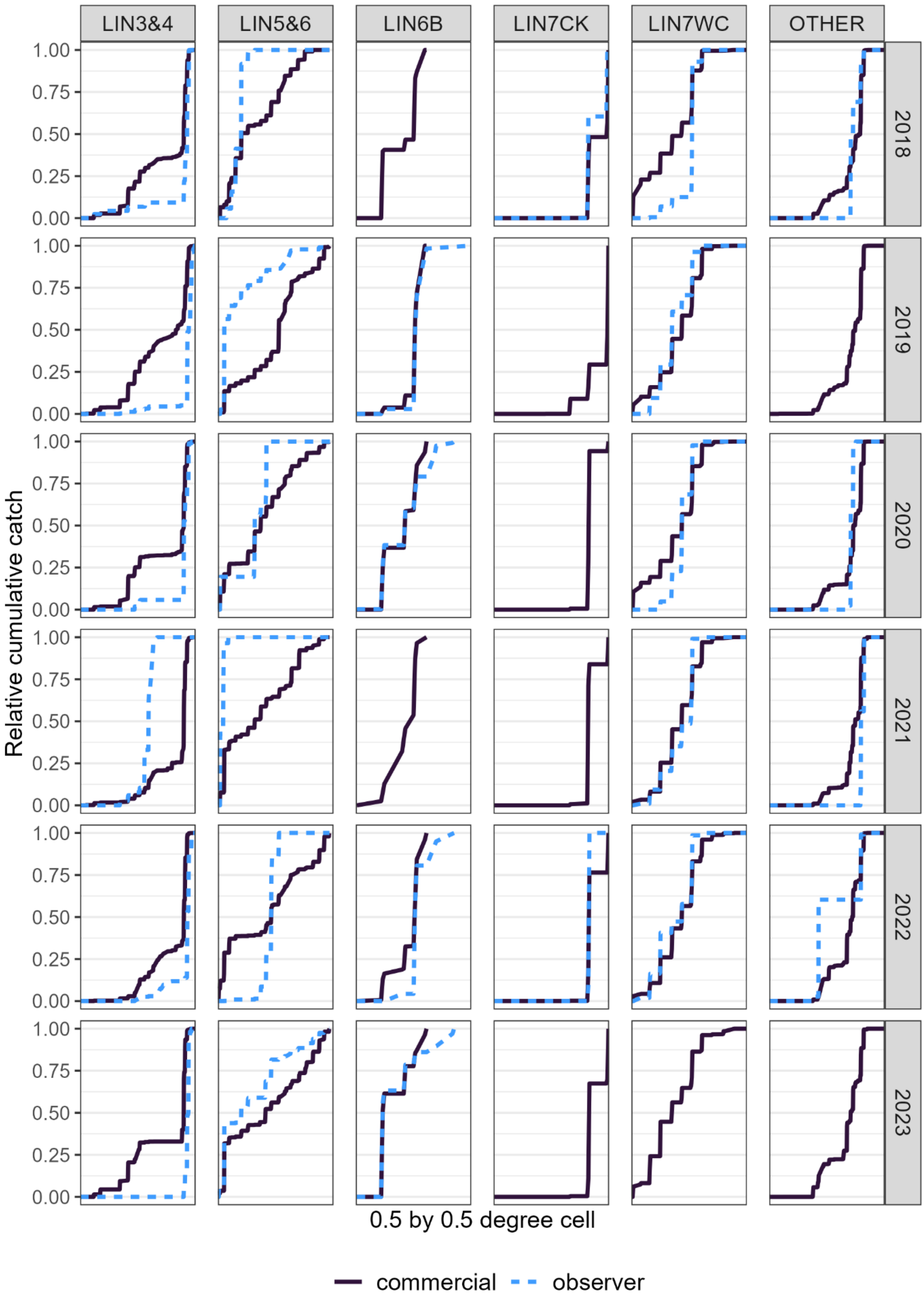

Figure A.3: Relative cumulative bottom longline ling catch from commercial and observer data by calendar year and 0.5° by 0.5° cell.

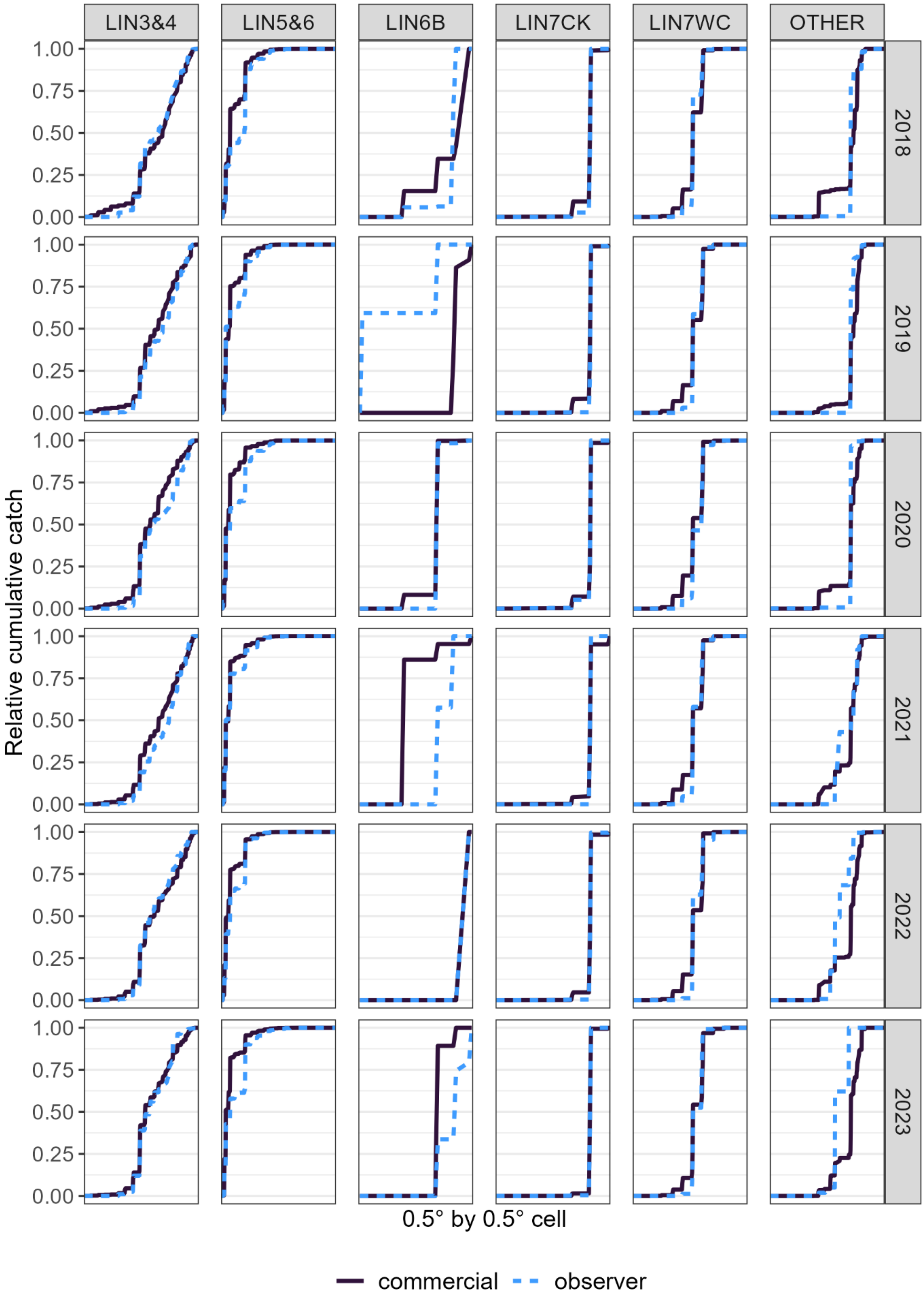

Figure A.4: Relative cumulative bottom and midwater trawl ling catch from commercial and observer data by calendar year and 0.5° by 0.5° cell.

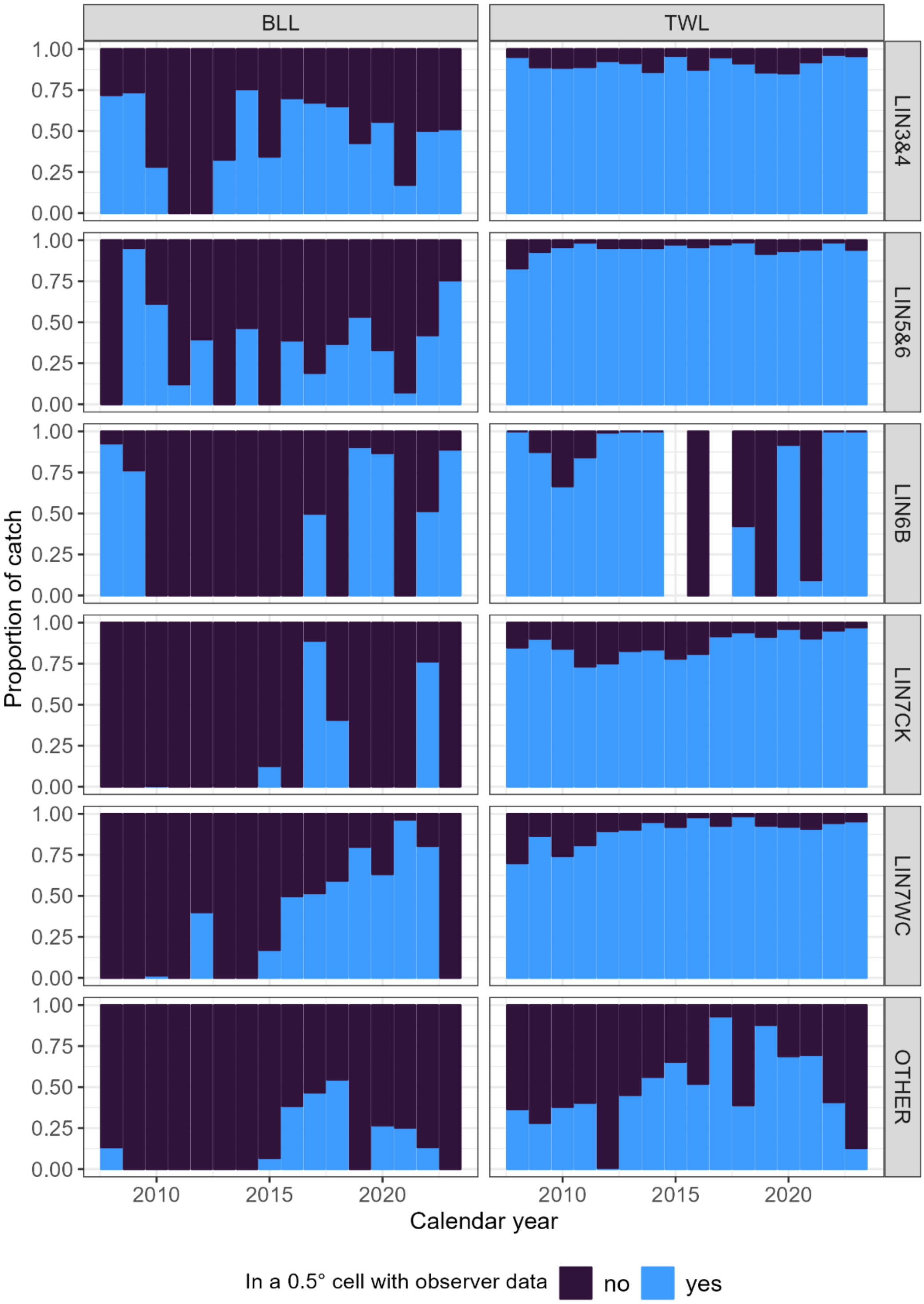

Figure A.5: Annual proportion of catch of ling from the 2008 to the 2023 calendar years by stock, method, and whether it was caught in a 0.5° by 0.5° cell where observer data were also collected in that year. Method is bottom longline (BLL) or bottom or midwater trawl (TWL). Only catches from returns with location data are included in this plot.

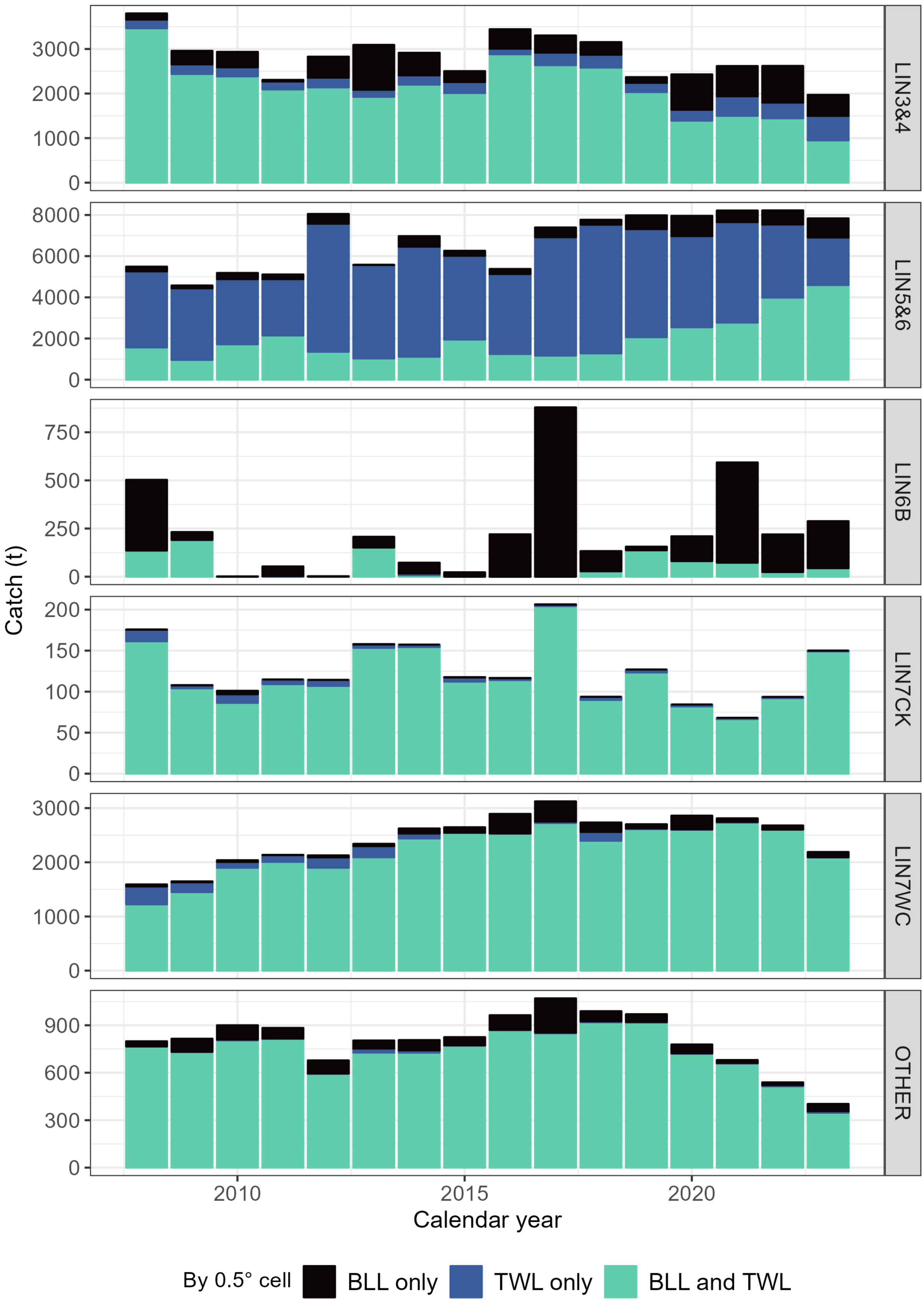

Figure A.6: Annual catch of ling from the 2008 to the 2023 calendar years by stock and whether it was caught in a 0.5° by 0.5° cell where only bottom longline (BLL only), only bottom or midwater trawl (TWL only) or bottom longline and trawl (BLL and TWL) were used to catch ling in that calendar year. Only catches from returns with location data are included in this plot.

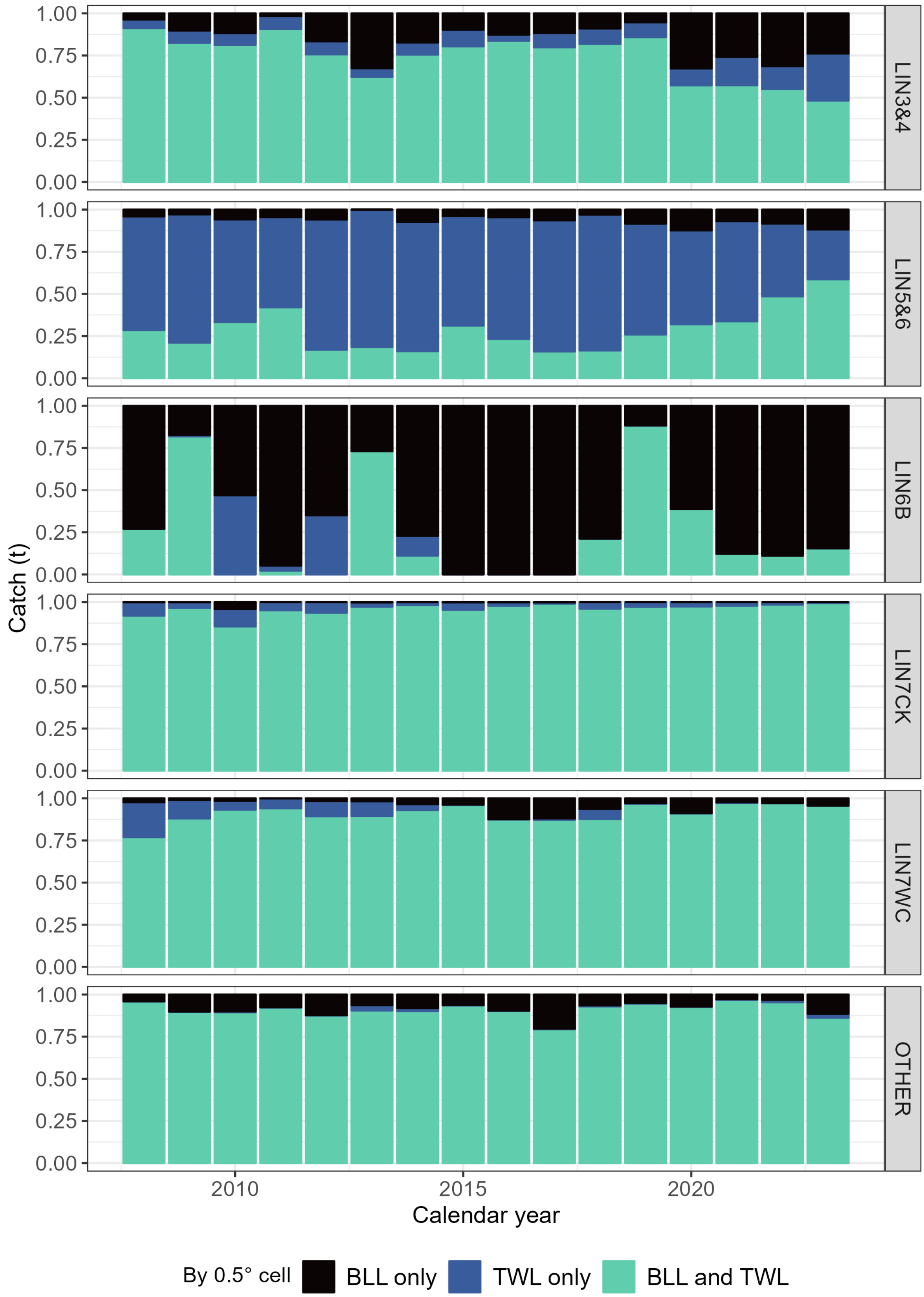

Figure A.7: Annual proportion of catch of ling from the 2008 to the 2023 calendar years by stock and whether it was caught in a 0.5° by 0.5° cell where only bottom longline (BLL only), only bottom or midwater trawl (TWL only) or bottom longline and trawl (BLL and TWL) used to catch ling that year. Only catches from returns with location data are included in this plot.

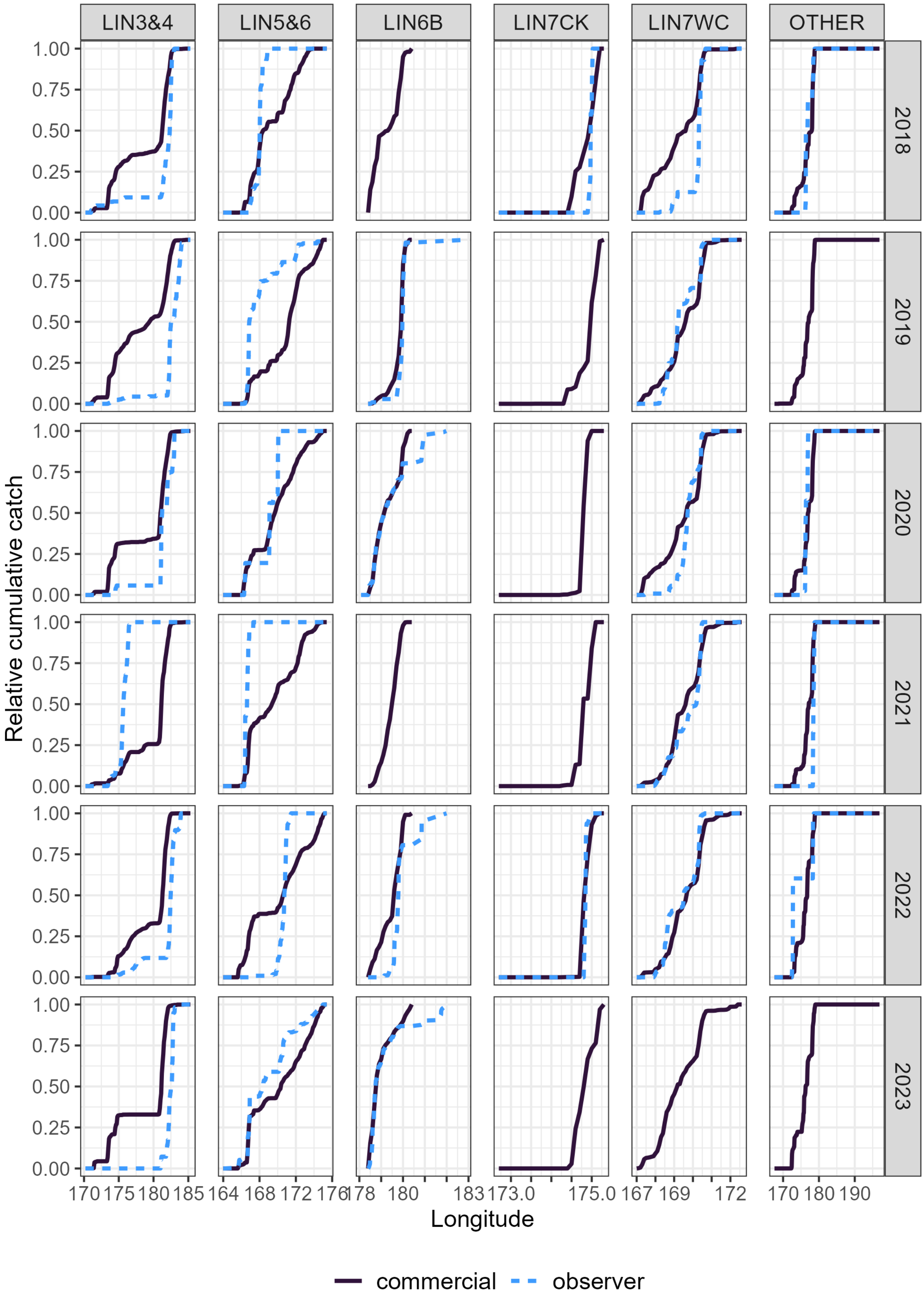

Figure A.8: Relative cumulative bottom longline ling catch from commercial and observer data by calendar year and longitude.

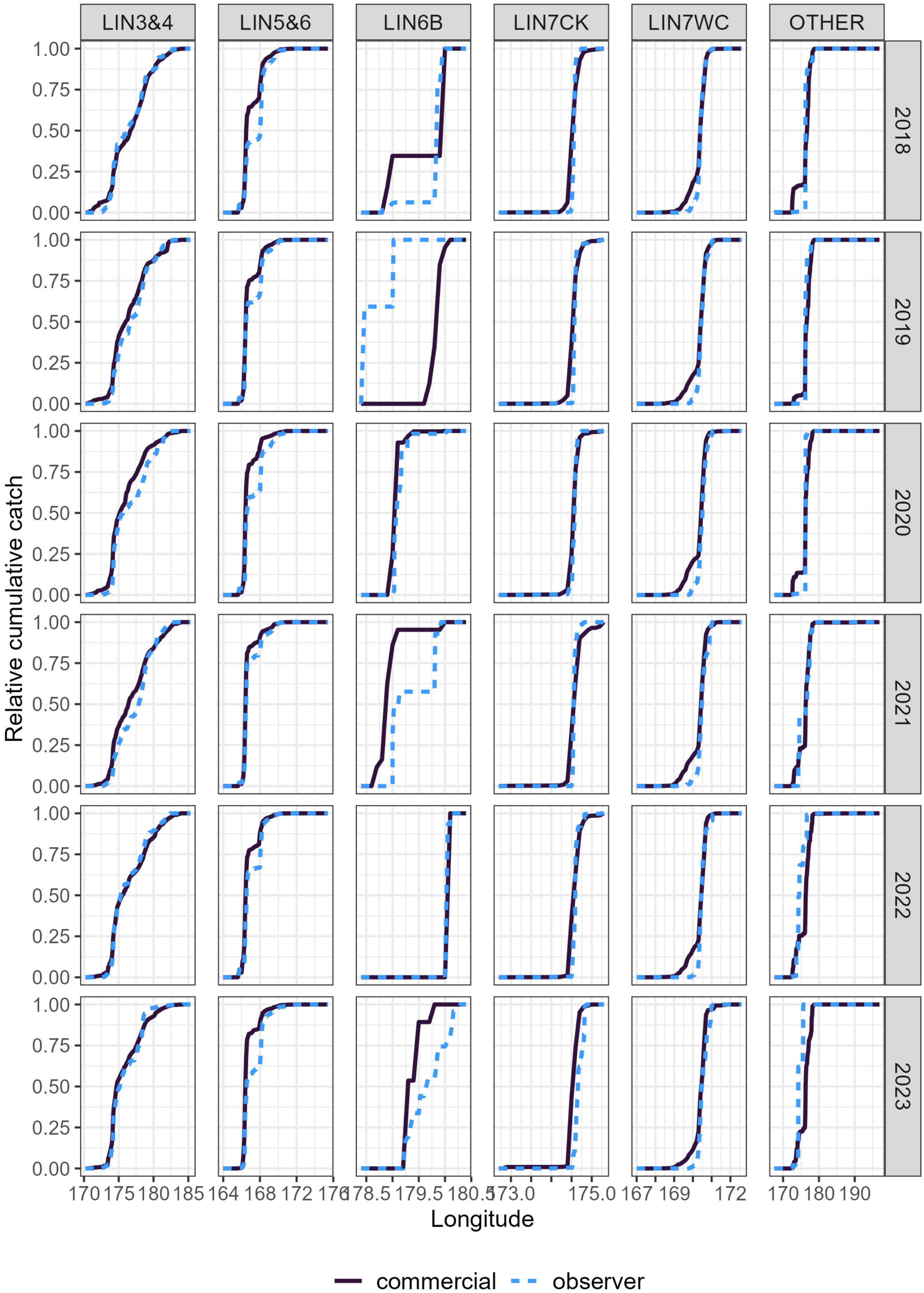

Figure A.9: Relative cumulative bottom and midwater trawl ling catch from commercial and observer data by calendar year and longitude.

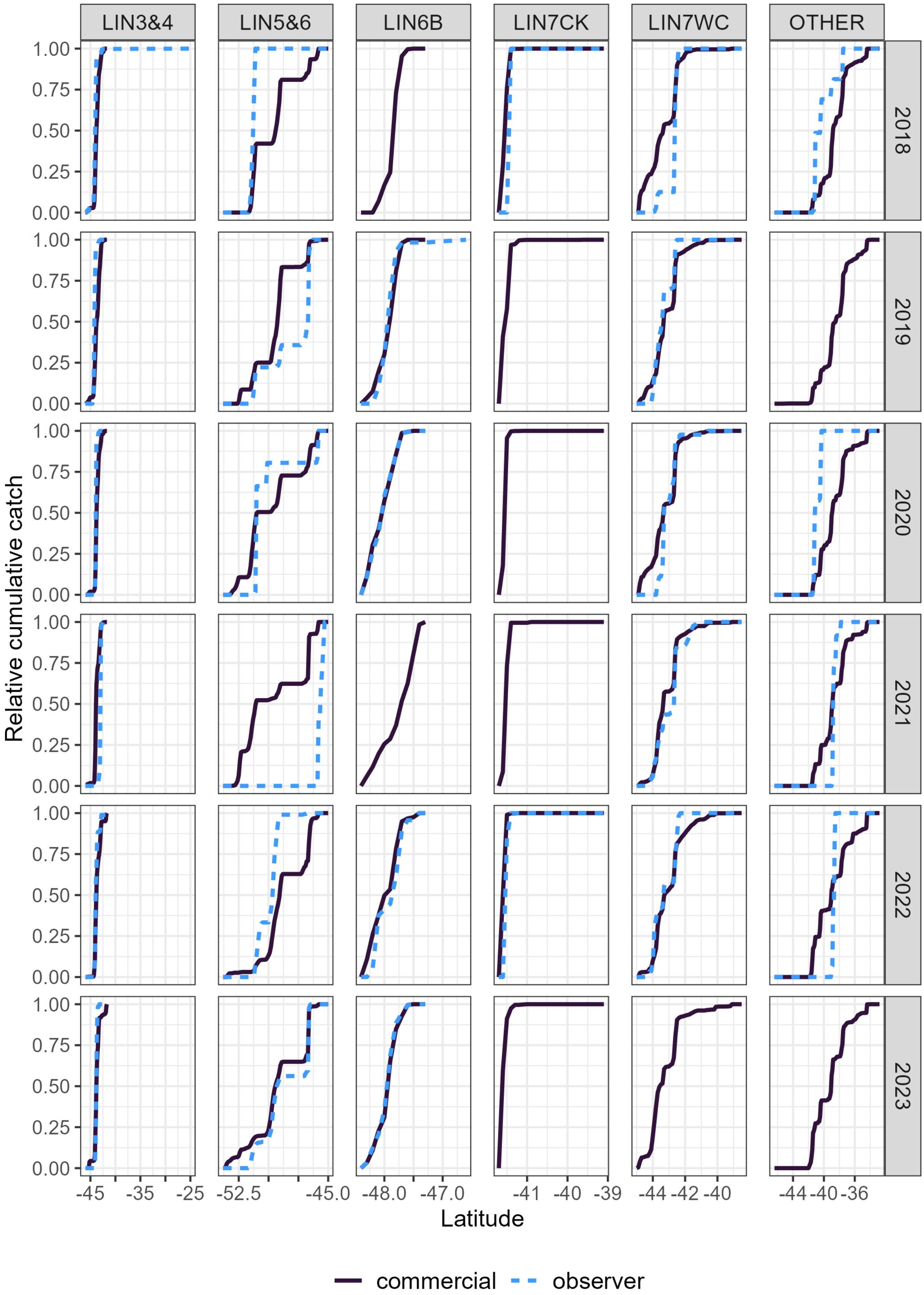

Figure A.10: Relative cumulative bottom longline ling catch from commercial and observer data by calendar year and latitude.

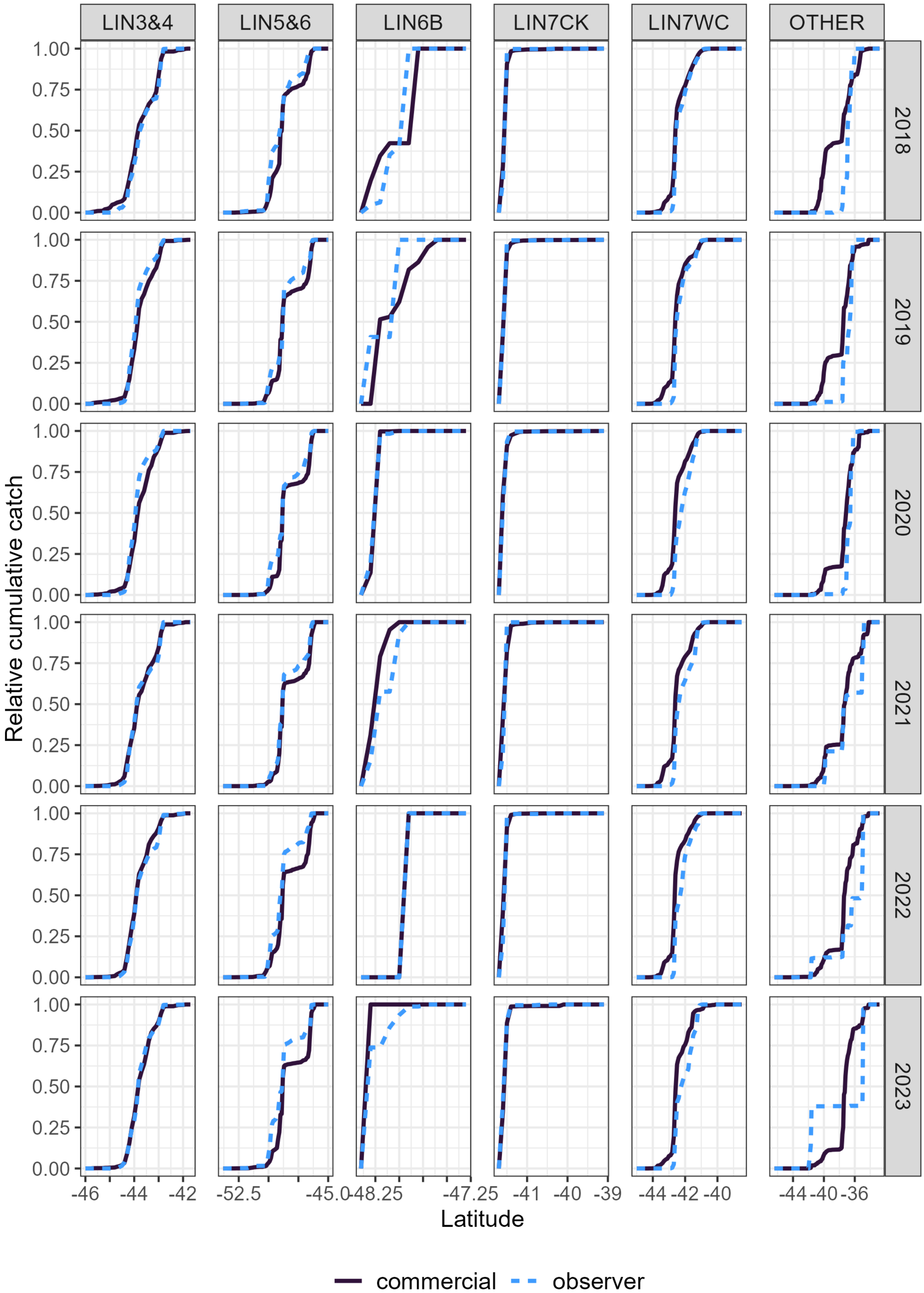

Figure A.11: Relative cumulative bottom and midwater trawl ling catch from commercial and observer data by calendar year and latitude.

APPENDIX B – Results of population models

Table B. 1: LIN 3&4 stock initial spawning stock biomass (B_o) in tonnes, spawning stock biomass at the end of the model in 2022 (B_{2022}) as a proportion of B_0, and natural mortality average (M_{av}) and difference (M_{diff}) parameters for the base case and the base case without bottom longline age compositions (basenoBLL). The table shows the median and 95% credible interval of the posterior distribution.

run		B_0 (t)			B_{2022} (%B_0)			M_{av}			M_{diff}	
	50%	2.50%	97.50%	50%	2.50%	97.50%	50%	2.50%	97.50%	50%	2.50%	97.50%
Base	110 040	100 660	129 890	55.8	46.9	66.3	0.156	0.142	0.172	-0.015	-0.023	-0.007
basenoBLL	119 010	104 870	147 390	64.3	45.6	94.9	0.161	0.146	0.176	-0.006	-0.016	0.004

Table B. 2: LIN 5&6 and LIN6B initial spawning stock biomass (B_o) in tonnes and spawning stock biomass at the end of the model in 2024 (B_{2024}) as a proportion of B_0. The table shows the median and 95% credible interval of the posterior distribution.

run		B_0 (t)			B_{2024} (%B_0)	
	50%	2.50%	97.50%	50%	2.50%	97.50%
Base	204 628	171 734	258 458	66.3	55.3	78.3
basenoBLL	212 692	175 995	275 733	69.3	57.6	82.1

Table B. 3: LIN 7WC initial spawning stock biomass (B_o) in tonnes and spawning stock biomass at the end of the model in 2023 (B_{2023}) as a proportion of B_0. The table shows the median and 95% credible interval of the posterior distribution.

run		B_0 (t)			B_{2023} (%B_0)	
	50%	2.50%	97.50%	50%	2.50%	97.50%
Base	62 168	55 006	74 123	55.0	46.1	65.4
basenoBLL	61 081	54 043	72 707	54.3	45.6	65.1

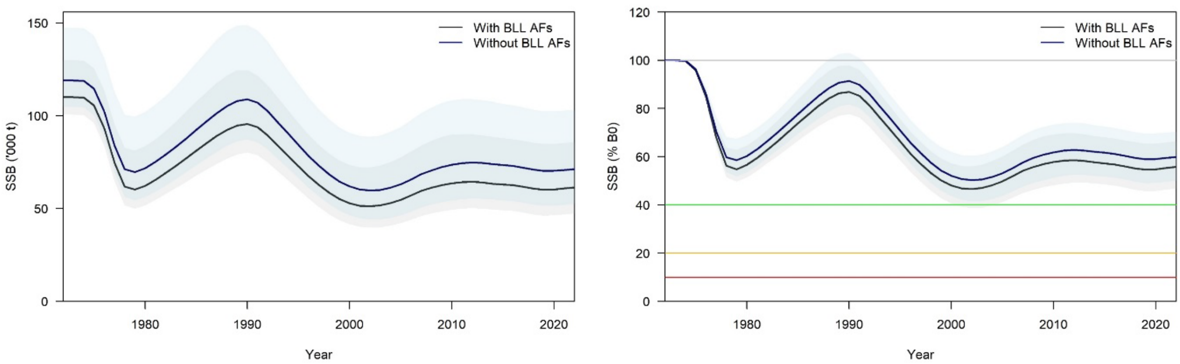

Figure B.1: LIN 3&4 estimated posterior distribution of the spawning stock biomass (*SSB* in tonnes, left) and of the proportion of initial spawning biomass (% B_0, right) trajectory with estimated initial spawning stock biomass reference points (40%, 20%, and 10% B_0) for the base case model (''With BLL AFs'') and the model excluding observer bottom longline age composition data (''Without BLL AFs'). The solid line represents the median values, the shading indicates the 95% credible interval.

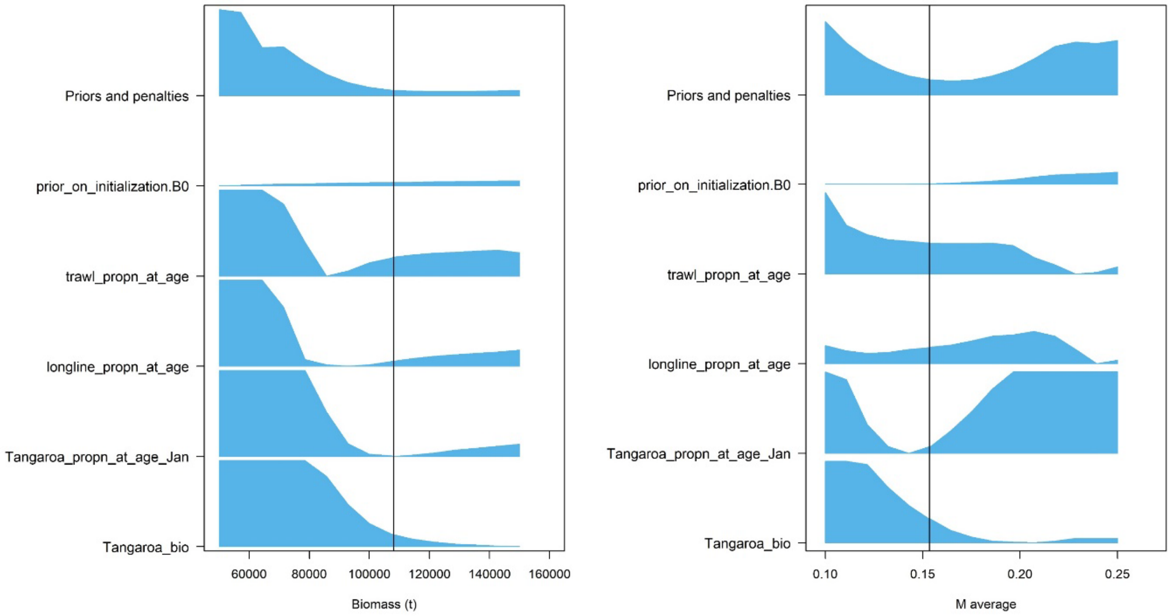

Figure B.2: LIN 3&4 MPD profile on initial spawning stock biomass (left) and on average natural mortality (right). The vertical line represents the MPD estimate. 'longline_propn_at_age' represents the bottom longline age composition which are derived from observer data.

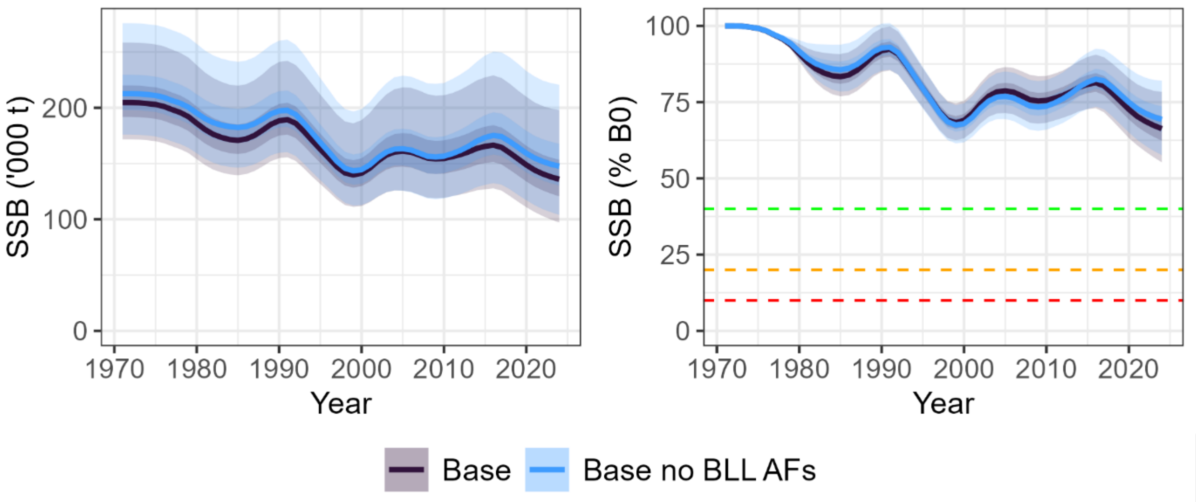

Figure B.3: LIN 5&6 and LIN 6B estimated posterior distribution of the spawning stock biomass (*SSB* in tonnes, left) and of the proportion of initial spawning biomass (% B_0, right) trajectory with estimated initial spawning stock biomass reference points (40%, 20%, and 10% B_0) for the base case model ('Base') and the model excluding observer bottom longline age composition data ('Base no BLL AFs'). The solid line represents the median values, the dark shading indicates the interquartile range and the light shading the 95% credible interval.

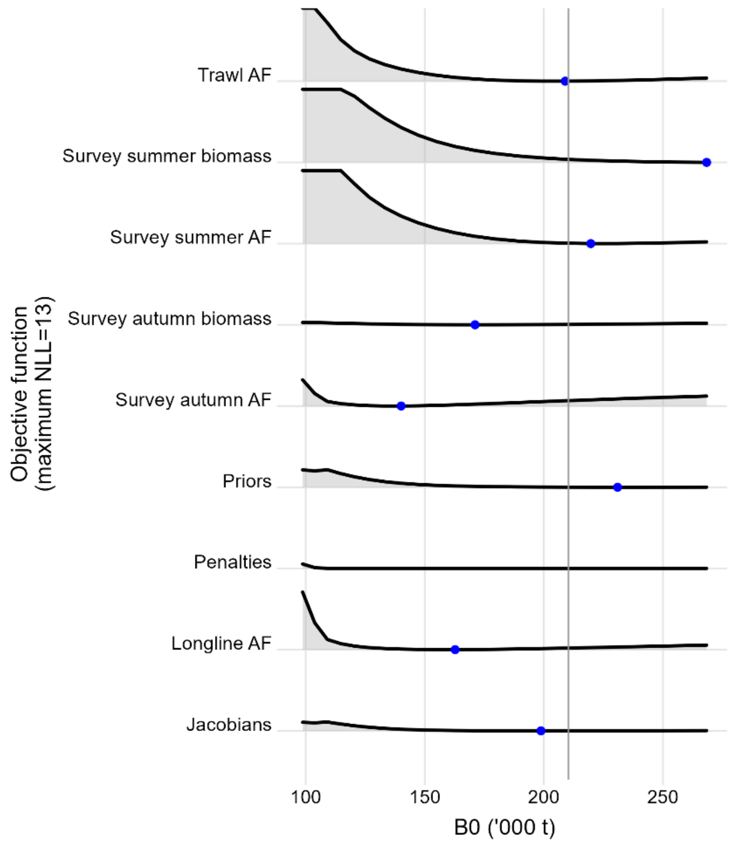

Figure B.4: **LIN 5&6 and LIN 6B MPD profile on initial spawning stock biomass. The vertical line represents the MPD estimate. NLL is negative log likelihood and AF is age frequencies (age compositions). 'Longline AF' represents the bottom longline age composition which are derived from observer data.**

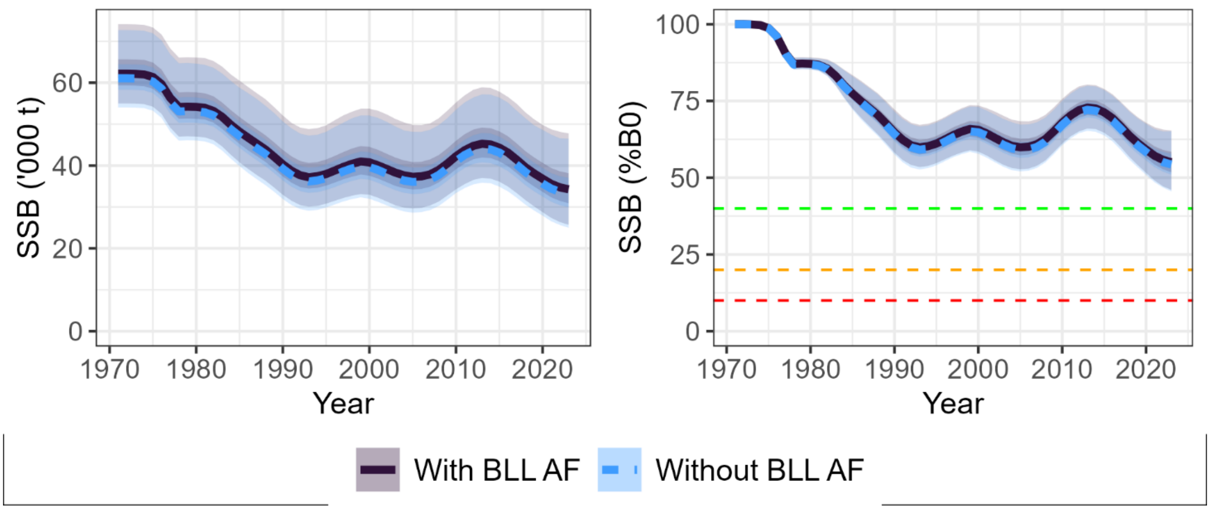

Figure B.5: **LIN 7WC estimated posterior distribution of the spawning stock biomass (*SSB* in tonnes, left) and of the proportion of initial spawning biomass (% B_0, right) trajectory with estimated initial spawning stock biomass reference points (40%, 20%, and 10% B_0) for the base case model ('with BLL AF') and the model excluding observer bottom longline age composition data ('without BLL AF'). The solid line represents the median values, the dark shading indicates the interquartile range and the light shading the 95% credible interval.**

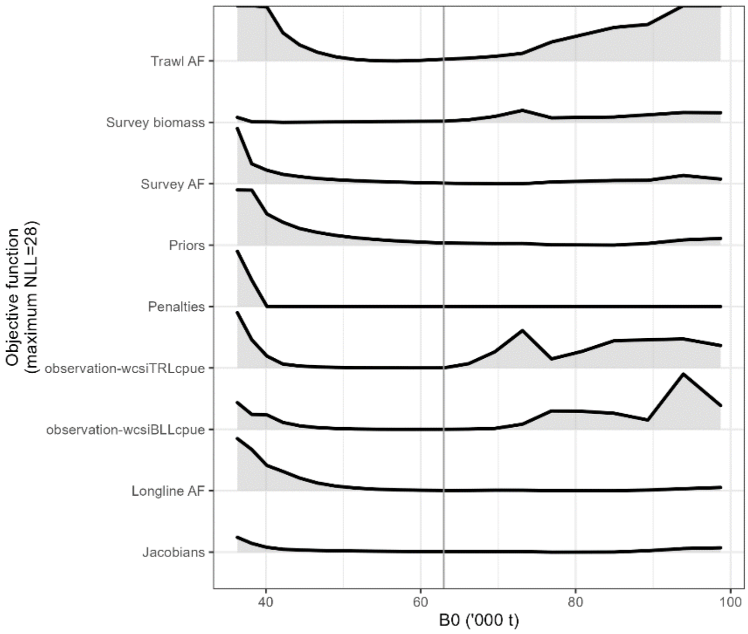

Figure B.6: LIN 7WC MPD profile on initial spawning stock. The vertical line represents the MPD estimate. NLL is negative log likelihood and AF is age frequencies (age compositions). 'Longline AF' represents the bottom longline age composition which are derived from observer data.