

2020 Alaska Statewide Weathervane Scallop GHL Supplement

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1 Background

This document summarizes weathervane scallop *Patinopecten caurinus* fishery dependent and fishery independent data to aid in setting guideline harvest levels (GHLs) for the 2020/21 scallop season, scheduled to begin July 1. Amendment 3 to the Fishery Management Plan for the Scallop Fishery off Alaska (FMP) delegated authority to manage all aspects of the federal waters scallop fishery except limited access to the State of Alaska. ADF&G sets GHLs prior to each season, opens and closes scallop fishing areas and districts, oversees the onboard observer program, monitors scallop fishery catch and bycatch inseason, summarizes scallop management activities in department publications, and participates in the federal management process through the North Pacific Fishery Management Council (NPFMC) and Scallop Plan Team (SPT) (NPFMC 2014).

Amendment 13 of the weathervane scallop FMP to incorporate Annual Catch Limits (ACLs) required by the 2006 reauthorization of the Magnuson-Stevens Act redefined the statewide overfishing level (OFL) from 1.24 million lb to 1.29 million lb of shucked scallop meats (NPFMC 2014). The change was made to account for all sources of fishing mortality including harvest, discarded scallop catch in the directed fishery, bycatch in other fisheries, and survey catches. The annual ACL will equal 90% of OFL, or 1.161 million lb of shucked meats, subject to annual approval by the NPFMC. For the ACL amendment analysis leading to the new OFL definition, mortality of scallops discarded in the fishery was assumed to be 20%, and meat recovery was set at 10% of scallop round weight (NPFMC 2014).

The state's vessel-based limited entry program for the state-waters scallop fishery sunsetted on December 31, 2013. Subsequently, the Alaska Board of Fisheries (BOF) passed a new state waters scallop fishery management plan (FMP). Details on the BOF action are available at <http://www.adfg.alaska.gov/index.cfm?adfg=fisheriesboard.meetinginfo&date=01-07-2014&meeting=kodiak>.

2 Data sources and updates

2.1 Fishery Data

Fishery data presented in this document include logbook information completed by vessel captains and data collection by observers during sampled dredges. All fishery data can be accessed on the Kodiak Wiki via the following link http://kodweb.fishgame.state.ak.us/index/Data_Access:Scallop_Observer. Although scallop vessel operators sign waivers that allow ADF&G to publish data collected by the onboard observer program, material included in this report such as individual vessel fishing locations, catches, and catch rates are *Confidential* and should not be released to the public.

Beds are the most basic population unit, and appear to undergo different dynamics even within the same district. As a result, bed specific data summaries are important to understanding interannual trends in fishing performance and biological characteristics of the fished stock. Beginning with this document, logbook information was assigned a bed code based on start locations of dredges (i.e., longitude, latitude). Most dredges could be assigned to a bed, but there are many that were outside of known bed boundaries throughout all seasons (for example exploratory effort) (Figure 1 - 7). Bed designations are preliminary and will be refined as appropriate bed boundaries are determined, and decision points are made regarding “unknown” locations. In the KSW district, bed was assigned for CPUE standardization (see below) as being north or south of 57.1° latitude (Figure 3).

Recent changes in management boundaries include the reclassification of the Karluk scallop beds to the Kodiak Southwest district (from Kodiak Shelikof), and merging of Yakutat Districts (previously D16 and D). Logbook data presented here that included both bed and location information here have been revised to reflect current management boundaries. This includes effort and retained catch analyses. Discard and Bycatch data are not summarized at the bed level in the database, and do not include location information in the current form of the data query. As a result, I was unable to revise timeseries to reflect current management reclassifications in the KSW and KSH district. **Discard and bycatch data of Karluk beds are presented here in the Kodiak Shelikof district as opposed to the Kodiak Southwest district.** Bycatch estimates for both historical Yakutat districts were combined.

Catch per unit effort (CPUE) estimates presented in this document include nominal (i.e., raw) meat weight CPUE, round weight CPUE, and standardized round weight CPUE. **All CPUE estimates presented here area nominal values unless stated otherwise.**

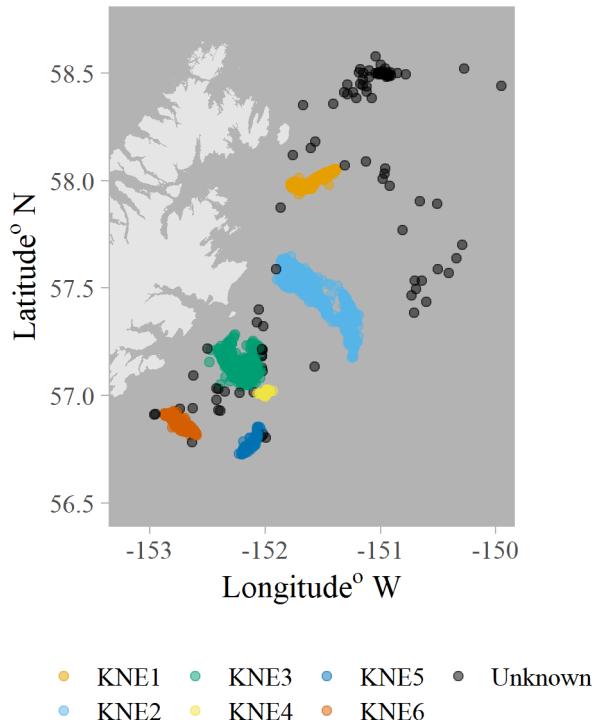


Figure 1: All dredge locations since the 2009/10 season in the KNE district by bed designation.

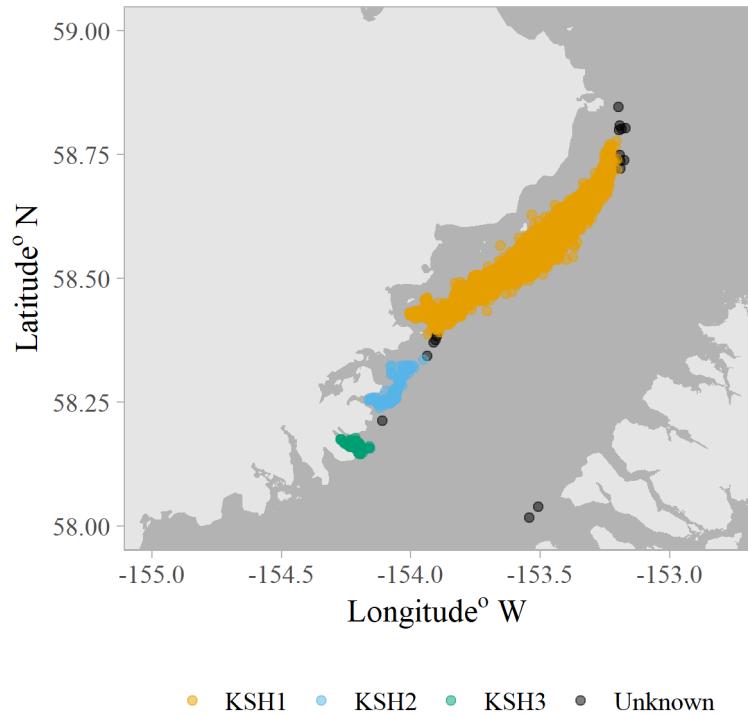


Figure 2: All dredge locations since the 2009/10 season in the KSH district by bed designation.

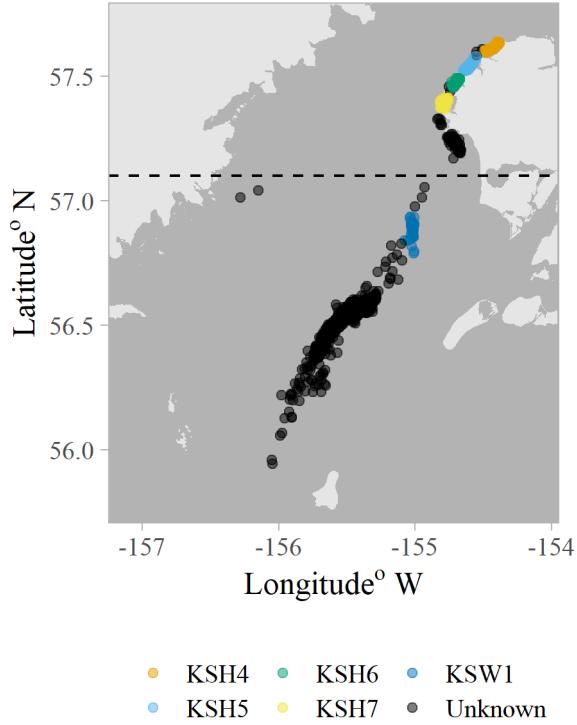


Figure 3: All dredge locations since the 2009/10 season in the KSW district by bed designation. For CPUE standardization bed was assigned as being north or south of 57.1 degrees latitude.

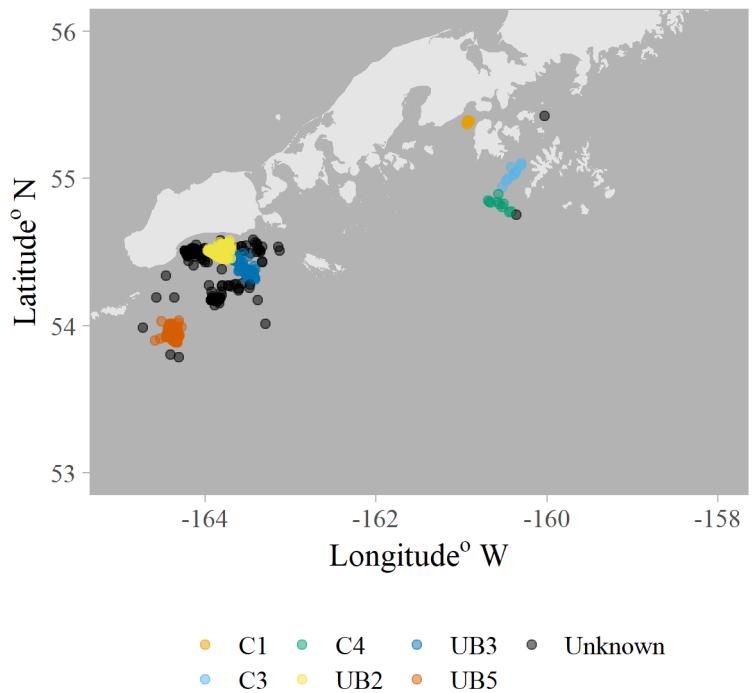


Figure 4: All dredge locations since the 2009/10 season in area M by bed designation.

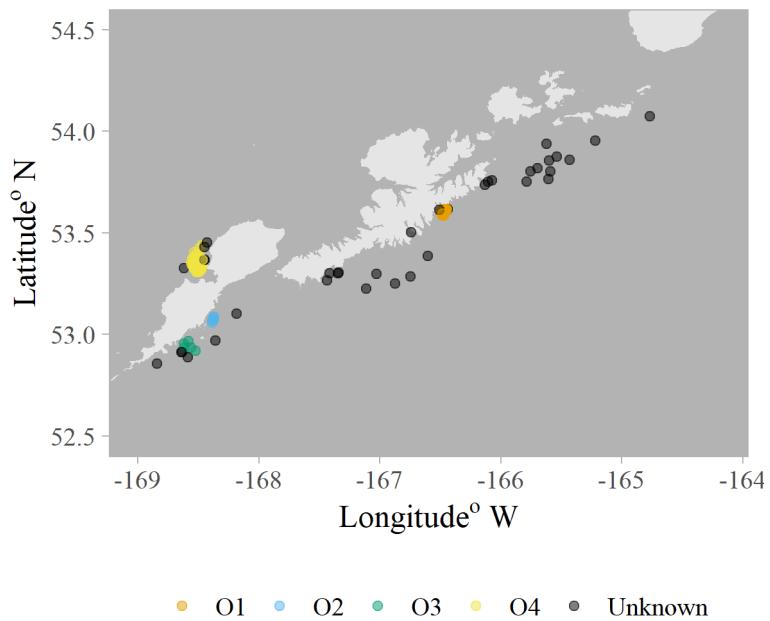


Figure 5: All dredge locations since the 2009/10 season in area O by bed designation.

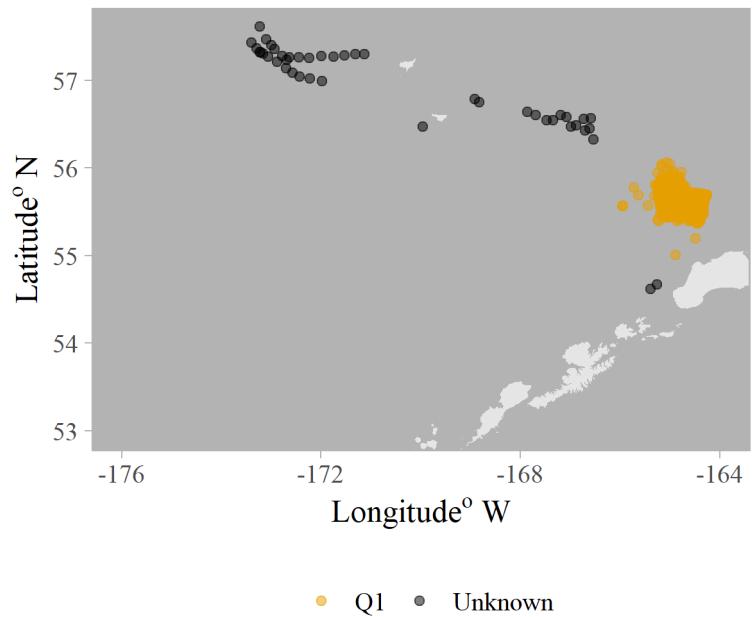


Figure 6: All dredge locations since the 2009/10 season in area Q by bed designation.

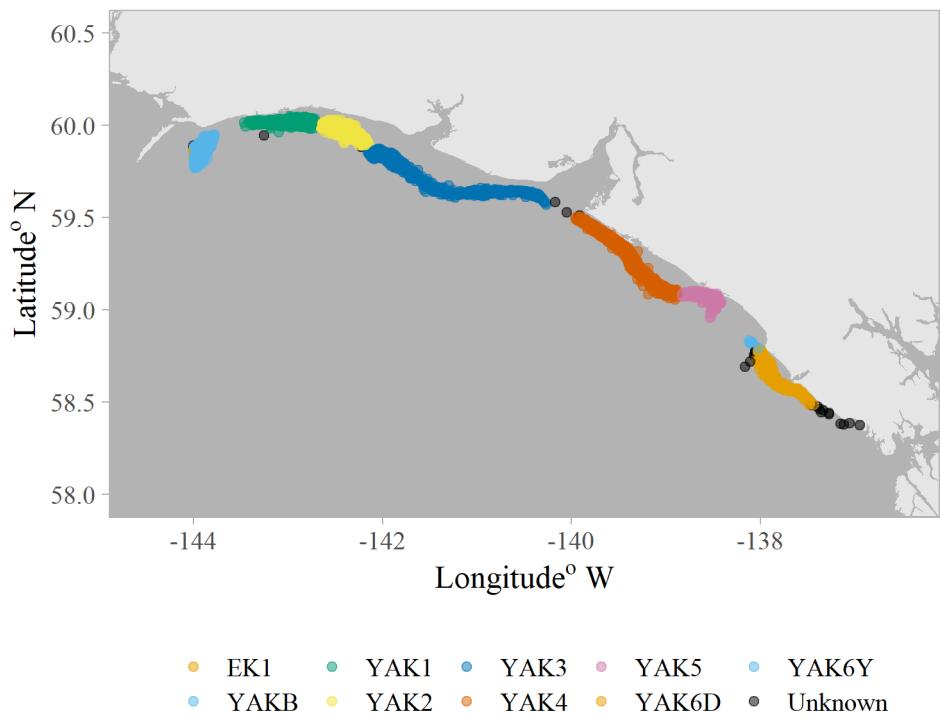


Figure 7: All dredge locations since the 2009/10 season in area D by bed designation.

2.2 Survey Data

Available recent survey data include the Statewide Weathervane Scallop Dredge survey (henceforth dredge survey) (Smith et al., 2016), the Westward Region Large-Mesh Bottom Trawl Survey (henceforth trawl survey) (Spalinger 2015), and the NMFS RACE EBS Bottom Trawl Survey (referred to as trawl survey for area Q only). For dredge survey data access, contact Ryan Burt (ryan.burt@alaska.gov). Trawl survey data can be accessed on the Kodiak Wiki via the following link http://kodweb.fishgame.state.ak.us/index/Data_Access:Trawl_Survey:Large_Mesh:. EBS trawl survey data are available via AKFIN. Dredge survey results are presented elsewhere and can be found in the most recently published survey report (Williams et al. 2017; Jackson *in prep*) or annual NPFMC SAFE reports (NPFMC 2017; NPFMC 2018; NPFMC 2019; NPFMC 2020).

Trawl survey tows were assigned to scallop management districts using spatial polygons constructed from district boundary lines and shorelines. It is important to note that fisheries independent data presented here do not represent direct estimates of abundance or biomass, rather indices that inform relative trends in those metrics. Further, trawl survey methods and gear configuration are not designed for sampling scallops and catchability of scallops (q) is unknown, though it's likely less than $q = 1$. While trawl survey data are presented here in comparison with fishery data, interpretation of these data should be done so conservatively.

3 Analyses

3.1 Spatial extent of catch

The spatial scale of the fishery effort and catch provides necessary insight to interpreting trends in fishing performance. For instance, good fishing performance corresponding to intense effort in a small area does not necessarily indicate good health of the stock as a whole, or vice versa. Here, spatial extent of the fishery catch was computed as the average pairwise distance among dredge start locations. Using this approach, both the range and density of fishing effort are considered in characterizing spatial extent. Units are decimal degrees of latitude and longitude, thus the value of spatial extent is not directly interpretable, rather it serves as a relative index over the fishery timeseries. Only hauls contributing the top 90% of a season's catch were included in this analysis, so not to include "exploratory" fishing effort that was not fruitful.

3.2 CPUE standardization

Interpretation of CPUE estimates as an index of abundance is reliant upon a fundamental relationship in fisheries analysis

$$C_t/E_t = qN_t \tag{1}$$

where C_t is catch at time t , E_t is the effort expended at time t , N_t is abundance at time t , and q is the portion of the stock captured by one unit of effort (catchability coefficient). Provided q is constant over time, CPUE is proportional to abundance, though it is rare that q is constant over the entire exploitation history.

Fishery statistics presented in this report are affected by many factors. In particular, these data are influenced by the spatial structure of the Alaska scallop population and non-random allocation of fishing effort. Scallop CPUE is affected by each vessel's choice of fishing location as well as weather, currents, sea state, captain and crew performance, gear tuning, processing capacity, markets, etc. Scallop shell height distributions from observer sampling are likewise affected by fishing locations and discarding as well as by the 4" diameter rings required by Alaska regulations that retain small scallops with lower efficiency than large scallops.

Standardizing CPUE (controlling for variables that affect catch aside from population abundance) is a difficult process, which may be subject to improvements over time. Standardized CPUE estimates presented in this document represent the most current standardization method (presented at the 2020 SPT meeting, Kodiak), which uses a generalized additive model (GAM) in the form of

$$(cpue + \gamma) = f_1(depth \cdot Bed) + f_2(longitude \cdot Bed) + Month + Vessel + Season \cdot Bed + \epsilon \quad (2)$$

where f_i are smoothing functions, and month, vessel, season, and bed are parametric effects, with an interaction between season and bed (to allow for beds to undergo different interannual trends in abundance). All standardization models were fit with a gamma response distribution and log-link. A small modifier (γ) was added to CPUE estimates to avoid zero values.

3.3 Discard estimation

Round weight and count of scallop discards, and number of clappers, is recorded by observers during every sampled dredge. Total discarded scallops (D) is estimated as

$$D = \frac{\sum_{i=1}^n d_i}{\sum_{i=1}^n s_i} \times \sum_{i=1}^n h_i \quad (3)$$

where d_i is the number, or round weight, of discards (or clappers), s_i is total observer sample hours, and h_i is total dredge hours in day i of the fishery. Discarded scallop count data is only available for intact scallop and not broken scallops. Therefore, **counts of scallop discards presented in this document should be interpreted as intact scallops only, whereas round weight of scallop discards includes both intact and broken scallops.** The ratio of intact to broken scallops in total discard weight is presented separately. Discard mortality is estimated to be 20% of total round weight or count of intact scallops, though additional research should be conducted to inform this analysis.

3.4 Bycatch estimation

Bycatch of Tanner crab (*Chionoecetes bairdi*), snow crab (*Chionoecetes opilio*), and red king crab (*Paralithodes camtschaticus*) is closely tracked in-season relative to a predetermined crab bycatch limit (CBL). All registration areas except for Yakutat utilize CBLs for at least one of these species. Other non-target species of interest include Dungeness crab (*Metacarcinus magister*) and Pacific halibut (*Hippoglossus stenolepis*), though no bycatch limits exist for those species. Total bycatch (C) of each species for a season is estimated as

$$C = \frac{\sum_{i=1}^n c_i}{\sum_{i=1}^n s_i} \times \sum_{i=1}^n h_i \quad (4)$$

where c_i is the catch (count) of a species, s_i is total observer sample hours, and h_i is total dredge hours in day i of the fishery. Total bycatch of red king crab is reported in fishery logbooks, thus no expansion calculation is necessary. In bycatch analyses presented by day, days without observer sampling are assigned the average bycatch rate for the season, in that district.

3.5 Fishery biological information

Shell height is measured for 40 retained and 40 discarded scallops during every observer sampled tow. Shell height distribution observed over the entire season is estimated by weighting the shell height composition of a given tow by the round weight catch of retained and discarded scallops of that tow, relative to all tows in the season.

Since the 2018/19 season, observers have collected individual meats from a subset of measured scallops per tow. The relationship between shell height and meat weight is allometric in the form of

$$W = \alpha L^\beta \quad (5)$$

where W is meat weight (g), L is shell height (mm), while α and β are shape and scale parameters of the allometric function, respectively. The meat weight ~ shell height relationship and the effect of season were evaluated among registration areas. Allometric growth parameters, α and β , were estimated via linear regression using the linearized form of the equation above with the addition of an interaction with season

$$\ln W = \ln \alpha_1 + \beta_1 \ln L + \ln \alpha_2 Season + \beta_2 \ln L \cdot Season + \epsilon \quad (6)$$

In the Kodiak (K) and Yakutat (D) registration areas, allometry varies slightly by district and/or bed. For these areas, the above model equation was fit with random effects on α by district in area K and by bed in area D.

4 Kodiak Registration Area (K)

The Kodiak registration area (K) contains five districts: Northeast (KNE), Shelikof (KSH), Southwest (KSW), Southeast (KSE), and Semidi Islands (KSEM). All districts were fished within GHLs during the 2020 except for KSEM, which has had zero fishing effort since the 2013/14 season, and KSE was has only been fished during the 2018/19 season. Accordingly, no fishery information regarding KSEM and KSE are presented in district specific analyses here. The most recent dredge surveys in area K were conducted in 2016 (KSH), 2017 (KSH, KNE), 2018 (KSH), and 2020 (KSH, KNE). The trawl survey is conducted within area K on an annual basis.

4.1 Fishery performance

4.1.1 KNE District

The 2019/20 Kodiak Northeast District scallop fishery opened on July 1, 2019 with a GHL of 15,000 lbs of scallop meats. Two vessels participated in the fishery harvesting 15,070 lbs scallop meat with a CPUE of 73.3 lbs meat/dredge hour. Total round weight of retained scallops was 165,989 lbs with a nominal CPUE of 807 lbs/dredge hour (Table 1). Fishing effort was restricted to two beds in the southern portion of the district, making the spatial extent of effort within the district the smallest since the 2016/17 season (Figures 8 - 9). Round weight CPUE increased from the 2018/19 season, however, most beds within the district (except KNE5) continue on a decreasing long-term trend (Table 2, Figures 10 - 11).

Table 1: KNE district catch summary. Meat and round weight CPUE represent nominal values.

Year	GHL	Retained catch (lb meat)	Retained catch (lb round)	Dredge hours	Number hauls	Meat wt cpue ^a	Round wt cpue ^b
1993/94		155,187	2,208,487	6,940	4,099	22	318
1994/95		35,517	384,052	1,773	986	20	217
1995/96	closed						
1996/97		11,430	147,269	581	319	20	253
1997/98		95,858	1,144,405	2,604	1,418	37	439
1998/99		120,010	1,366,648	2,747	1,331	44	498
1999/00	75,000	77,119	952,972	1,383	673	56	689
2000/01	80,000	79,965	681,198	1,101	556	73	619
2001/02	80,000	80,470	822,110	1,142	591	70	720
2002/03	80,000	80,000	871,918	1,350	725	59	646
2003/04	80,000	79,965	747,517	1,248	684	64	599
2004/05	80,000	80,105	848,527	1,227	662	65	692
2005/06	80,000	79,990	831,378	1,759	881	46	473
2006/07	90,000	75,150	703,388	1,168	688	64	602
2007/08	90,000	75,105	822,697	1,170	671	63	703
2008/09	90,000	74,863	808,277	1,356	793	55	596
2009/10	75,000	69,410	831,709	1,222	625	57	681
2010/11	65,000	64,475	672,246	1,015	618	64	662
2011/12	70,000	61,209	667,008	986	699	62	676
2012/13	60,000	62,496	749,644	1,322	938	47	567
2013/14	55,000	54,926	526,156	934	681	59	563
2014/15	55,000	55,659	667,962	752	444	74	888
2015/16	55,000	55,577	634,481	1,228	768	45	517
2016/17	55,000	24,401	292,760	1,096	683	22	267
2017/18	55,000	14,190	136,295	349	196	41	391
2018/19	15,000	15,210	155,334	262	162	58	593
2019/20	15,000	15,070	165,989	206	124	73	807

^alb scallop meat/dredge hour

^blb scallop round/dredge hour

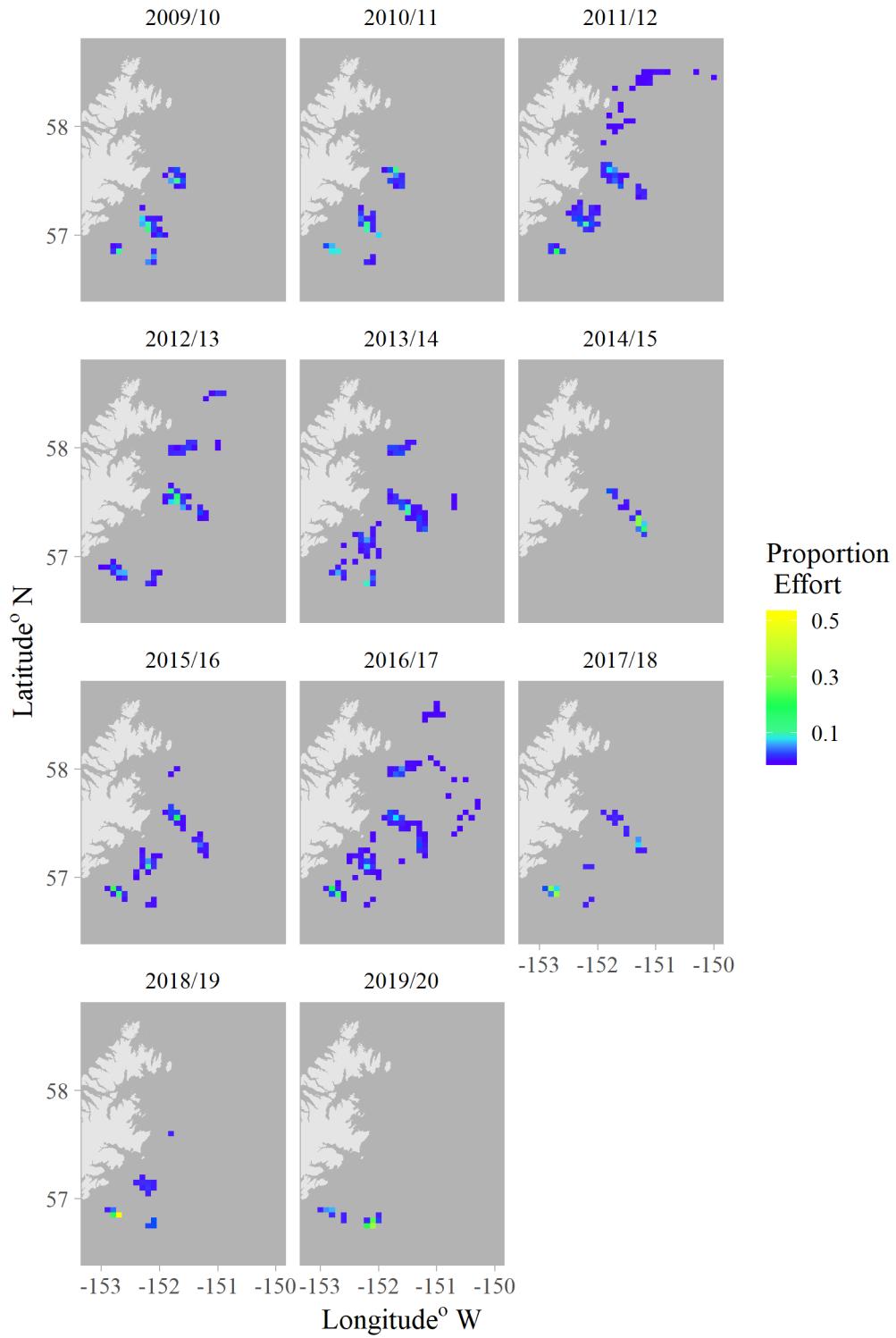


Figure 8: Heat map of fishing effort within the KNE district. Warmer colors indicate areas accounting for a greater proportion of fishing effort.

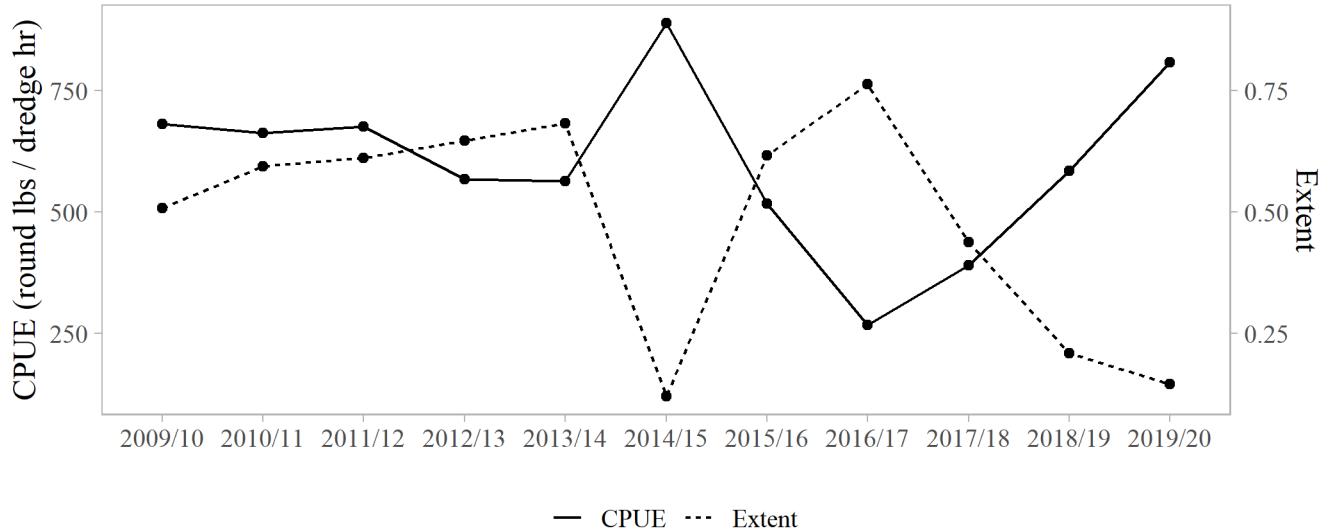


Figure 9: Nominal CPUE (round lbs / dredge hr) (solid line) and relative spatial extent of fishing effort (dotted line) within the KNE district by season

Table 2: KNE district nominal and standardized CPUE estimates (round lbs / dredge hour) by season.

Season	Nominal CPUE			Standardized CPUE
	(total)	(median)	(sd)	
2009/10	680.80	597.35	348.78	603.39
2010/11	662.21	594.59	371.43	734.18
2011/12	676.46	547.73	423.57	819.00
2012/13	567.18	529.60	289.00	662.62
2013/14	563.06	440.33	446.76	686.43
2014/15	888.07	885.25	385.44	709.30
2015/16	516.73	487.60	241.47	478.18
2016/17	267.06	240.96	176.56	264.82
2017/18	390.81	407.19	166.14	457.29
2018/19	592.51	419.00	573.97	435.60
2019/20	807.34	752.34	451.85	871.06

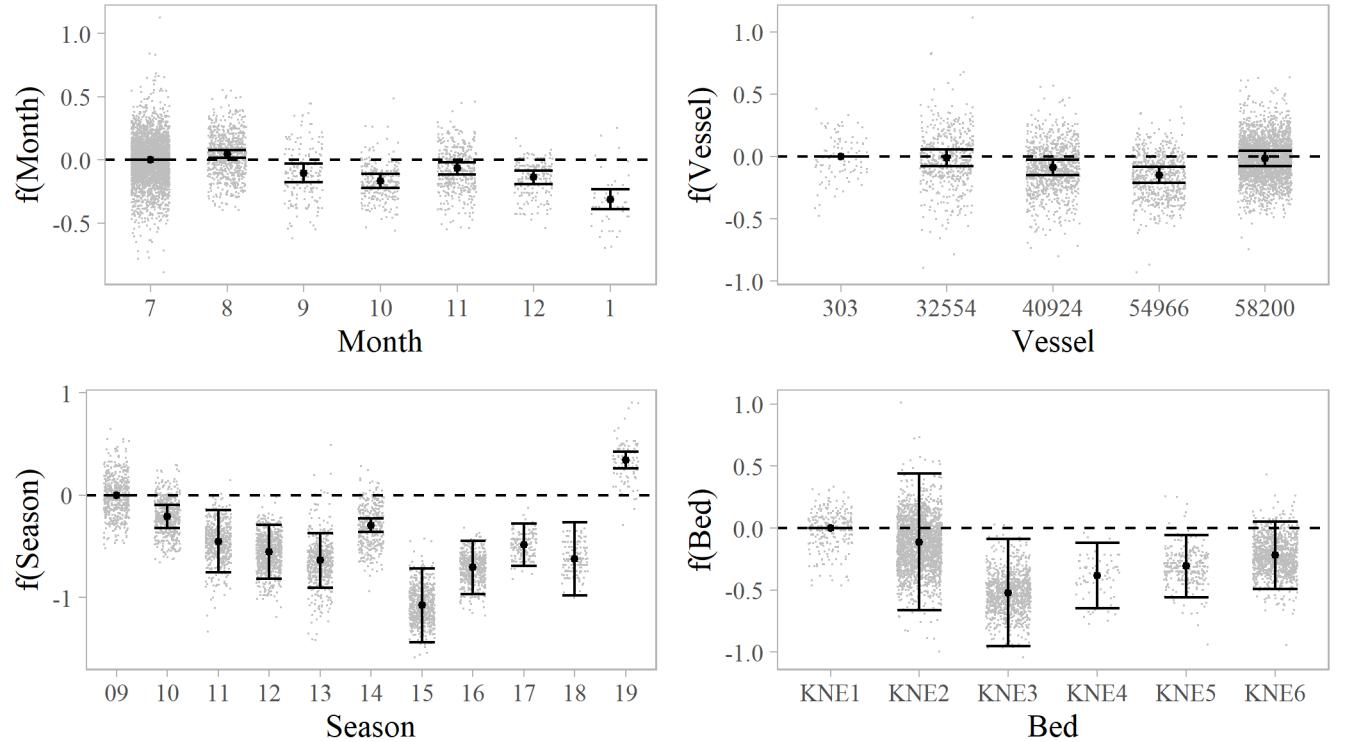


Figure 10: Partial effects of Month, Vessel, Season, and Bed on CPUE within the KNE district. Season values represent the last two digits of the year the fishery opened.

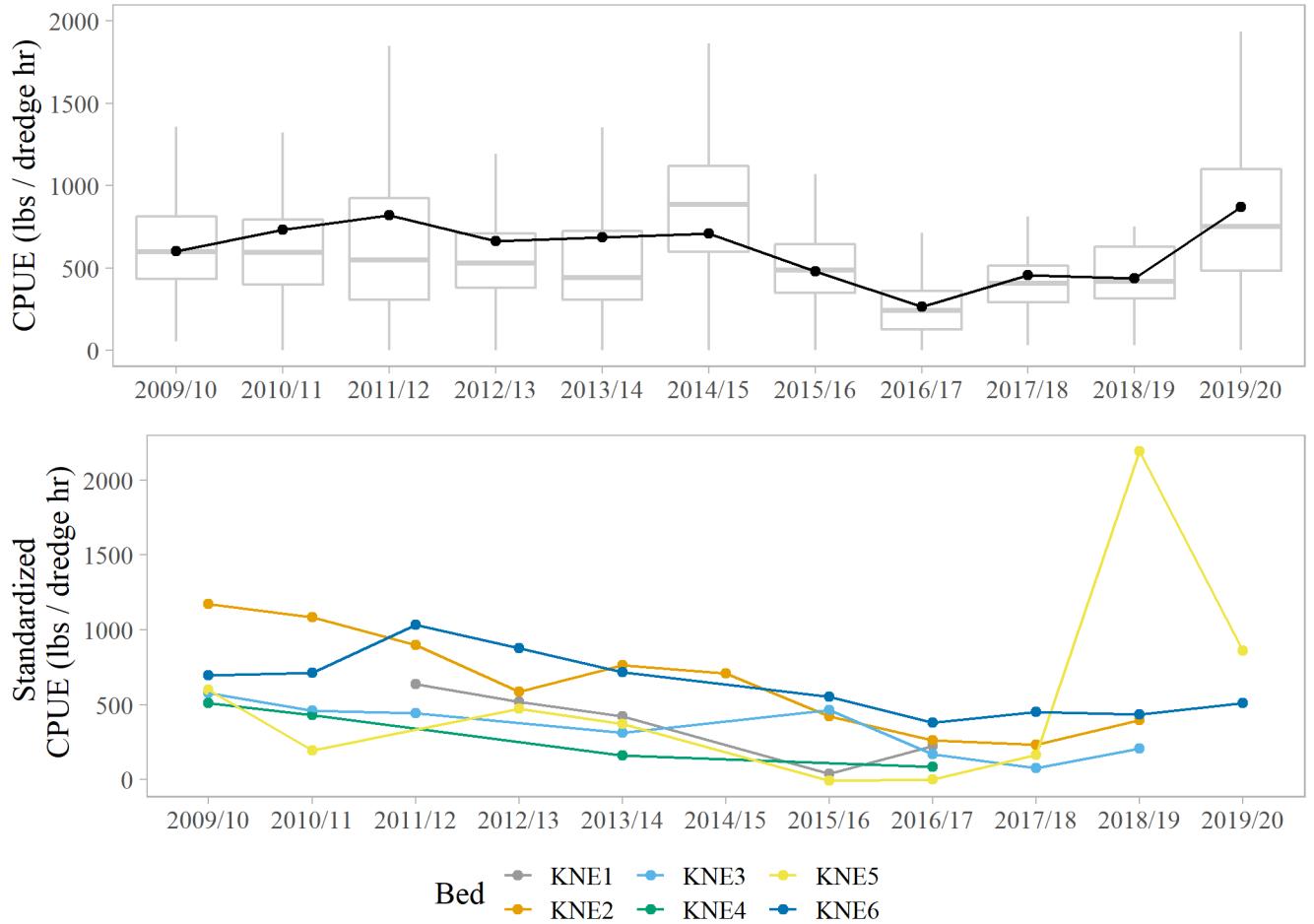


Figure 11: Boxplots of nominal CPUE (round lbs / dredge hr) overlaid with standardized CPUE (round lbs / dredge hr) by season (black line) (top) and standardized CPUE by bed and season (bottom) within the KNE district.

4.1.2 KSH District

The 2019/20 Kodiak Shelikof District scallop fishery opened on July 1, 2019 with a GHL of 20,000 lbs of scallop meats. Two vessels participated in the fishery harvesting 20,125 lbs scallop meat with a nominal CPUE of 53.0 lbs meat/dredge hour. Total round weight of retained scallops was 249,287 lbs with a nominal CPUE of 657 lbs/dredge hour (Table 3). Fishing effort was the most spatially concentrated it has been since the 2009/10 season, and nominal CPUE was the highest in the entire timeseries (since the 1993/94 season) (Table 3 - 4, Figures 12 - 15).

Table 3: KSH district catch summary. Meat and round weight CPUE represent nominal values.

Year	GHL	Retained catch (lb meat)	Retained catch (lb round)	Dredge hours	Numer hauls	Meat wt cpue ^a	Round wt cpue ^b
1993/94		105,017	1,169,664	2,491	1,684	42	542
1994/95		320,111	3,452,842	8,662	5,204	37	565
1995/96	closed						
1996/97		219,305	1,877,268	3,466	1,914	63	542
1997/98		258,346	3,097,992	5,488	3,042	47	565
1998/99		179,870	2,128,025	4,076	2,109	44	522
1999/00	180,000	187,963	1,901,953	4,295	2,004	44	443
2000/01	180,000	180,087	1,768,376	2,905	1,403	62	609
2001/02	180,000	177,112	1,830,265	3,398	1,830	53	539
2002/03	180,000	180,580	1,857,466	3,799	2,071	47	489
2003/04	180,000	180,011	1,724,498	3,258	1,722	64	529
2004/05	180,000	174,622	1,641,608	3,467	1,793	50	474
2005/06	160,000	159,941	1,453,656	2,278	1,217	70	638
2006/07	160,000	162,537	1,404,134	2,181	1,280	74	644
2007/08	170,000	169,968	1,695,563	2,937	1,736	58	577
2008/09	150,000	13,761	2,053,912	3,286	1,825	46	625
2009/10	170,000	170,021	1,667,958	3,496	1,921	49	477
2010/11	170,000	167,293	1,839,480	3,407	2,142	49	540
2011/12	135,000	136,435	1,437,093	2,437	1,659	56	590
2012/13	105,000	106,040	992,665	2,001	1,346	53	496
2013/14	105,000	104,725	899,261	2,449	1,616	43	367
2014/15	105,000	62,556	609,092	1,548	996	40	393
2015/16	75,000	35,626	431,843	1,188	815	30	364
2016/17	25,000	20,606	264,153	719	459	29	367
2017/18	25,000	20,870	211,277	481	264	43	439
2018/19	25,000	21,701	239,700	416	250	52	577
2019/20	20,000	20,125	249,287	380	205	53	657

^alb scallop meat wt/dredge hour

^blb scallop round wt/dredge hour

^cGHLs in prior to 2019/20 were based on the inclusion of scallops beds adjacent to the Karluk River

^d2008/09 inseason closure at due to Tanner crab bycatch

^e2014/15, 2015/16 inseason closure due to poor fishing performance

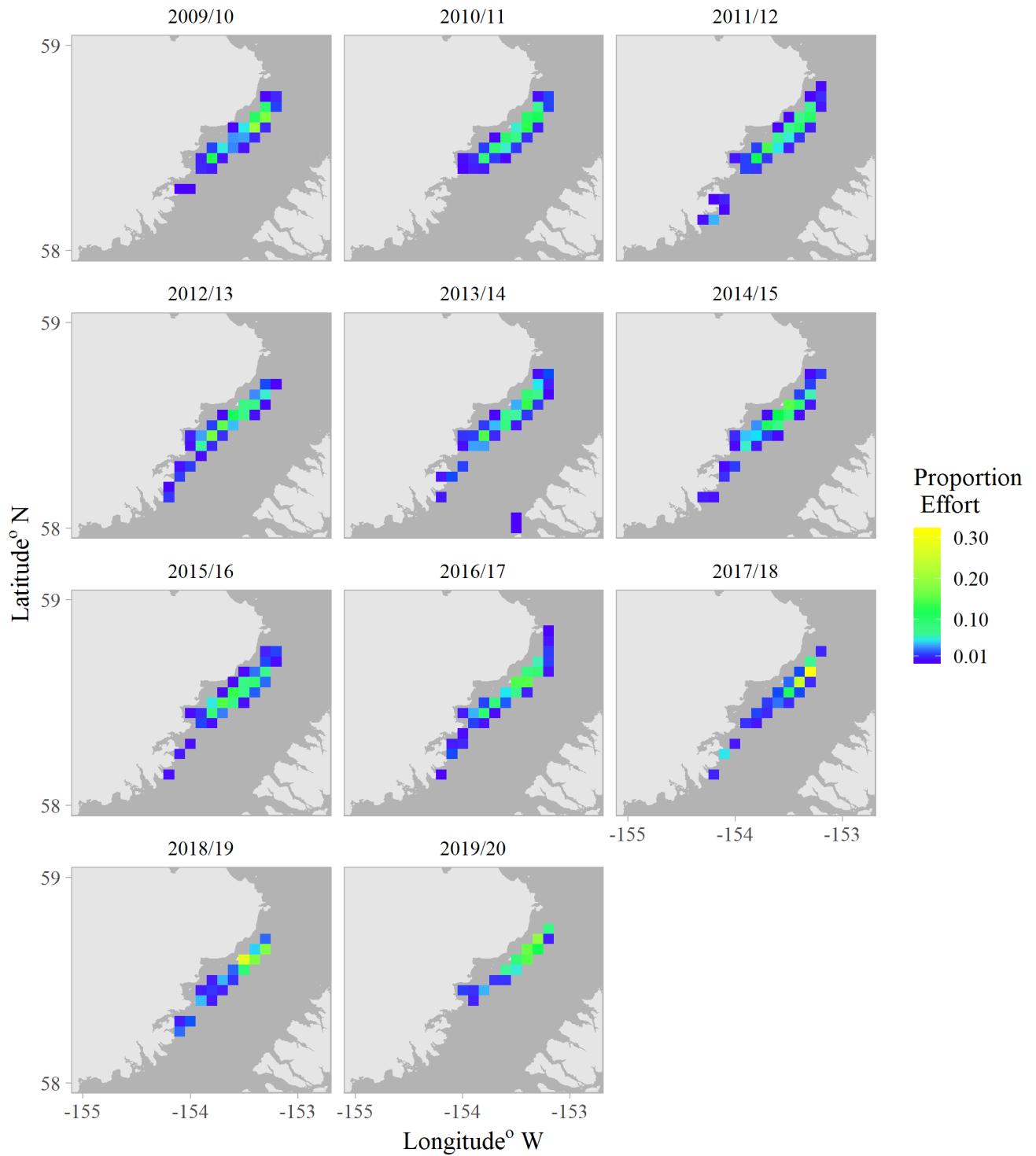


Figure 12: Heat map of fishing effort within the KSH district. Warmer colors indicate areas accounting for a greater proportion of fishing effort.

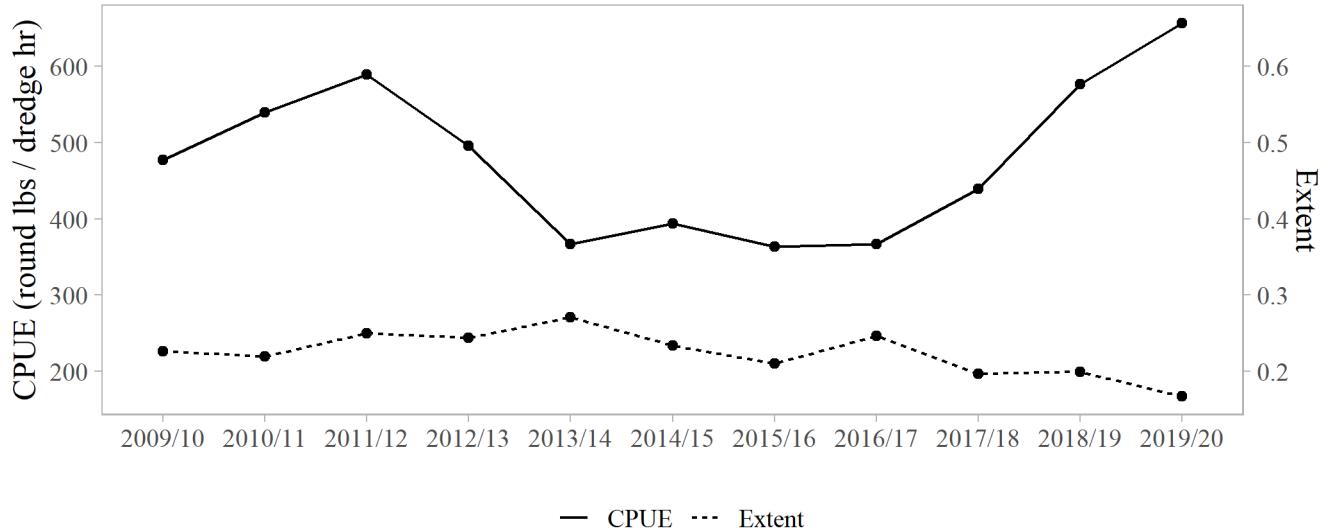


Figure 13: Nominal CPUE (round lbs / dredge hr) (solid line) and relative spatial extent of fishing effort (dotted line) within the KSH district by season

Table 4: KSH district nominal and standardized CPUE estimates (round lbs / dredge hour) by season.

Season	Nominal CPUE			Standardized CPUE
	(total)	(median)	(sd)	
2009/10	477.09	475.36	158.07	519.29
2010/11	539.90	536.70	210.74	656.03
2011/12	589.67	573.25	231.85	657.85
2012/13	496.20	470.38	164.54	543.70
2013/14	367.18	372.60	130.51	428.41
2014/15	393.44	379.28	136.99	421.56
2015/16	363.61	350.86	130.15	382.37
2016/17	367.14	378.26	124.83	415.18
2017/18	439.29	429.04	98.73	517.62
2018/19	576.66	572.75	144.80	628.50
2019/20	656.54	659.90	262.21	760.58

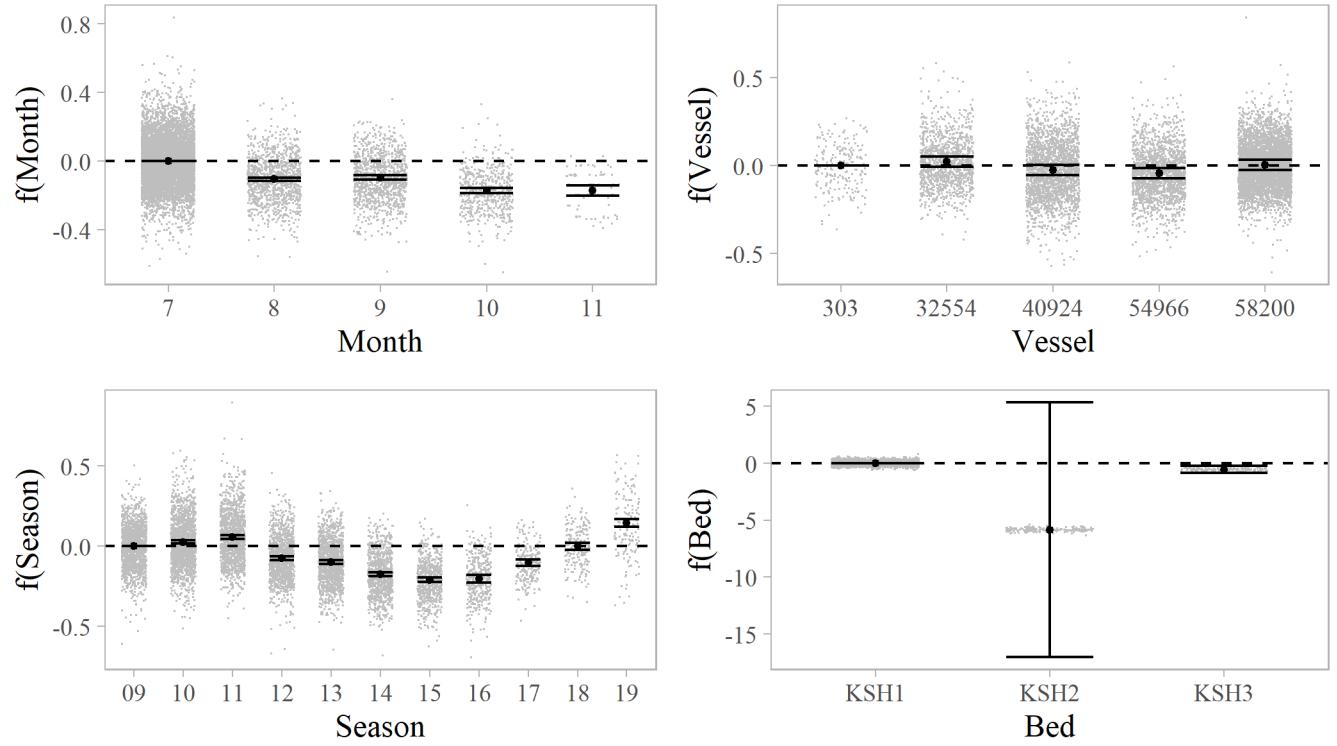


Figure 14: Partial effects of Month, Vessel, Season, and Bed on CPUE within the KSH district. Season values represent the last two digits of the year the fishery opened.

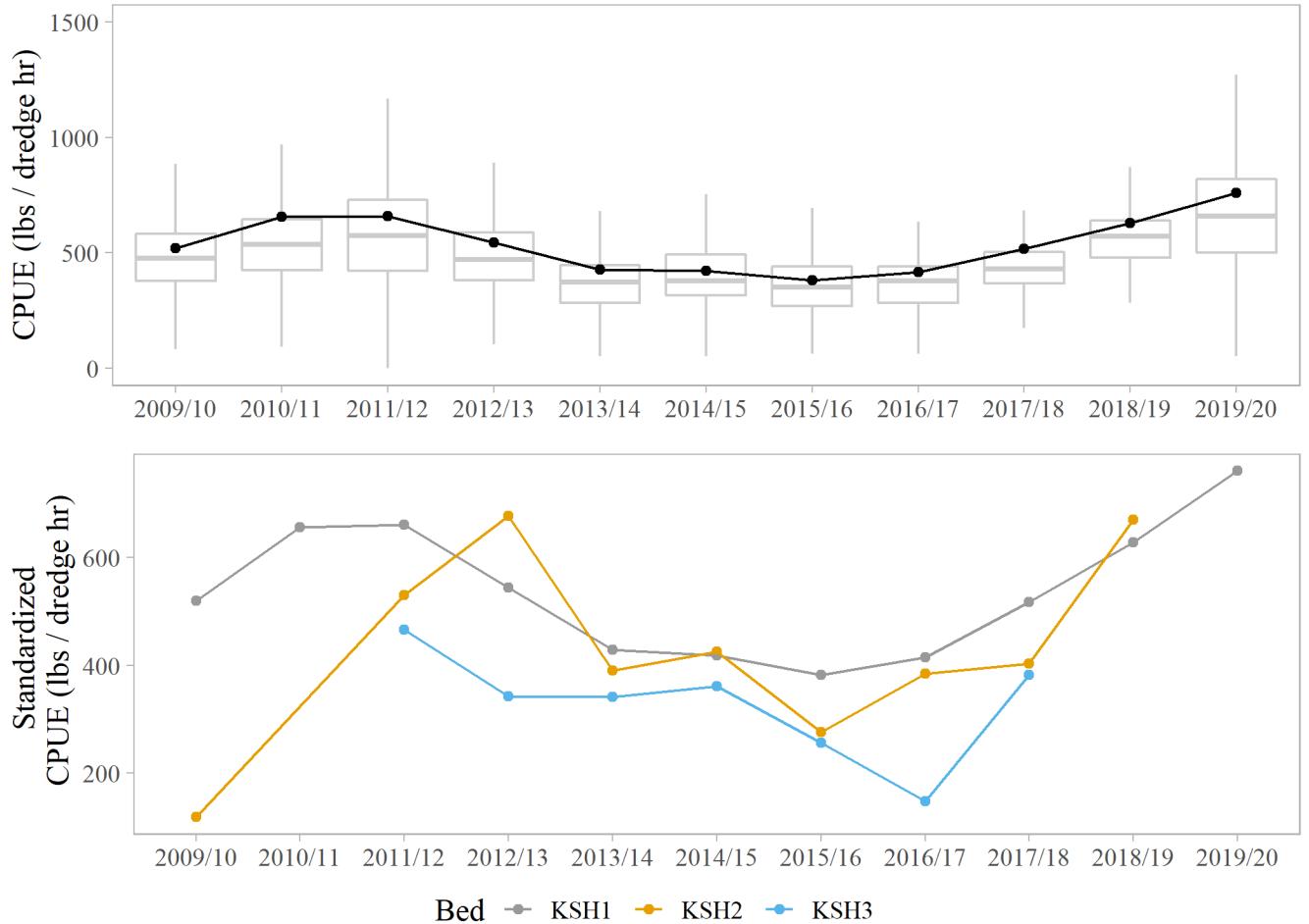


Figure 15: Boxplots of nominal CPUE (round lbs / dredge hr) overlaid with standardized CPUE (round lbs / dredge hr) by season (black line) (top) and standardized CPUE by bed and season (bottom) within the KSH district.

4.1.3 KSW District

The 2019/20 Kodiak Southwest District scallop fishery opened on July 1, 2019 with a GHL of 35,000 lbs of scallop meats. Two vessels participated in the fishery harvesting 35,010 lbs scallop meat with a nominal CPUE of 55.1 lbs meat/dredge hour. Total round weight of retained scallops was 450,976 lbs with a nominal CPUE of 709 lbs/dredge hour (Table 5). Fishing effort occurred over a broader spatial area than in recent seasons (Figure 16), though the spatial extent of the resulting catch was smaller than in 2018/19 (Figure 17). Standardized round weight CPUE suggests fishing performance within the district slightly improved from the 2018/19 season (Table 6, Figure 19), despite a decreasing ‘season’ effect in the model (Figure 18), though the KSW1 bed specifically underwent a slight decrease in fishing performance (Figure 19).

Table 5: KSW district catch summary. Meat and round weight CPUE represent nominal values.

Year	GHL	Retained catch (lb meat)	Retained catch (lb round)	Dredge hours	Numer hauls	Meat wt cpue ^a	Round wt cpue ^b
2009/10	25,000	3,480	62,241	159	125	22	392
2010/11	25,000	3,783	49,485	100	76	38	493
2011/12	25,000	25,110	348,142	455	311	55	766
2012/13	25,000	25,014	261,318	671	431	37	389
2013/14	25,000	21,715	241,692	549	371	40	440
2014/15	25,000	28,555	352,196	636	400	45	554
2015/16	25,000	15,614	208,140	417	293	37	499
2016/17	25,000	29,624	503,046	558	349	53	901
2017/18	25,000	29,200	384,891	441	233	66	872
2018/19	30,000	33,319	398,928	510	314	65	782
2019/20	35,000	35,010	450,977	636	412	55	709

^alb scallop meat wt/dredge hour

^blb scallop round wt/dredge hour

^cGHLs in prior to 2019/20 were not based on the inclusion of scallops beds adjacent to the Karluk River

^d2015/16 Inseason closure due to Tanner bycatch

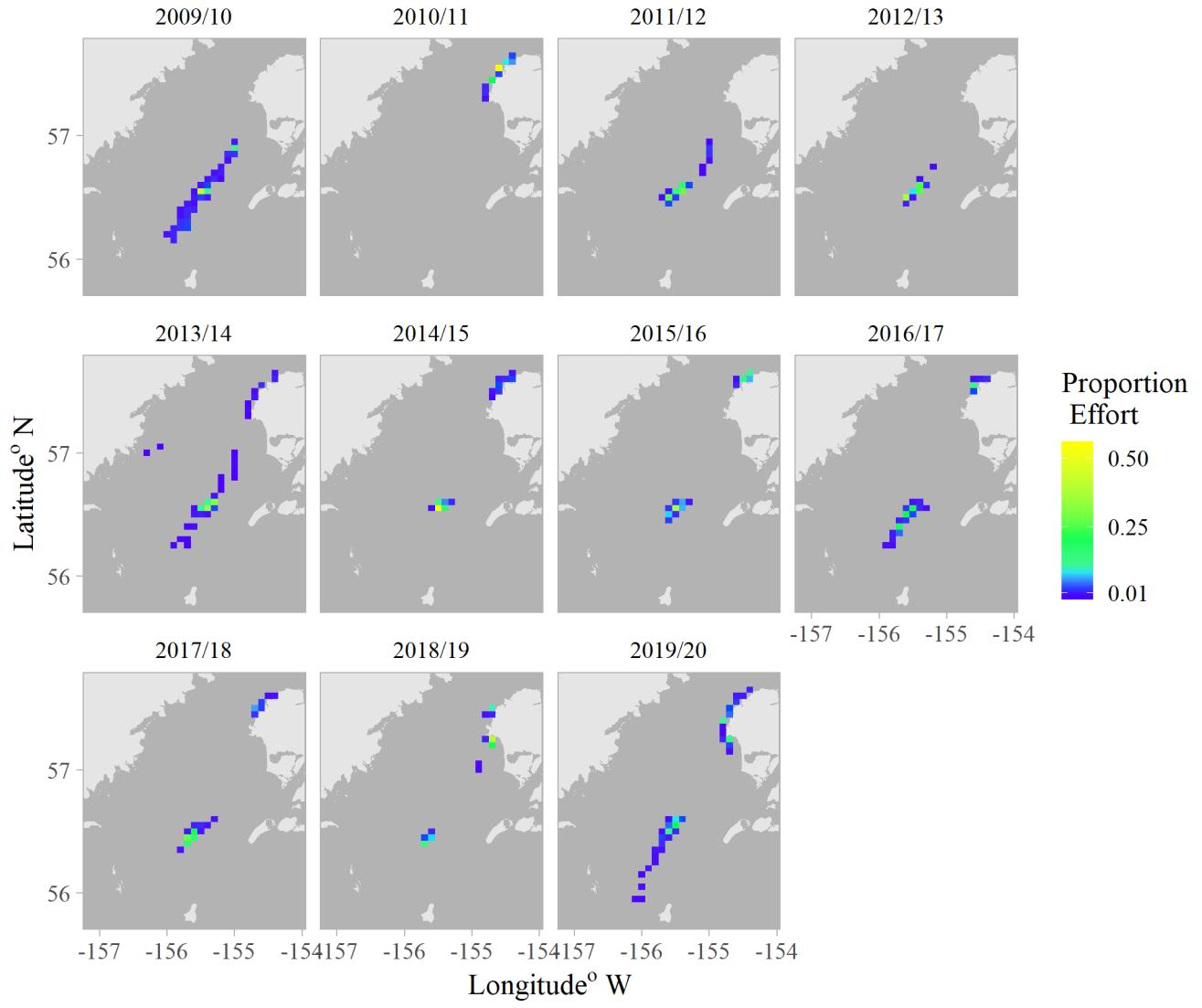


Figure 16: Heat map of fishing effort within the KSW district. Warmer colors indicate areas accounting for a greater proportion of fishing effort.

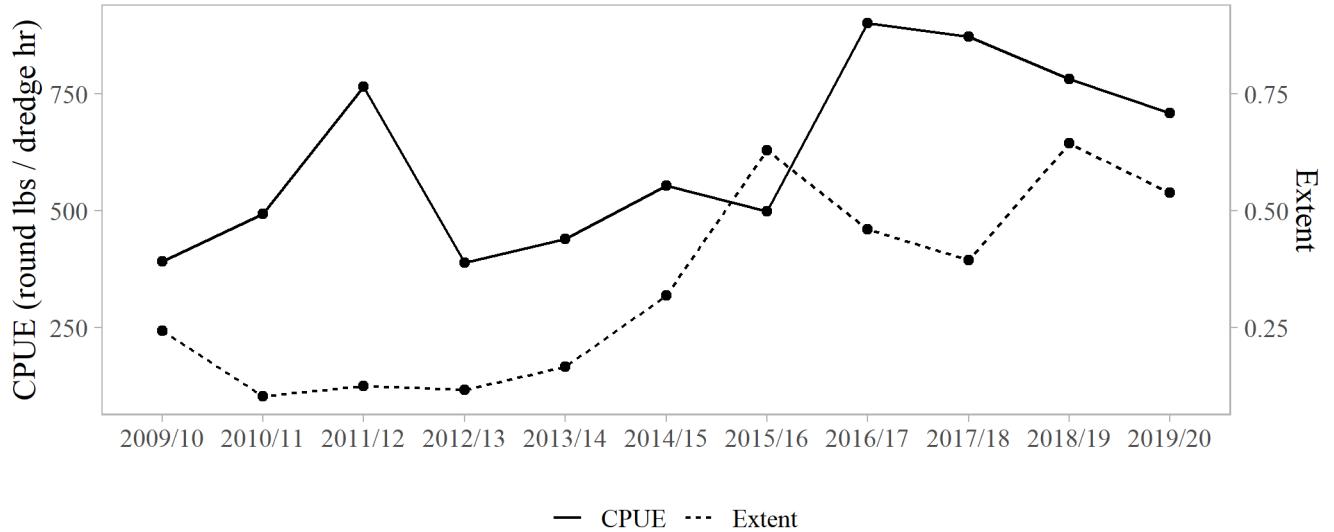


Figure 17: Nominal CPUE (round lbs / dredge hr) (solid line) and relative spatial extent of fishing effort (dotted line) within the KSW district by season

Table 6: KSW district nominal and standardized CPUE estimates (round lbs / dredge hour) by season.

Season	Nominal CPUE			Standardized CPUE
	(total)	(median)	(sd)	
2009/10	391.92	382.85	220.89	419.43
2010/11	493.03	393.60	314.69	586.67
2011/12	765.72	785.63	304.94	779.36
2012/13	389.43	360.06	188.26	419.08
2013/14	440.30	348.13	254.71	436.34
2014/15	553.94	550.22	224.14	538.61
2015/16	499.36	422.34	242.73	534.24
2016/17	900.71	719.52	551.82	835.76
2017/18	872.02	851.85	324.85	769.89
2018/19	781.51	634.07	455.82	535.89
2019/20	709.46	669.40	339.65	577.26

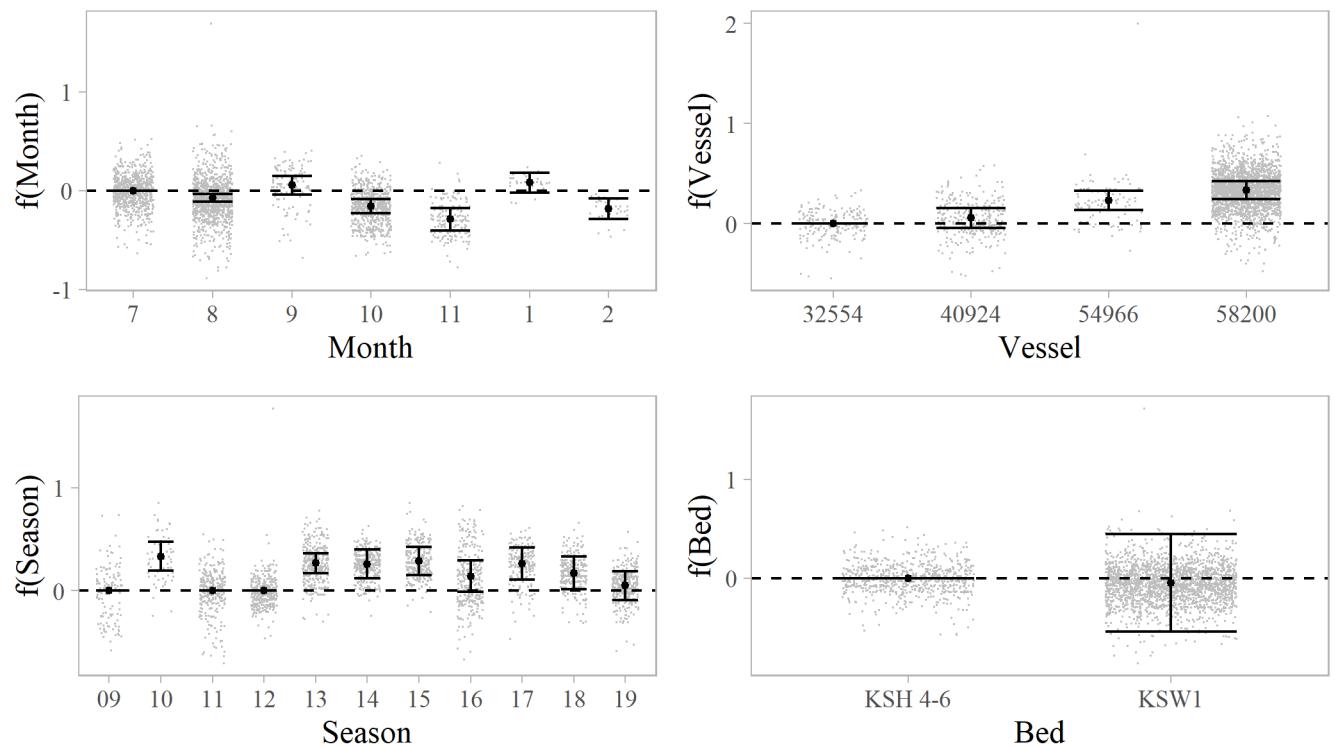


Figure 18: Partial effects of Month, Vessel, Season, and Bed on CPUE within the KSW district. Season values represent the last two digits of the year the fishery opened.

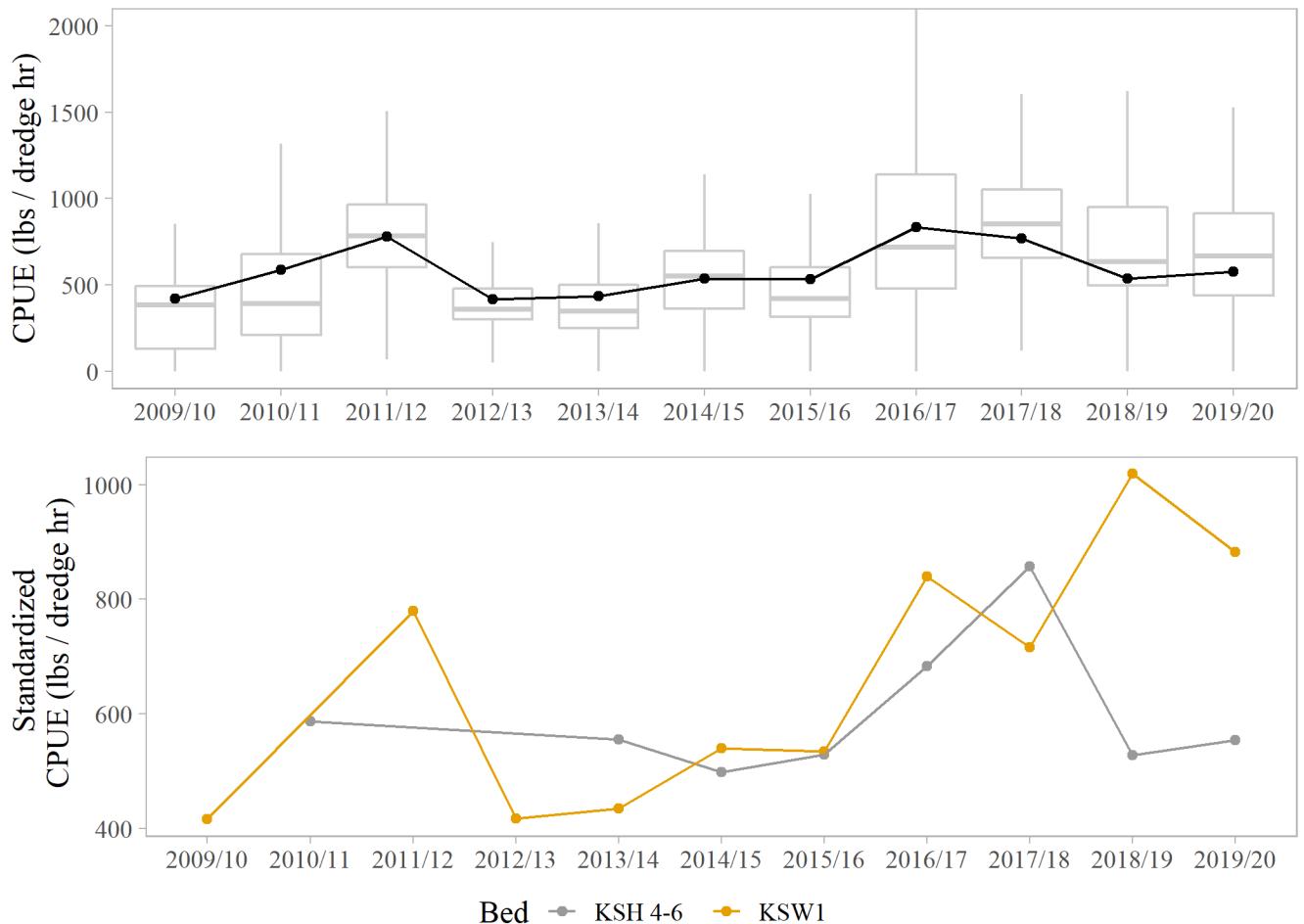


Figure 19: Boxplots of nominal CPUE (round lbs / dredge hr) overlaid with standardized CPUE (round lbs / dredge hr) by season (black line) (top) and standardized CPUE by bed and season (bottom) within the KSW district.

4.2 Fishery discards

Estimated scallop discards during the 2019/20 season were 46,604 round weight lbs (134,494 intact scallops) in the KNE district (Table 7), 114,800 lbs (437,154 intact scallops) in the KSH district (Table 8), and 86,988 (212,173 intact scallops) in the KSW district (Table 9, Figure 20). KSH had the highest discard ratio (lbs discarded:retained) (0.46), followed by KNE (0.28), and KSW (0.19) (Figure 21). The catch rate of clappers in all districts increased markedly from the 2018/19 season (Tables 10 - 12, Figure 22). Intact scallops outweighed broken scallops in most hauls in all districts (Figure 23 - 25).

Table 7: KNE discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), associated discard rates (lbs or count per dredge hr), and estimated discard mortality.

Season	Retained (lbs)	Discarded (lbs)	Discarded (count)	Discard ratio	Discard rate (lbs)	Discard rate (count)	Discard mortality (lbs)	Discard mortality (count)
2009/10	831,709	119,824	156,068	0.14	98	128	23,965	31,214
2010/11	672,246	72,192	118,841	0.11	71	117	14,438	23,768
2011/12	667,008	86,688	120,860	0.13	88	123	17,338	24,172
2012/13	749,644	94,761	130,443	0.13	72	99	18,952	26,089
2013/14	526,156	62,859	62,541	0.12	67	67	12,572	12,508
2014/15	667,962	53,020	24,764	0.08	70	33	10,604	4,953
2015/16	634,481	83,398	156,510	0.13	68	127	16,680	31,302
2016/17	292,760	26,893	46,745	0.09	25	43	5,379	9,349
2017/18	136,295	20,917	30,515	0.15	60	87	4,183	6,103
2018/19	155,334	57,806	154,189	0.37	220	588	11,561	30,838
2019/20	165,989	46,604	134,494	0.28	227	654	9,321	26,899

Table 8: KSH discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), associated discard rates (lbs or count per dredge hr), and estimated discard mortality.

Season	Retained (lbs)	Discarded (lbs)	Discarded (count)	Discard ratio	Discard rate (lbs)	Discard rate (count)	Discard mortality (lbs)	Discard mortality (count)
2009/10	1,667,958	317,896	871,193	0.19	91	249	63,579	174,239
2010/11	1,839,480	369,685	888,898	0.20	105	253	73,937	177,780
2011/12	1,437,093	115,676	236,030	0.08	47	97	23,135	47,206
2012/13	992,665	114,859	333,665	0.12	57	167	22,972	66,733
2013/14	899,261	77,071	168,274	0.09	31	68	15,414	33,655
2014/15	609,092	43,313	104,673	0.07	27	64	8,663	20,935
2015/16	431,843	54,737	145,970	0.13	41	110	10,947	29,194
2016/17	264,153	48,290	129,833	0.18	58	156	9,658	25,967
2017/18	211,277	44,991	141,835	0.21	83	260	8,998	28,367
2018/19	239,700	153,972	468,802	0.64	325	991	30,794	93,760
2019/20	249,287	114,800	437,154	0.46	302	1,151	22,960	87,431

Table 9: KSW discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), associated discard rates (lbs or count per dredge hr), and estimated discard mortality.

Season	Retained (lbs)	Discarded (lbs)	Discarded (count)	Discard ratio	Discard rate (lbs)	Discard rate (count)	Discard mortality (lbs)	Discard mortality (count)
2009/10	62,241	3,754	4,035	0.06	24	25	751	807
2011/12	348,142	16,772	12,567	0.05	37	28	3,354	2,513
2012/13	261,318	15,596	15,187	0.06	23	23	3,119	3,037
2013/14	241,692	13,154	6,230	0.05	25	12	2,631	1,246
2014/15	352,196	8,023	2,725	0.02	14	5	1,605	545
2015/16	208,140	6,465	5,642	0.03	23	20	1,293	1,128
2016/17	503,046	23,754	84,429	0.05	53	188	4,751	16,886
2017/18	384,891	80,874	296,106	0.21	214	785	16,175	59,221
2018/19	398,928	95,189	196,184	0.24	210	433	19,038	39,237
2019/20	450,977	86,988	212,173	0.19	137	334	17,398	42,435

Table 10: KNE district clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	Clappers	
		(rate)	(count)
2009/10	1,222	16.67	20,361
2010/11	1,015	9.01	9,149
2011/12	986	34.02	33,540
2012/13	1,322	20.04	26,489
2013/14	934	10.12	9,455
2014/15	752	9.65	7,255
2015/16	1,228	4.65	5,712
2016/17	1,095	3.51	3,844
2017/18	349	1.55	539
2018/19	262	0.61	159
2019/20	206	18.19	3,740

Table 11: KSH district clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	Clappers	
		(rate)	(count)
2009/10	3,496	20.32	71,039
2010/11	3,507	18.98	66,561
2011/12	2,437	7.77	18,926
2012/13	2,002	16.27	32,559
2013/14	2,472	15.82	39,104
2014/15	1,629	21.61	35,210
2015/16	1,323	5.36	7,091
2016/17	830	6.25	5,189
2017/18	545	2.32	1,267
2018/19	473	3.47	1,641
2019/20	380	7.93	3,011

Table 12: KSW district clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	Clappers	
		(rate)	(count)
2009/10	159	14.25	2,263
2011/12	455	4.79	2,177
2012/13	671	9.21	6,180
2013/14	526	4.90	2,579
2014/15	555	4.87	2,700
2015/16	281	3.78	1,063
2016/17	448	6.21	2,784
2017/18	377	12.35	4,660
2018/19	453	1.19	538
2019/20	636	8.33	5,292

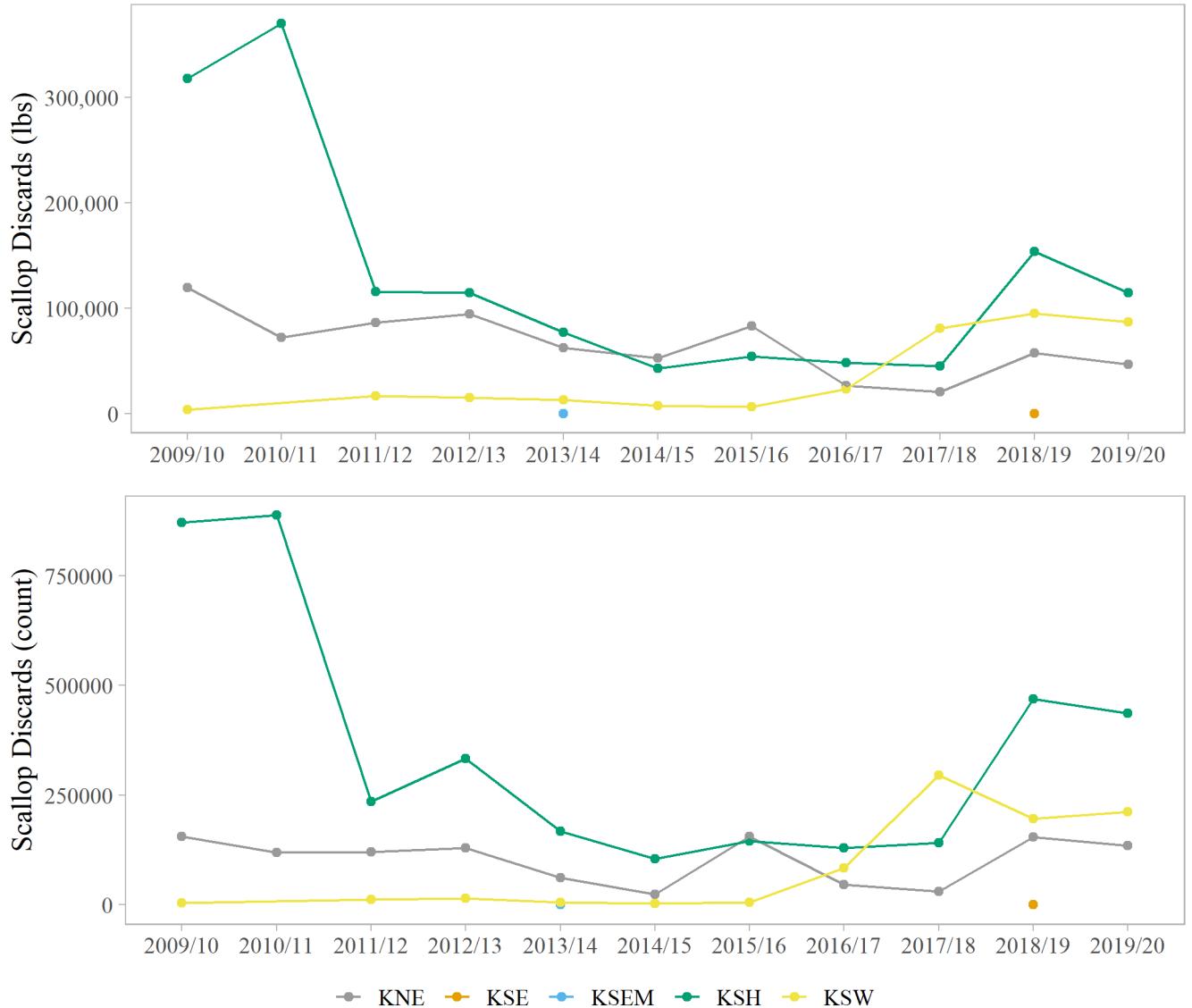


Figure 20: Total discarded scallops as round weight (top) and number of count (bottom) for each district by season.

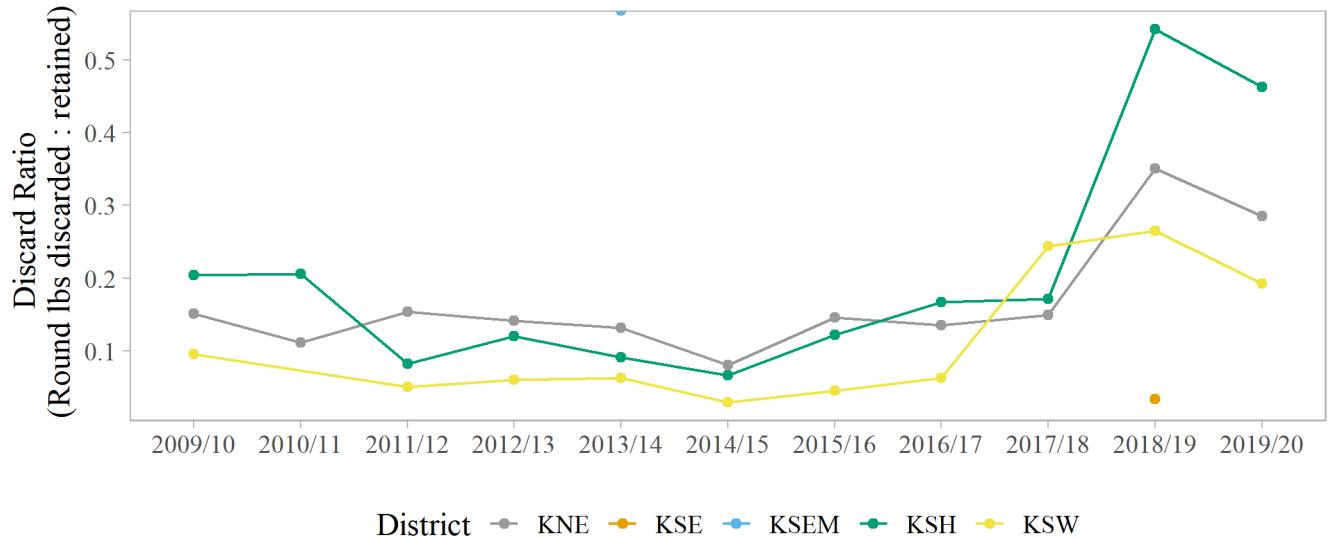


Figure 21: Scallop discard ratio (round weight discarded : retained) for each district by season.

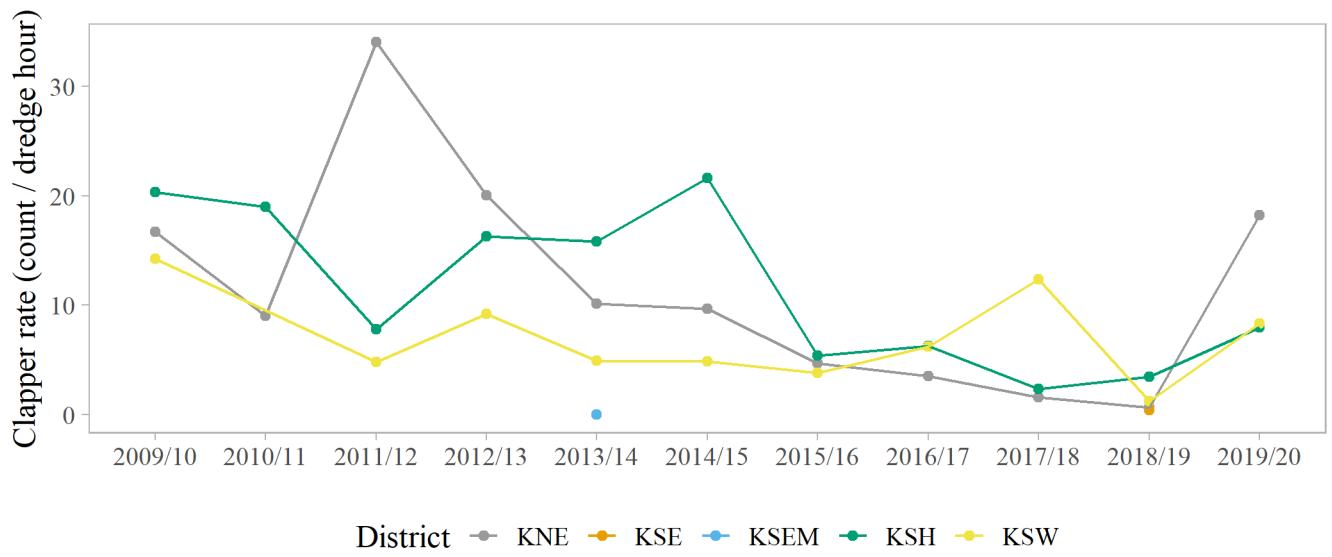


Figure 22: Rate of clapper catch for each district by season in area K.

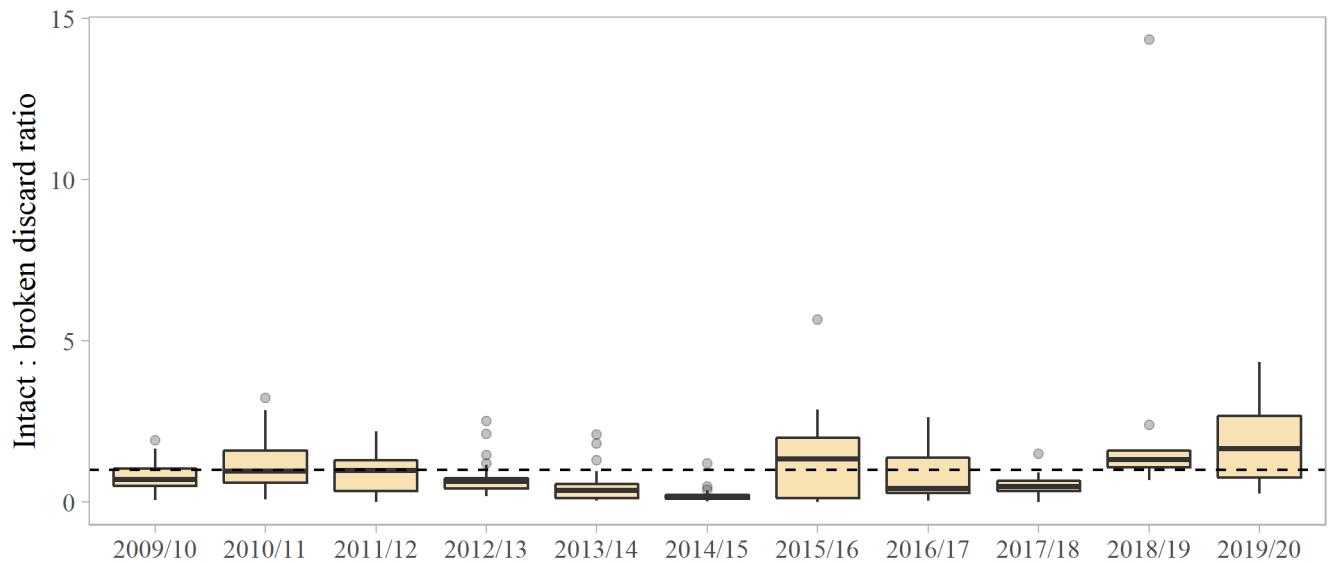


Figure 23: Boxplots of the ratio between intact and broken scallop discards in every haul within the KNE district. The dotted line represents a 1:1 ratio.

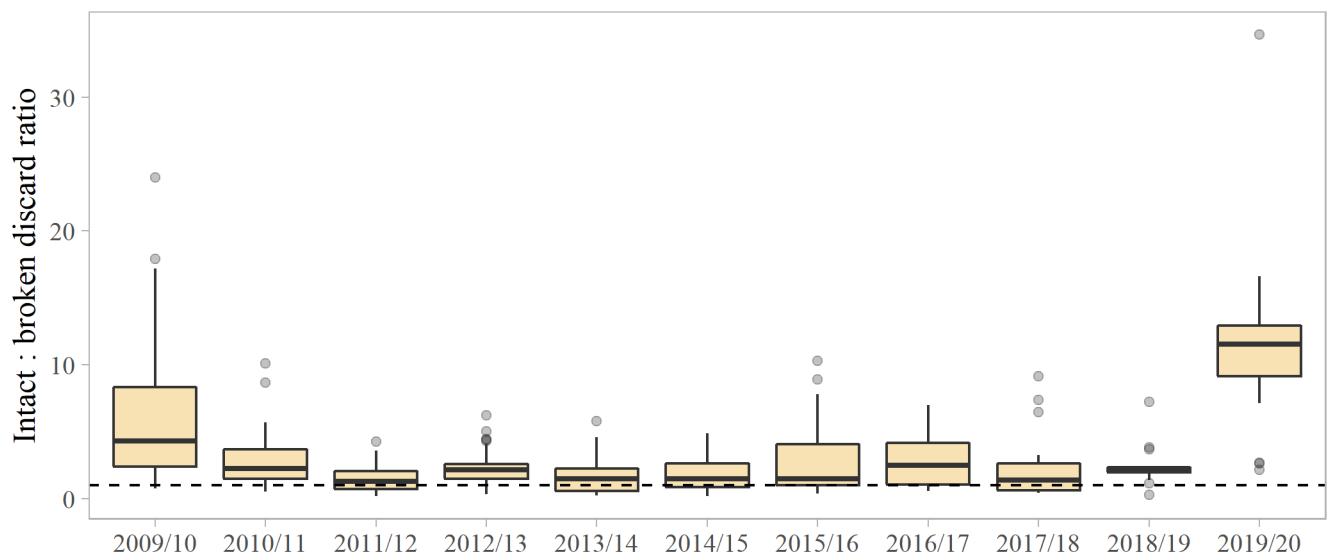


Figure 24: Boxplots of the ratio between intact and broken scallop discards in every haul within the KSH district. The dotted line represents a 1:1 ratio.

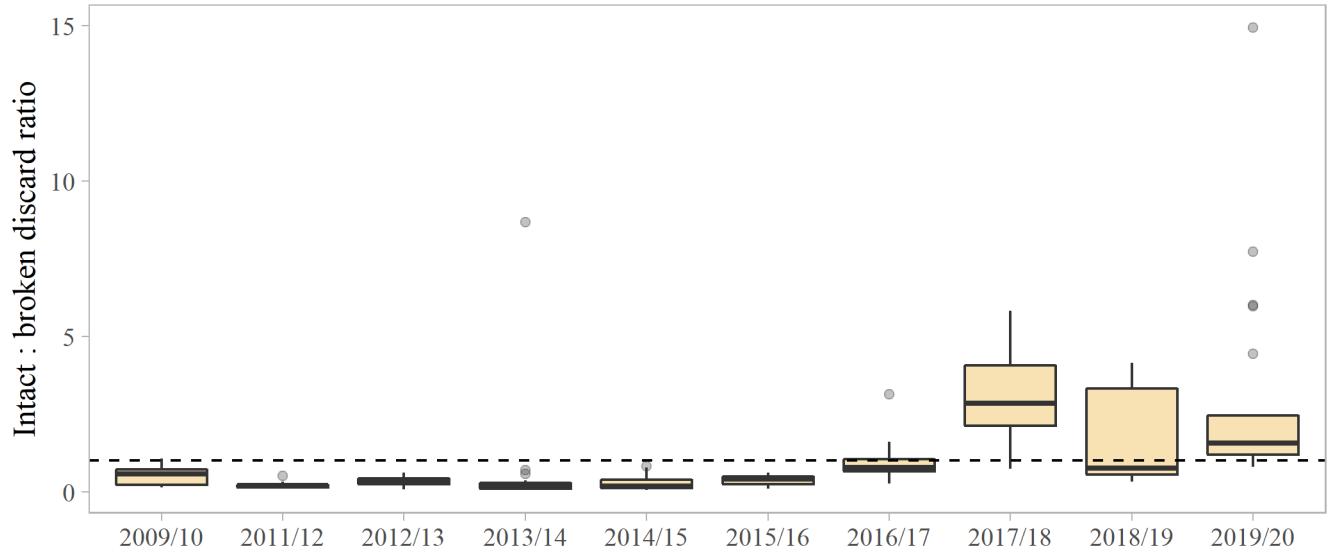


Figure 25: Boxplots of the ratio between intact and broken scallop discards in every haul within the KSW district. The dotted line represents a 1:1 ratio.

4.3 Fishery bycatch

Area K utilizes CBLs for Tanner crab and red king crab. During the 2019/20 season, the Tanner crab CBL was 9,000 crab in KNE, 10,000 crab in KSH, 17,500 crab in KSW, and 9,000 crab in KSE (Table 13 - 15). The red king crab CBL for all districts was 25 crab. No district exceeded the CBL for either species, nor were any districts closed prior to meeting the GHL in anticipation of exceeding the CBL (Table 13 - 15). Tanner crab bycatch ratio (crab:lbs retained scallop meat) was highest in KSW (0.312), followed by KNE (0.21), and KSH (0.08) (Figure 26).

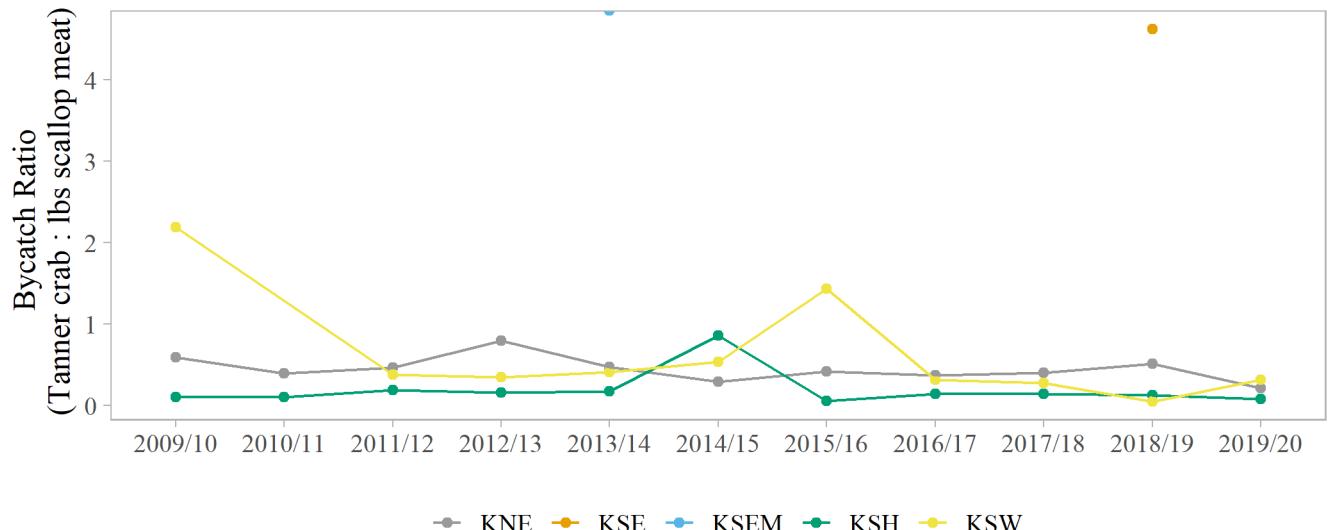


Figure 26: Bycatch ratio, expressed as number of Tanner crab per pound of scallop meat weight, by year and district within area K

4.3.1 KNE District

Bycatch of Tanner crab and Pacific halibut decreased from the 2018/19 season, and no red king crab or Dungeness crab were caught. Dungeness crab have not been caught in the KNE district during any season in the timeseries (Table 13, Figure 27). The remaining allowable crab bycatch remained safely above the remaining GHL of scallops for the entirety of the season (Figure 28). Tanner crab bycatch included mostly small, immature crab (Figure 29).

Table 13: KNE bycatch summary including total number caught for each species as well as the ratio of number caught to meat weight of scallops retained. No Dungeness crab were caught during any season in the timeseries.

Season	Scallop GHL	Tanner crab CBL	Tanner crab (total)	Tanner crab (ratio)	Red king crab (total)	Red king crab (ratio)	Pacific halibut (total)	Pacific halibut (ratio)
2009/10	75,000	217,000	43,809	0.63	0	0.00	252	0.00
2010/11	65,000	169,925	27,793	0.43	0	0.00	626	0.01
2011/12	70,000	147,956	28,499	0.47	0	0.00	340	0.01
2012/13	60,000	50,874	48,550	0.78	0	0.00	295	0.00
2013/14	55,000	49,124	22,431	0.41	1	0.00	229	0.00
2014/15	55,000	256,466	16,415	0.29	0	0.00	1,440	0.03
2015/16	55,000	93,929	24,342	0.44	0	0.00	3,422	0.06
2016/17	55,000	20,816	9,124	0.37	0	0.00	630	0.03
2017/18	55,000	19,388	5,463	0.39	0	0.00	132	0.01
2018/19	15,000	9,000	8,893	0.58	0	0.00	116	0.01
2019/20	15,000	9,000	3,507	0.23	0	0.00	58	0.00

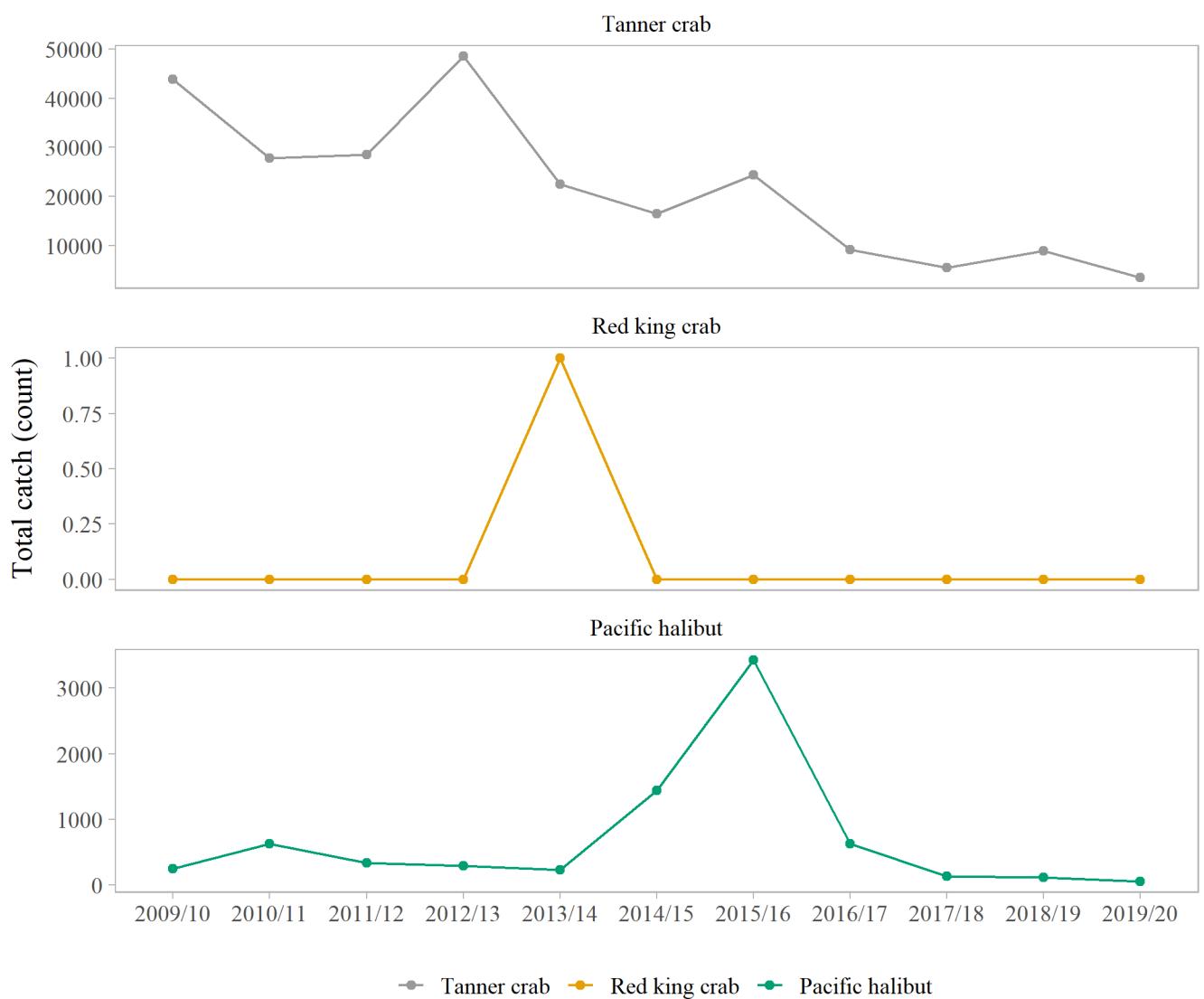


Figure 27: Total bycatch of Tanner crab, red king crab, and Pacific halibut by fishing season within the KNE district.

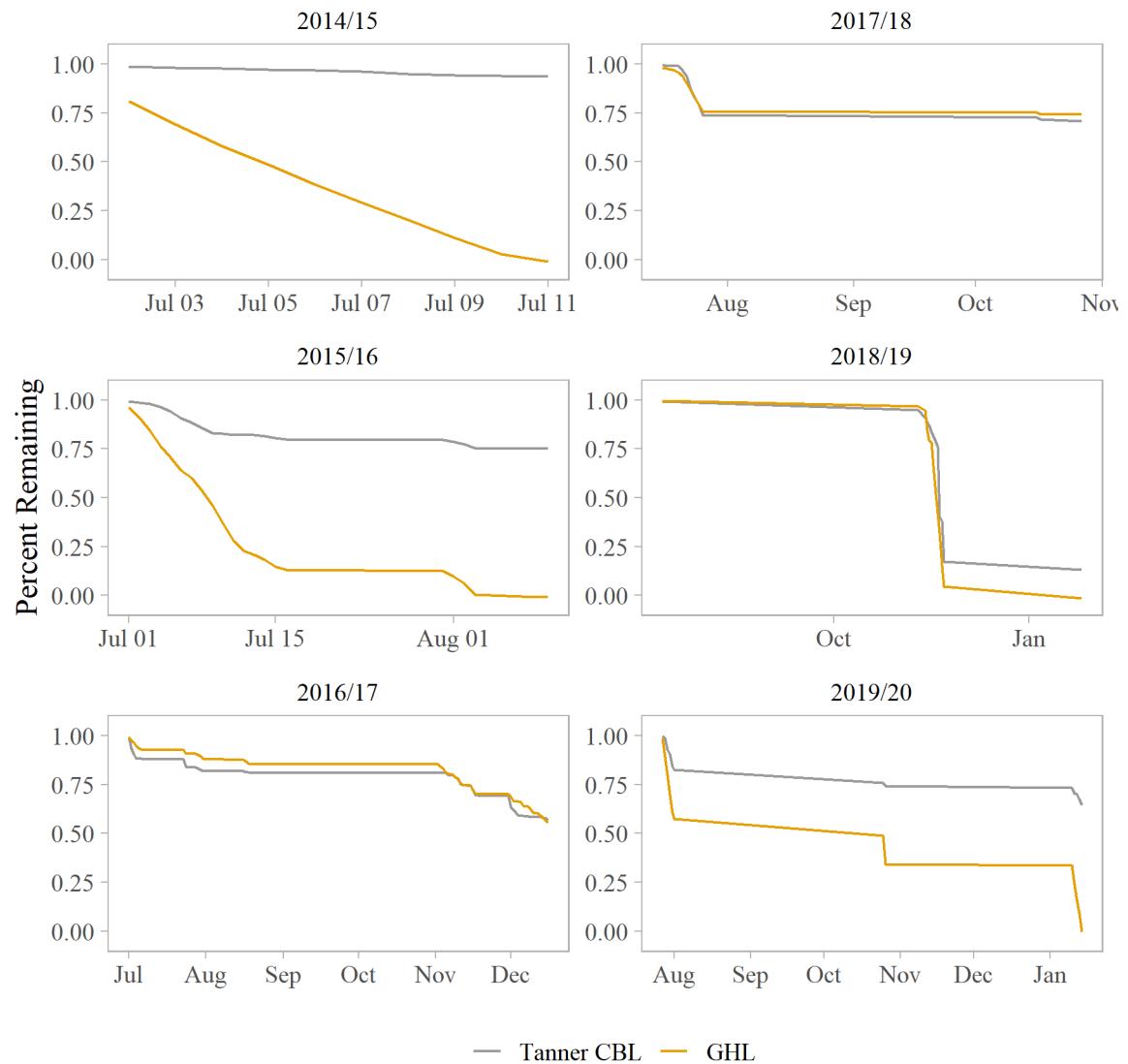


Figure 28: Percent reduction in scallop GHL and Tanner crab CBL throughout recent seasons within the KNE district.

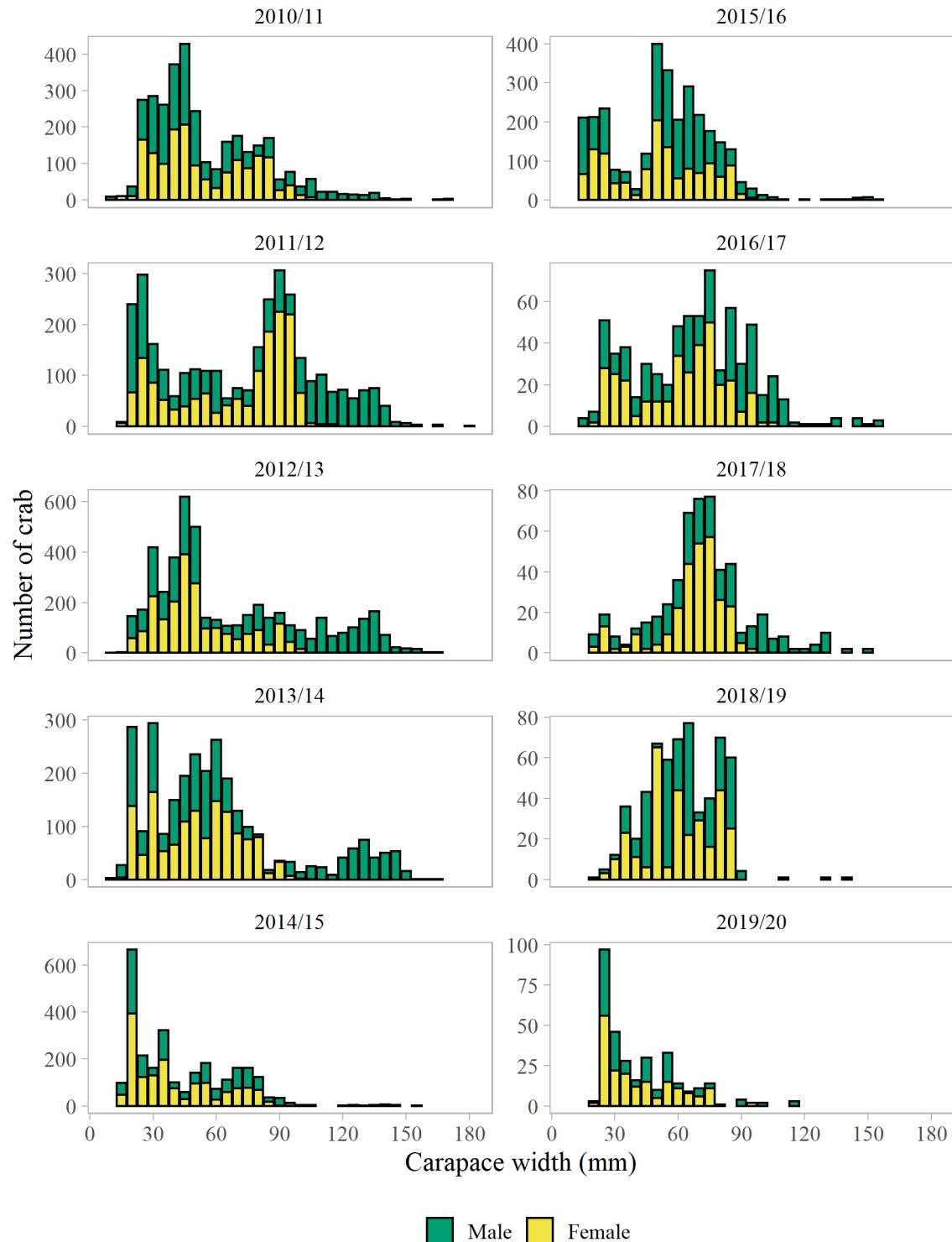


Figure 29: Size frequency histogram of the number of Tanner crab caught by sex during each season in the KNE district.

4.3.2 KSH District

Bycatch of Tanner crab and Pacific halibut slightly decreased, while Dungeness crab bycatch sharply increased from the 2018/19 season. No red king crab were caught in the 2019/20 season (Table 14, Figure 30). The remaining allowable crab bycatch remained safely above the remaining GHL of scallops for the entirety of the season (Figure 31). Tanner crab bycatch included mostly small, immature crab (Figure 32).

Table 14: KSH bycatch summary including total number caught for each species as well as the ratio of number caught to meat weight of scallops retained.

Season	Scallop GHL	Tanner crab CBL	Tanner crab (total)	Tanner crab (ratio)	Red king crab (total)	Red king crab (ratio)	Dungeness crab (total)	Dungeness crab (ratio)	Pacific halibut (total)	Pacific halibut (ratio)
2009/10	170,000	25,000	15,933	0.09	0	0.00	188	0.00	196	0.00
2010/11	170,000	26,400	17,869	0.10	0	0.00	639	0.00	402	0.00
2011/12	135,000	28,636	24,388	0.18	0	0.00	22	0.00	248	0.00
2012/13	105,000	80,540	17,112	0.16	0	0.00	18	0.00	239	0.00
2013/14	105,000	27,450	21,188	0.20	1	0.00	155	0.00	393	0.00
2014/15	105,000	42,144	51,975	0.79	5	0.00	60	0.00	202	0.00
2015/16	75,000	19,107	2,236	0.06	0	0.00	50	0.00	178	0.00
2016/17	25,000	43,477	3,698	0.15	1	0.00	451	0.02	129	0.01
2017/18	25,000	63,926	3,657	0.15	0	0.00	4,819	0.19	29	0.00
2018/19	25,000	12,500	3,099	0.12	0	0.00	1,563	0.06	39	0.00
2019/20	20,000	10,000	1,438	0.07	0	0.00	18,329	0.91	36	0.00

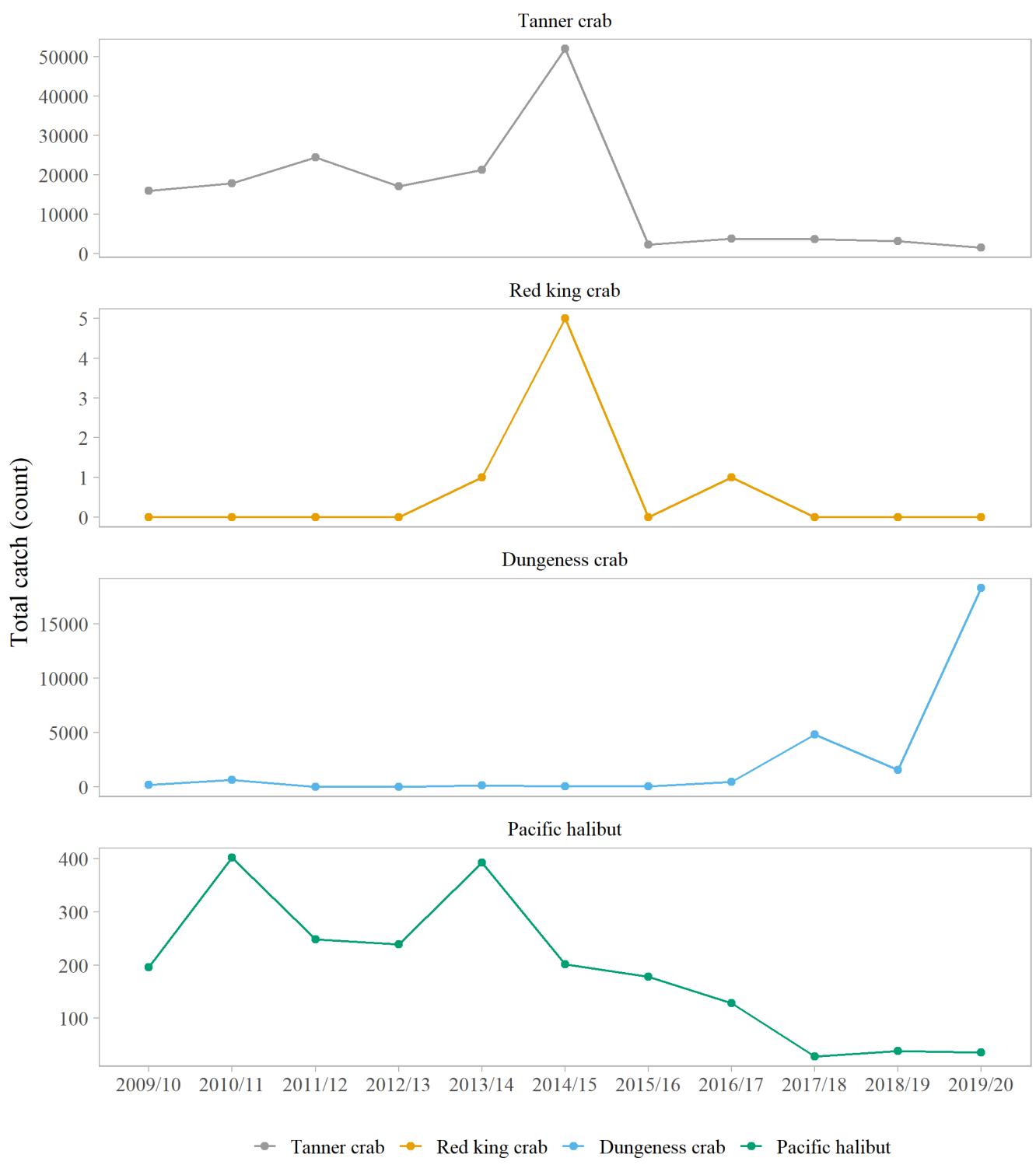


Figure 30: Total bycatch of Tanner crab, red king crab, and Pacific halibut by fishing season within the KSH district.



Figure 31: Percent reduction in scallop GHL and Tanner crab CBL throughout recent seasons within the KSH district.

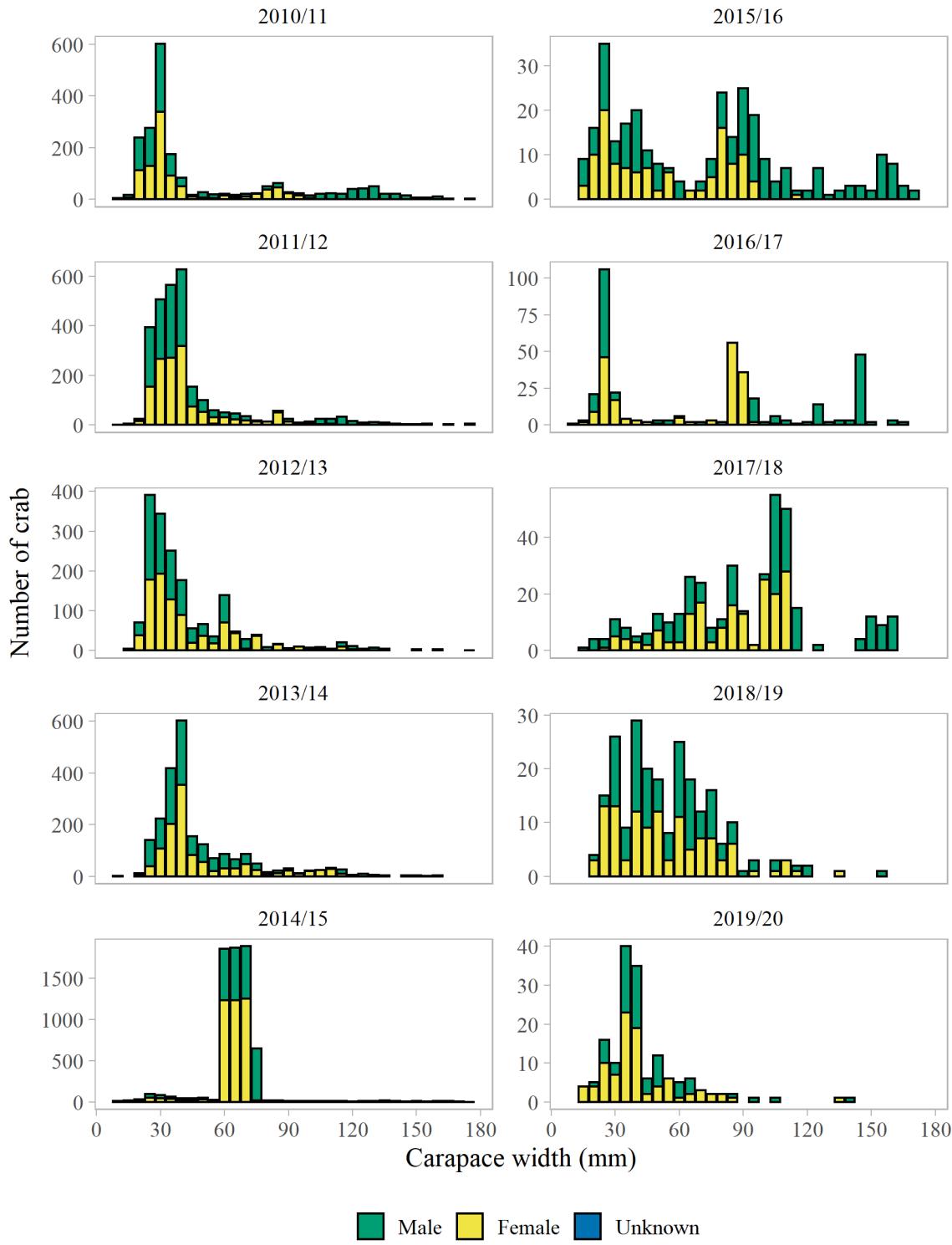


Figure 32: Size frequency histogram of the number of Tanner crab caught by sex during each season in the KSH district.

4.3.3 KSW District

Bycatch of all crab species increased from the 2018/19, while Pacific halibut bycatch slightly decreased (Table 14, Figure 30). The proportion of crab bycatch limit remaining was below the proportion of scallop GHL remaining during several days in late July, but ended the season well above the limit (Figure 34). Tanner crab bycatch included mostly small, immature crab, but more crab between 90 - 120 mm than in KNE and KSH (Figure 35).

Table 15: KSW bycatch summary including total number caught for each species as well as the ratio of number caught to meat weight of scallops retained.

Season	Scallop GHL	Tanner crab CBL	Tanner crab (total)	Tanner crab (ratio)	Red king crab (total)	Red king crab (ratio)	Dungeness crab (total)	Dungeness crab (ratio)	Pacific halibut (total)	Pacific halibut (ratio)
2009/10	25,000	12,000	8,623	2.48	15	0.00	0	0.00	10	0.00
2011/12	25,000	12,000	10,175	0.41	14	0.00	0	0.00	43	0.00
2012/13	25,000	12,000	8,919	0.36	12	0.00	9	0.00	188	0.01
2013/14	25,000	12,000	9,323	0.46	11	0.00	0	0.00	210	0.01
2014/15	25,000	12,000	18,168	0.73	9	0.00	0	0.00	143	0.01
2015/16	25,000	12,000	15,234	1.39	0	0.00	0	0.00	30	0.00
2016/17	25,000	12,000	8,017	0.32	7	0.00	0	0.00	56	0.00
2017/18	25,000	12,000	6,912	0.28	2	0.00	0	0.00	134	0.01
2018/19	30,000	18,000	1,460	0.05	1	0.00	1,089	0.04	179	0.01
2019/20	35,000	17,500	10,870	0.31	5	0.00	9,286	0.27	177	0.01

^a2015/16 Inseason closure due to Tanner bycatch

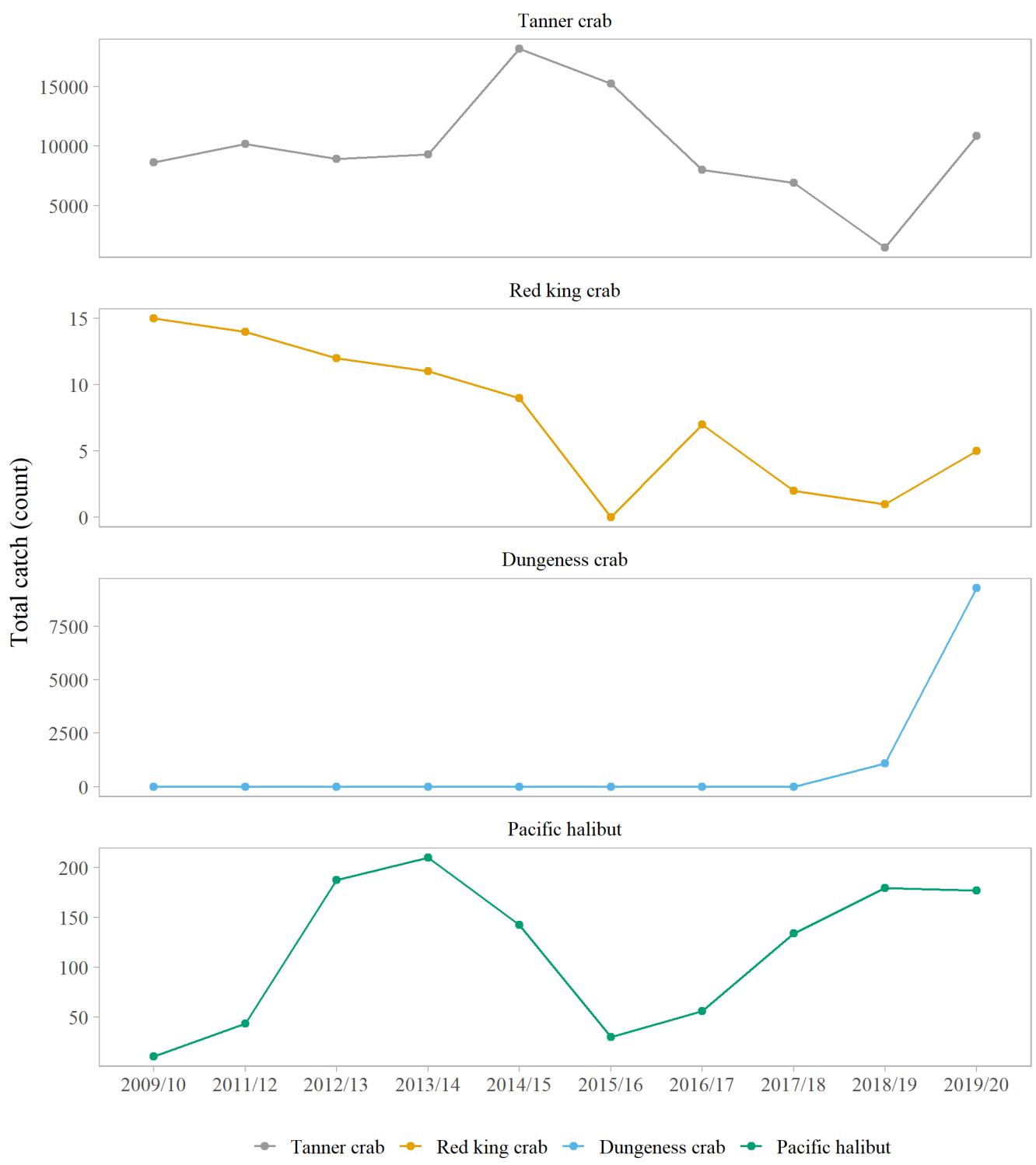


Figure 33: Total bycatch of Tanner crab, red king crab, and Pacific halibut by fishing season within the KSW district.



Figure 34: Percent reduction in scallop GHL and Tanner crab CBL throughout recent seasons within the KSW district.

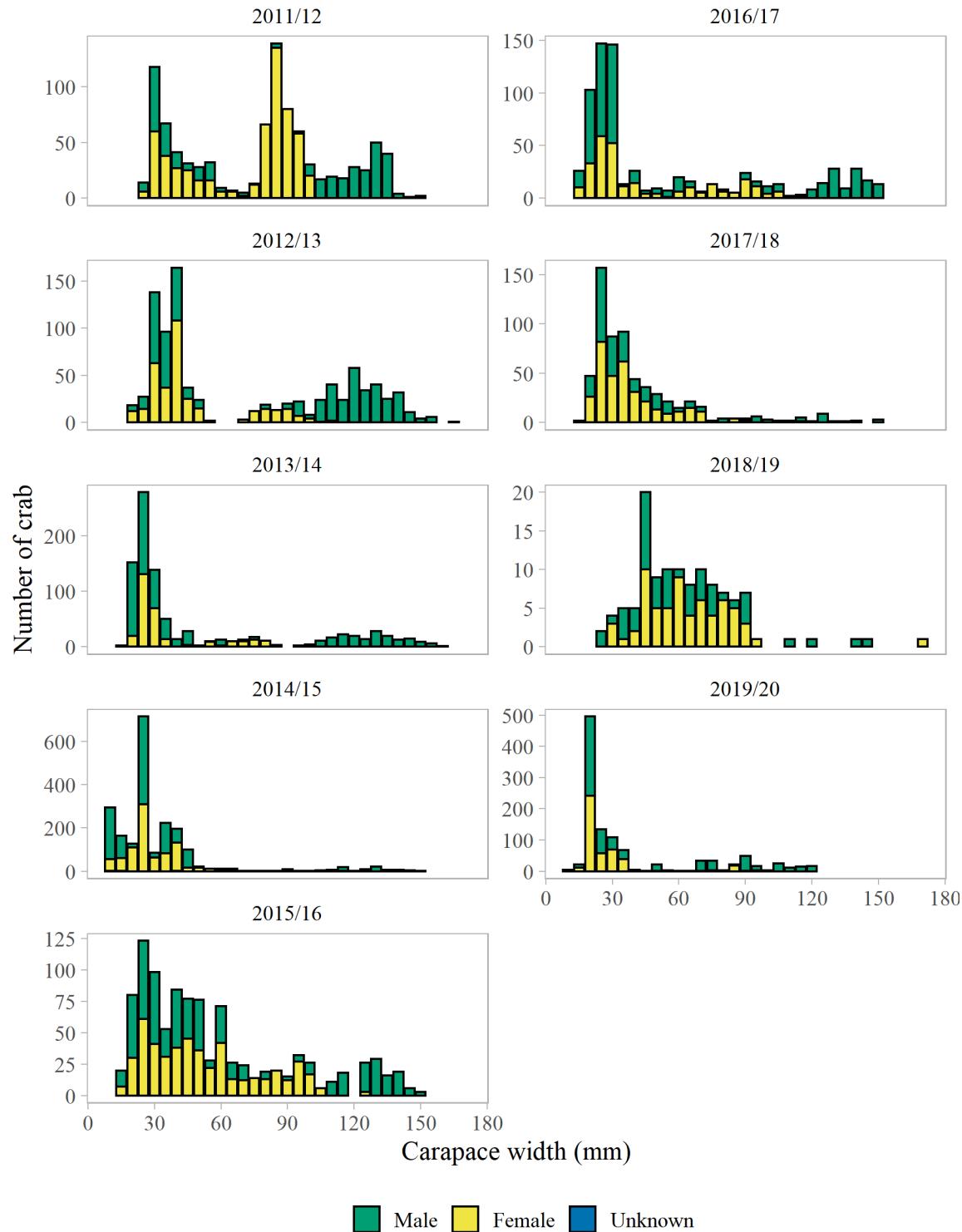


Figure 35: Size frequency histogram of the number of Tanner crab caught by sex during each season in the KSW district.

4.4 Fishery biological information

Shell height composition of catch in the KNE district suggests the presence of three distinct cohorts in the KNE district, one of retained size and two of discarded size (Figure 36). In the KSH district, there appears to be a prominent discarded cohort ~ 95 mm, a cohort that was split retained/discard, and a weak trailing cohort of large scallops (Figure 37). Smaller cohorts present in KNE and KSH were absent from KSW. Most scallops caught in KSW were between 100 - 130 mm, and there appears to be a strong cohort of large scallops ~ 155 mm that was lacking in KNE and KSH (Figure 38).

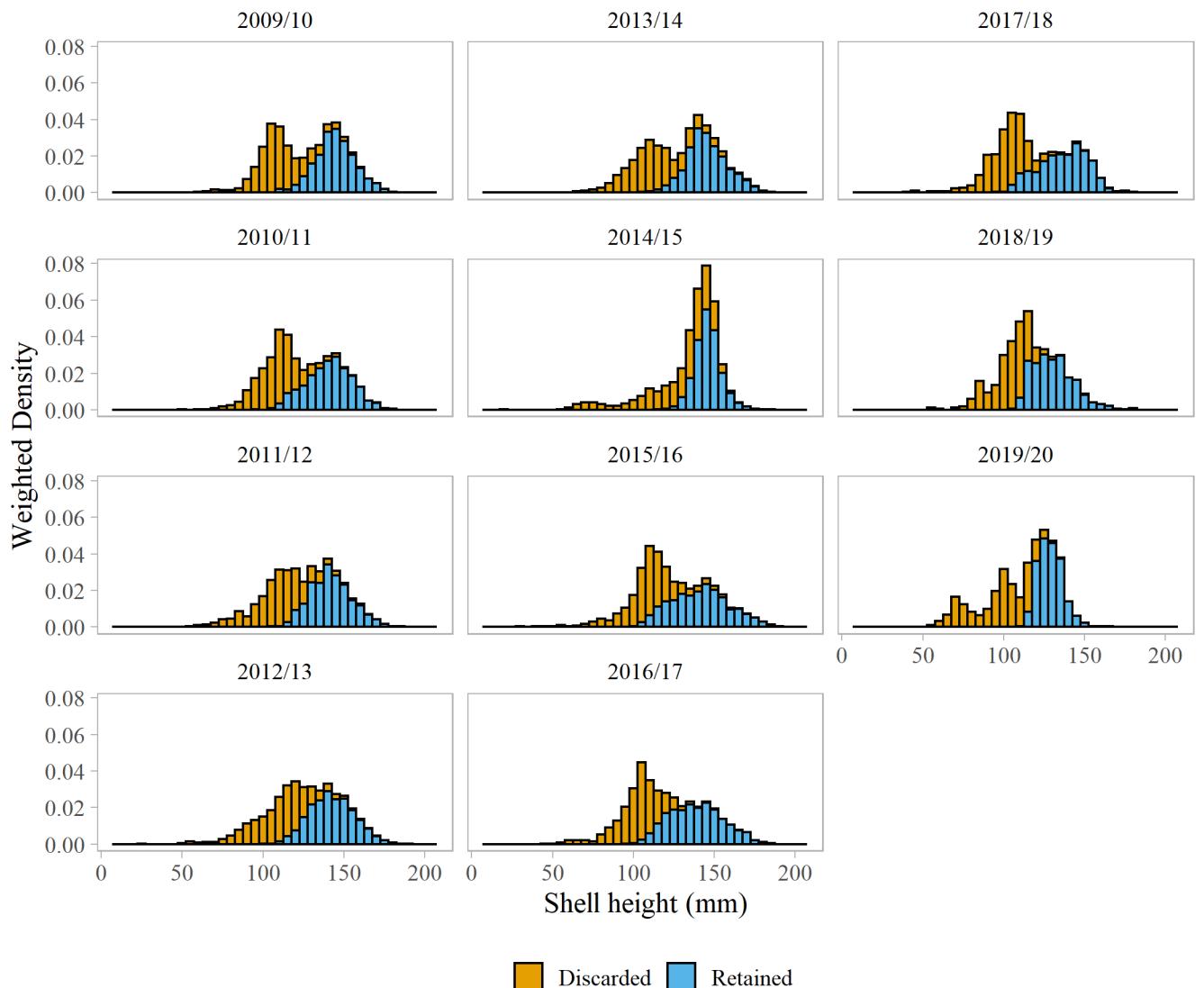


Figure 36: Shell height composition of scallops caught within the KNE district in 5mm bins expressed as a weighted probability density function.

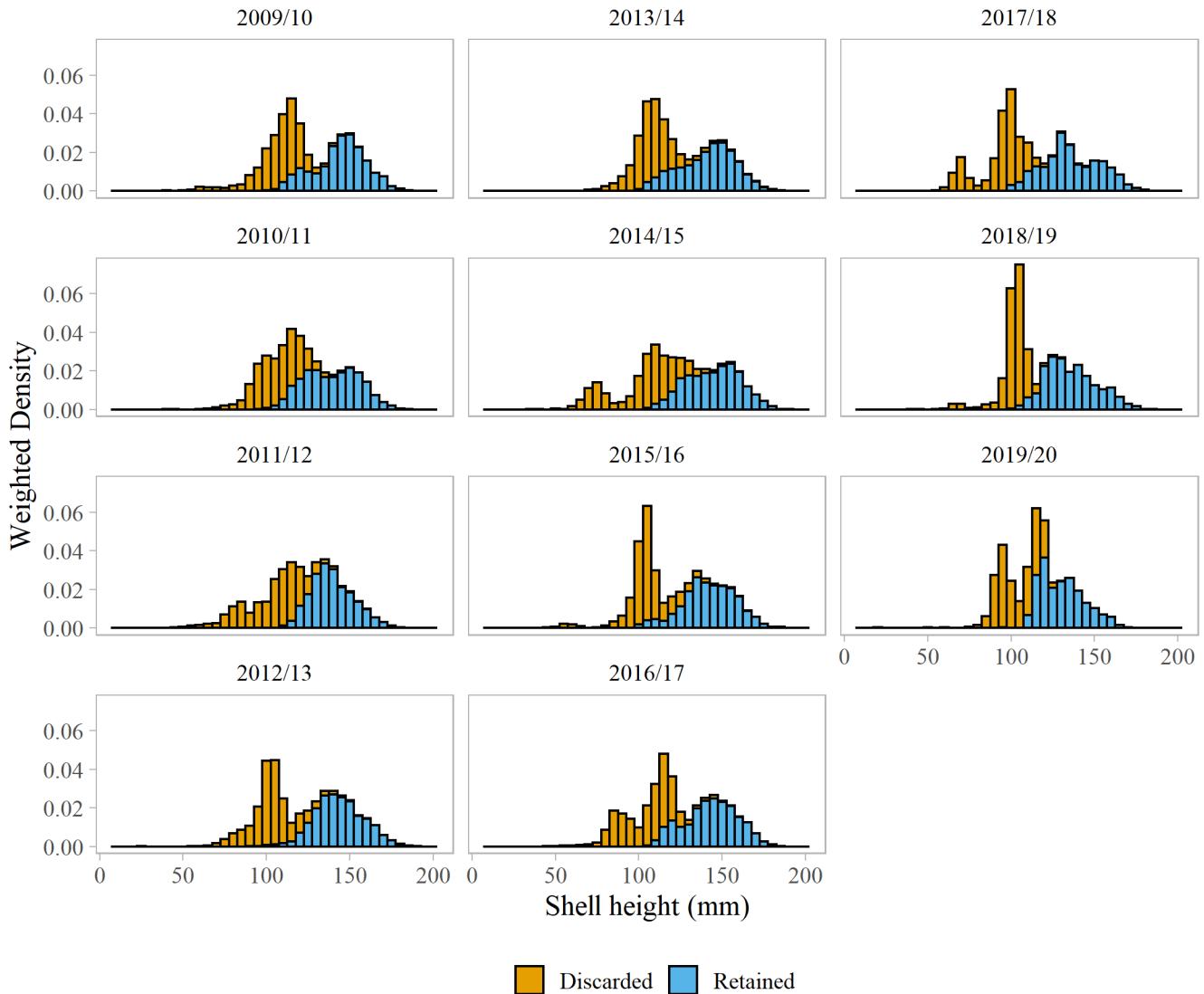


Figure 37: Shell height composition of scallops caught within the KSH district in 5mm bins expressed as a weighted probability density function.

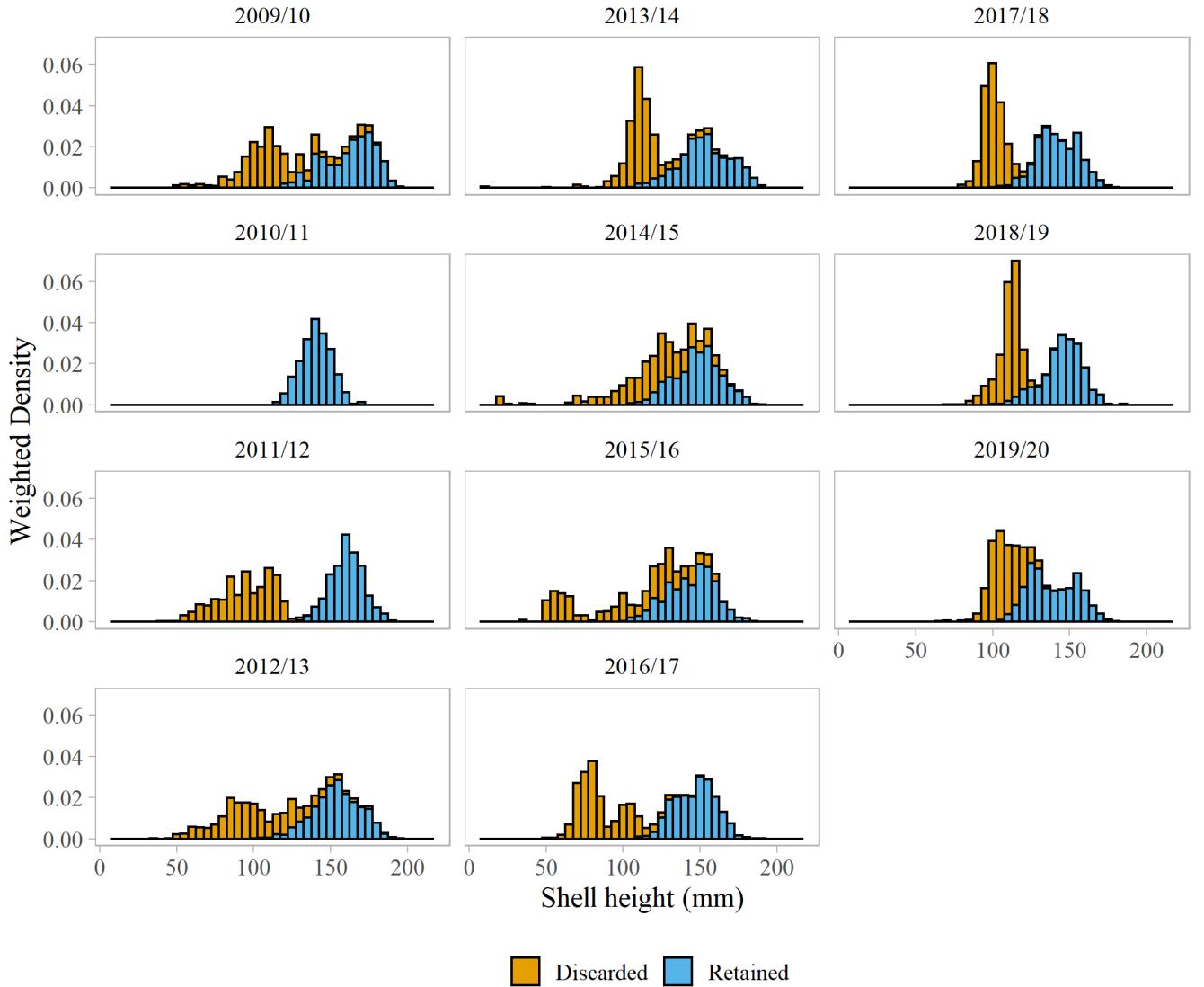


Figure 38: Shell height composition of scallops caught within the KSW district in 5mm bins expressed as a weighted probability density function.

The effect of season on allometric growth parameters of the meat weight \sim shell height relationship was significant without random effects ($\alpha_2, p = 0.01; \beta_2, p < 0.01$), but not after incorporating random effects on α by district ($\sigma = 0.18$) ($\alpha_2, p = 0.12; \beta_2, p = 0.06$). Still, the observed shift in allometry between seasons is clear and was visible by fisherman in the field, thus it is likely biologically relevant (Table 16, Figure 39 - 40).

Table 16: Allometric growth parameters characterizing the meat weight, shell height relationship in area K by season.

Season	α	β
2018/19	3.51e-06	3.205
2019/20	1.63e-05	2.830

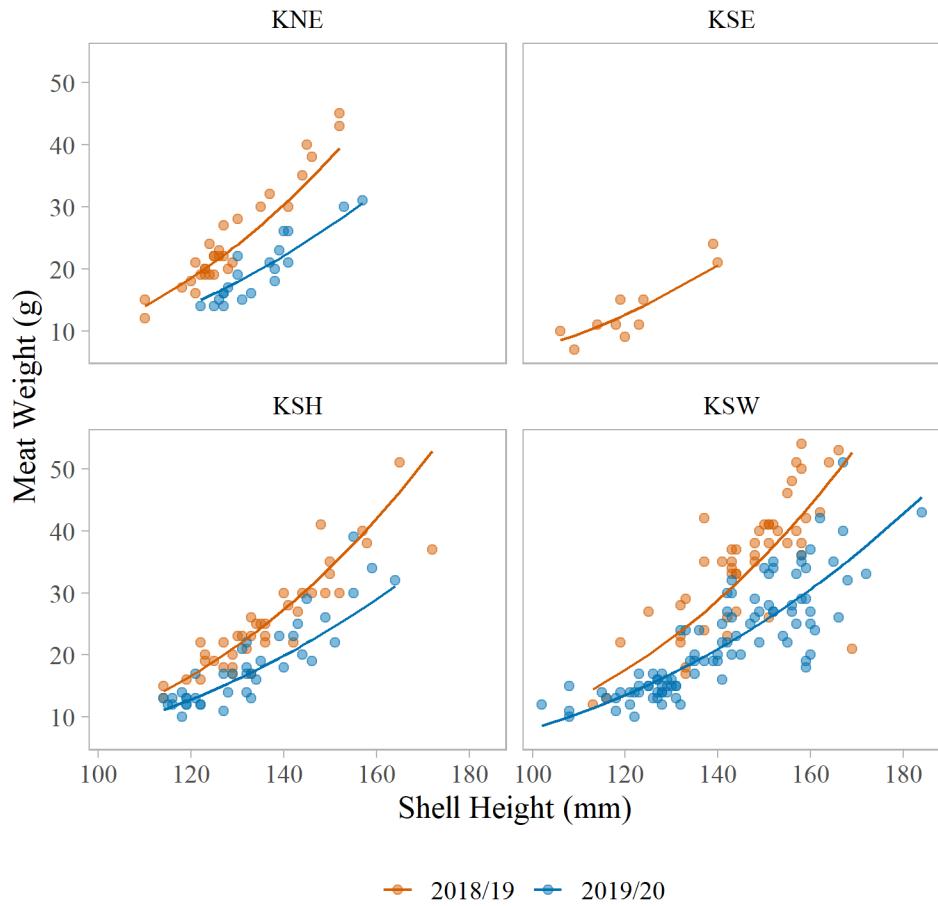


Figure 39: Individual meat weight (g) as a function of shell height (mm) for scallops caught in area K during the 2018/19 and 2019/20 seasons, by district.

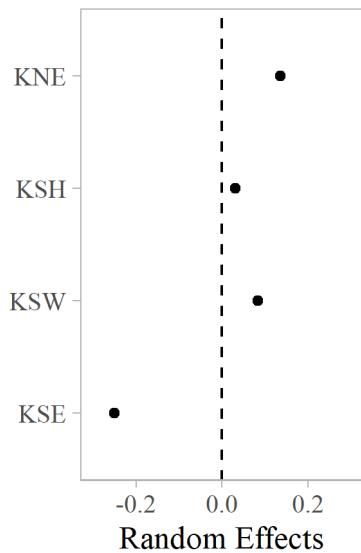


Figure 40: Random effects on the parameter α by district.

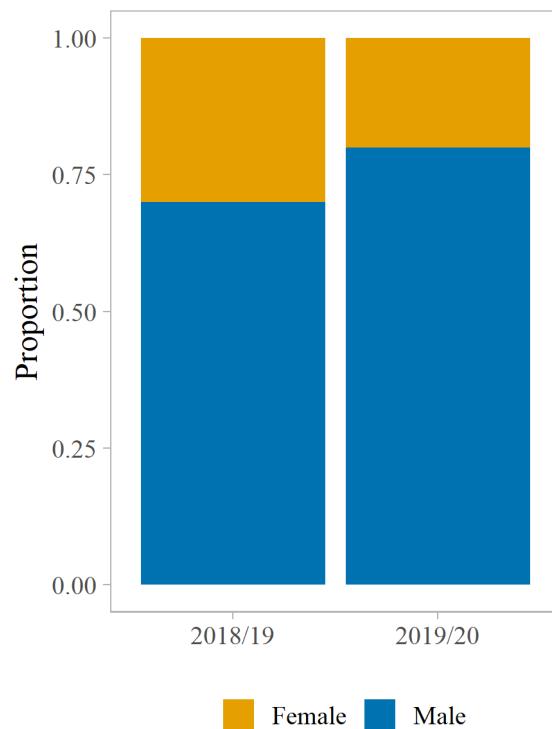


Figure 41: Proportion by sex in the KNE district.

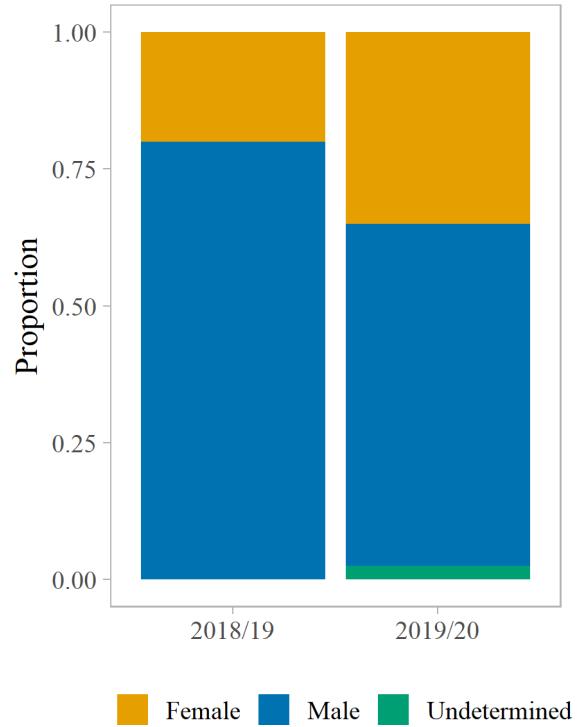


Figure 42: Proportion by sex in the KSH district.

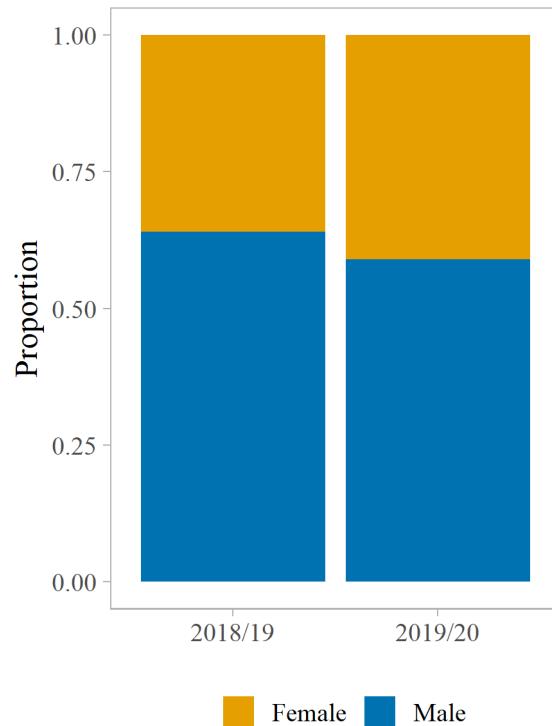


Figure 43: Proportion by sex in the KSW district.

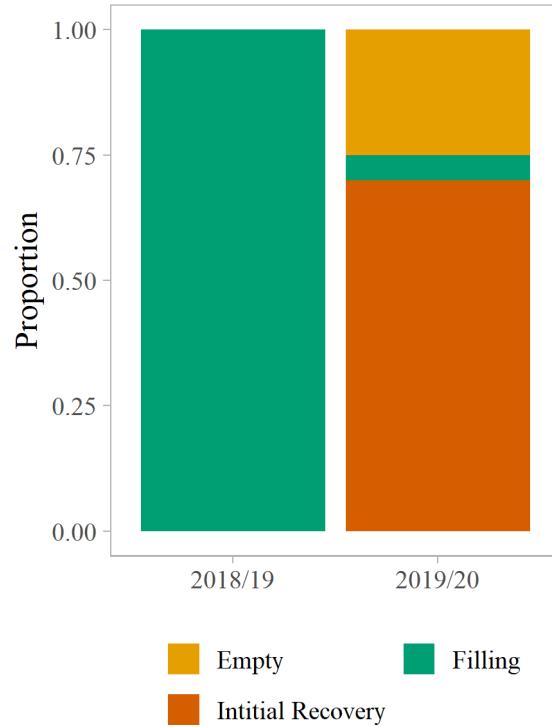


Figure 44: Proportion by gonad condition in the KNE district.

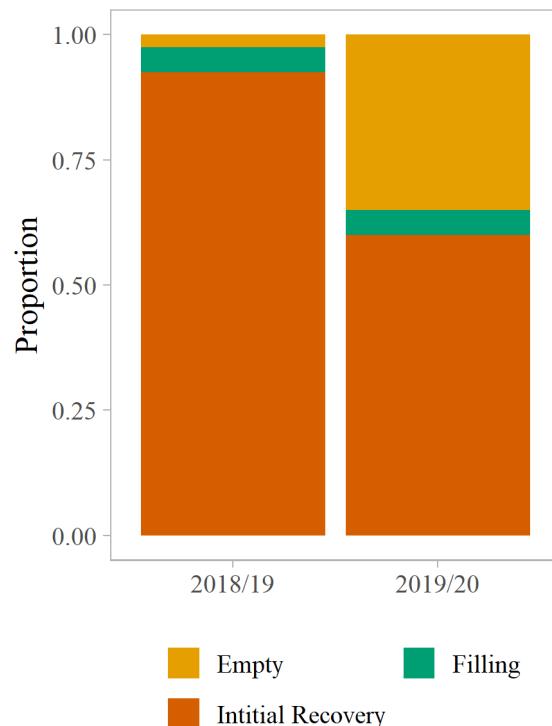


Figure 45: Proportion by gonad condition in the KSH district.

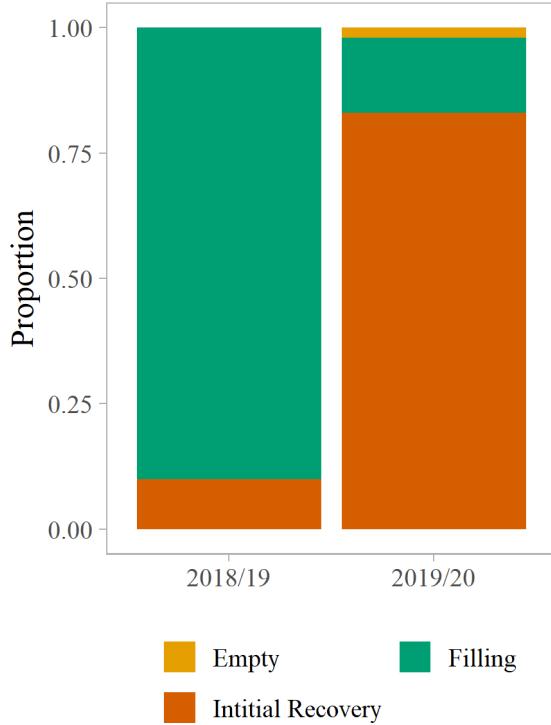


Figure 46: Proportion by gonad condition in the KSW district.

4.5 Fishery independent information

4.5.1 Trawl survey

In 2019, the trawl survey completed 210 hauls within area K (Figure 47). The trawl survey spans each district except for KSEM. Data summary figures shown below (Figures 48 - 56).

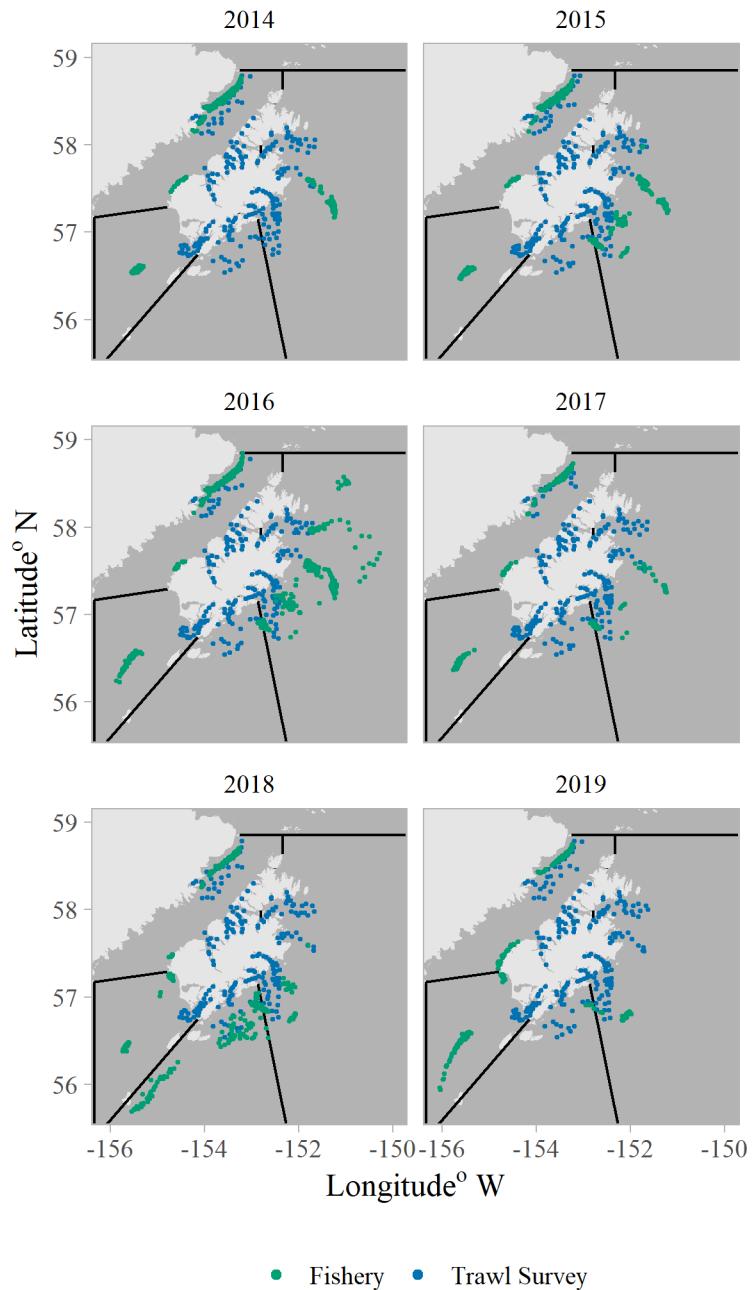
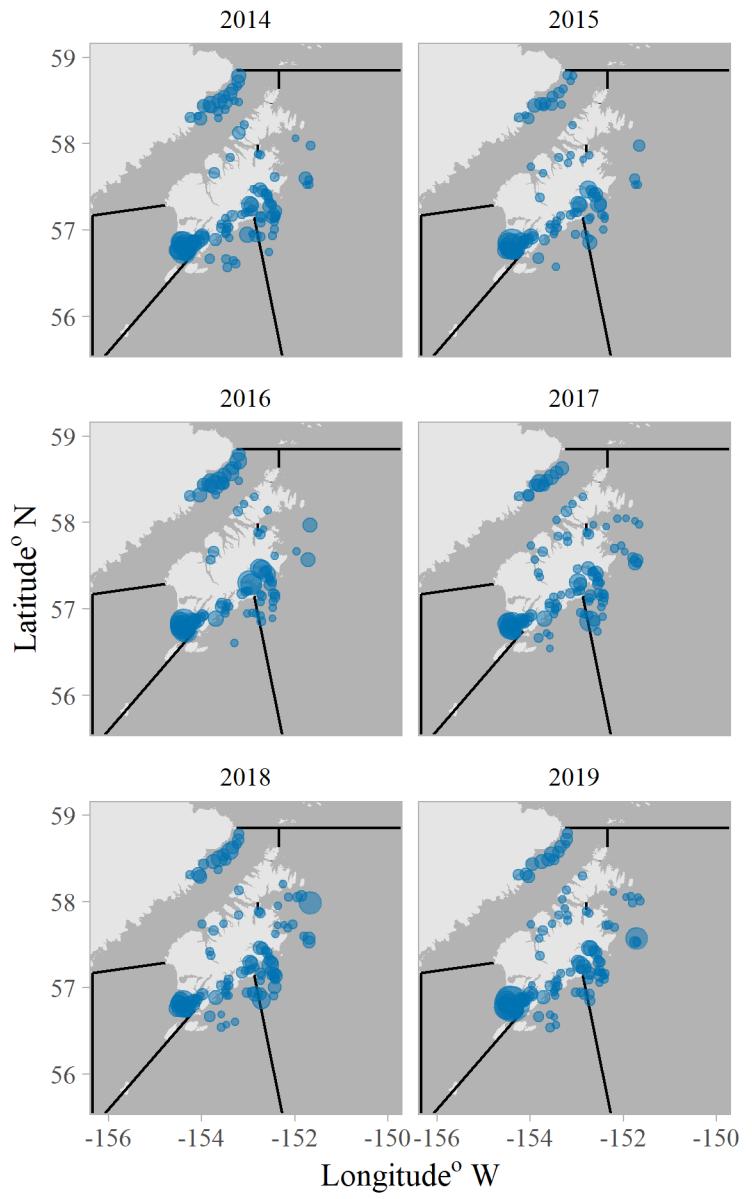


Figure 47: Trawl survey haul locations (blue) in comparison to the location of fishing effort (green) in area K from 2015 - 2019.



Round Weight CPUE (kg / sq km) ● 4000 ● 8000 ● 12000 ● 16000

Figure 48: Trawl survey CPUE (kg / sq nm).

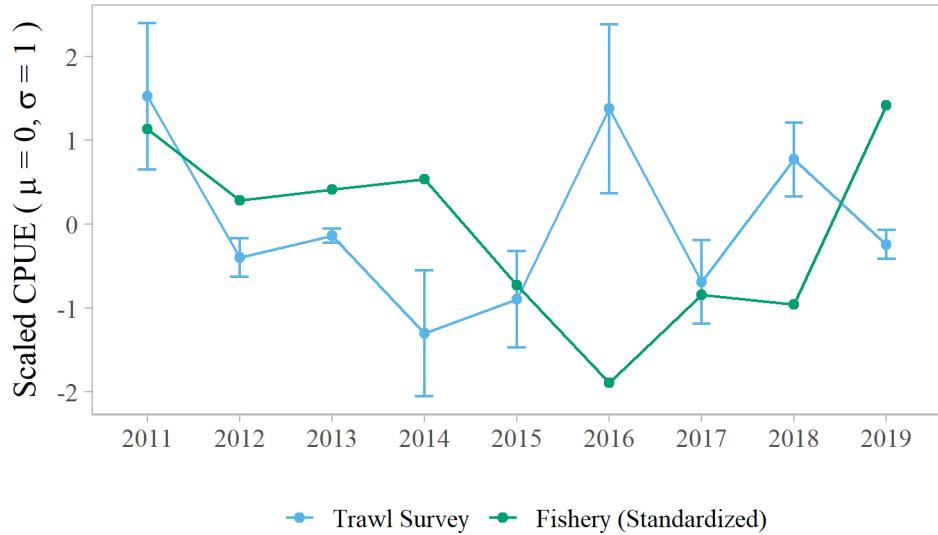


Figure 49: Trawl survey CPUE (+/- 95% confidence interval) (blue) in comparison to standardized fishery CPUE within the KNE district. Both indices are scaled to a standard normal distribution to compare trends.

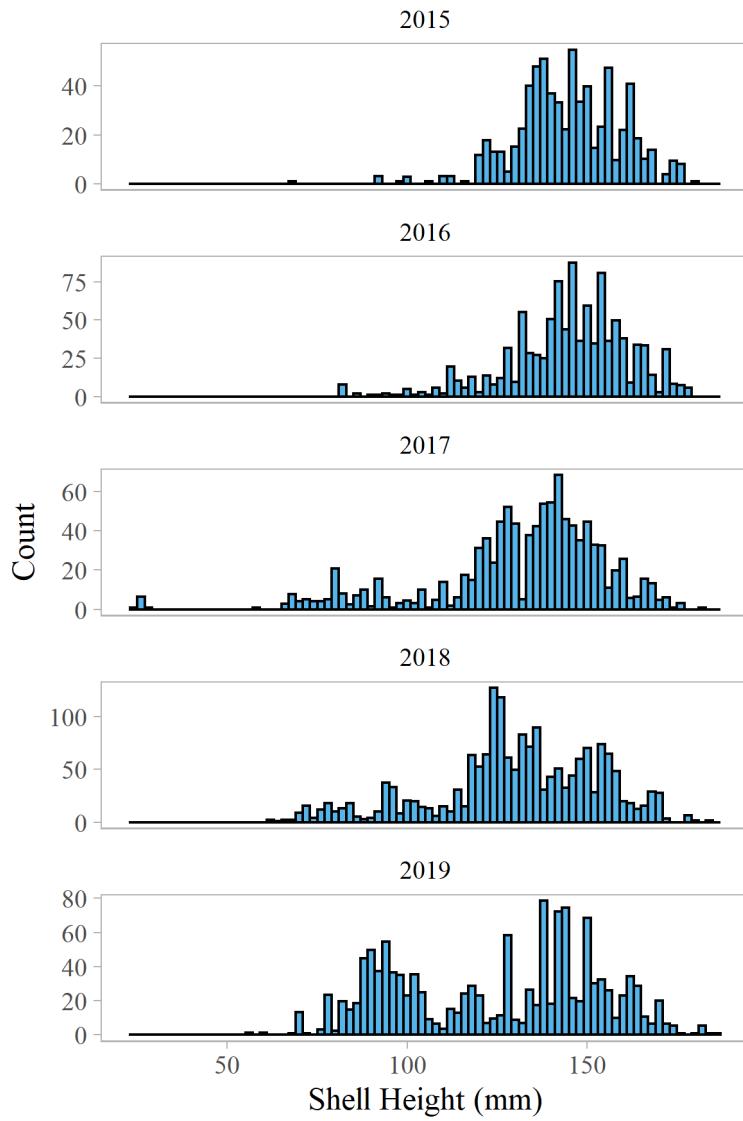


Figure 50: Size composition of scallops caught in the trawl survey from 2015 to 2019 in the KNE district

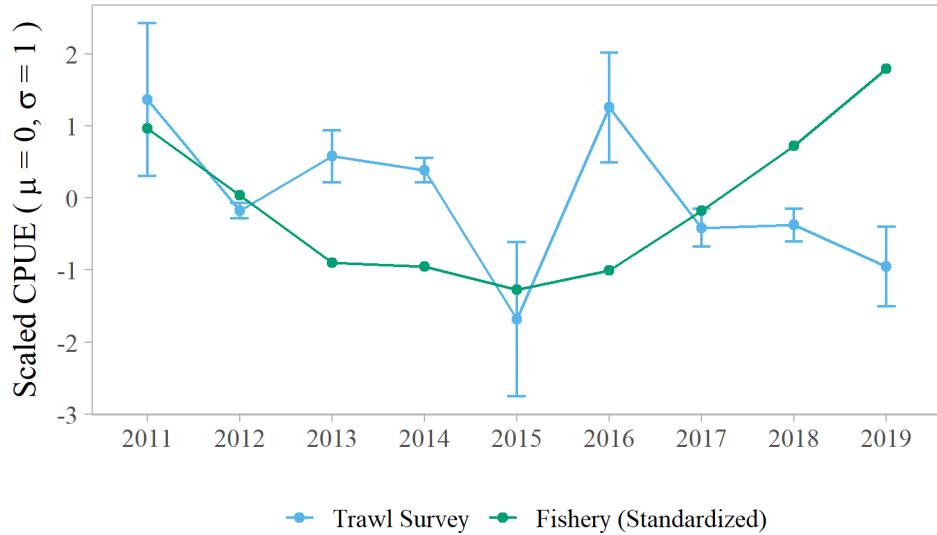


Figure 51: Trawl survey CPUE (+/- 95% confidence interval) (blue) in comparison to standardized fishery CPUE within the KSH district. Both indices are scaled to a standard normal distribution to compare trends.

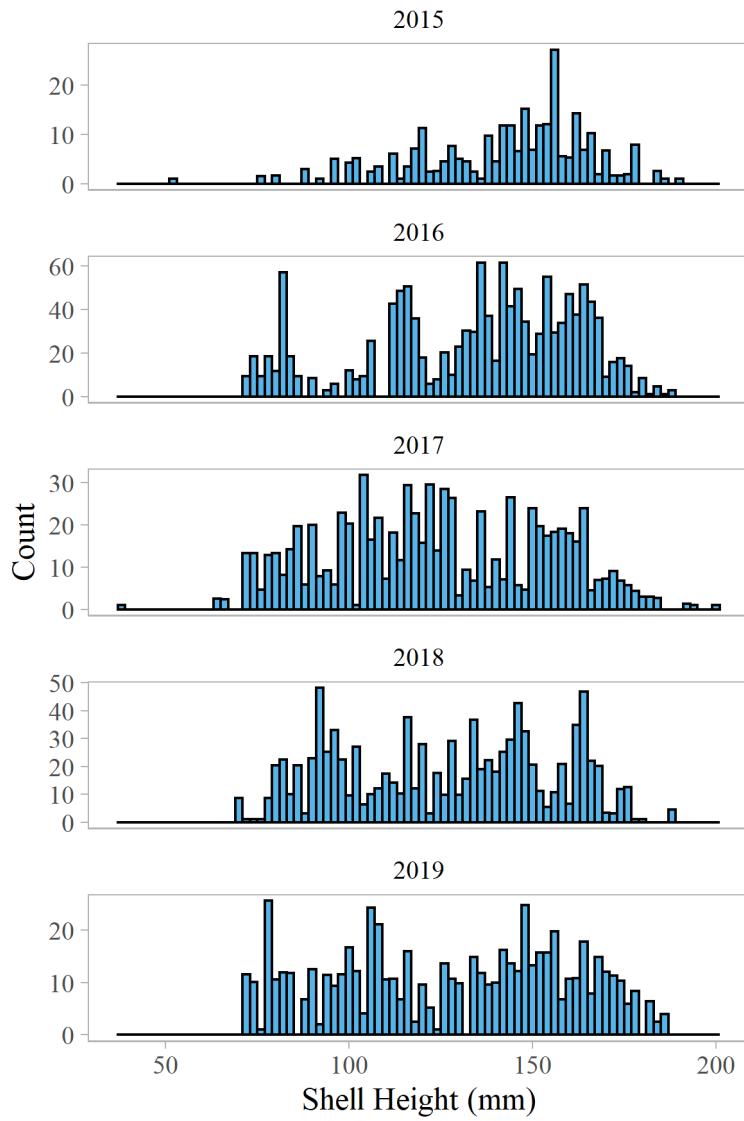


Figure 52: Size composition of scallops caught in the trawl survey from 2015 to 2019 in the KSH district

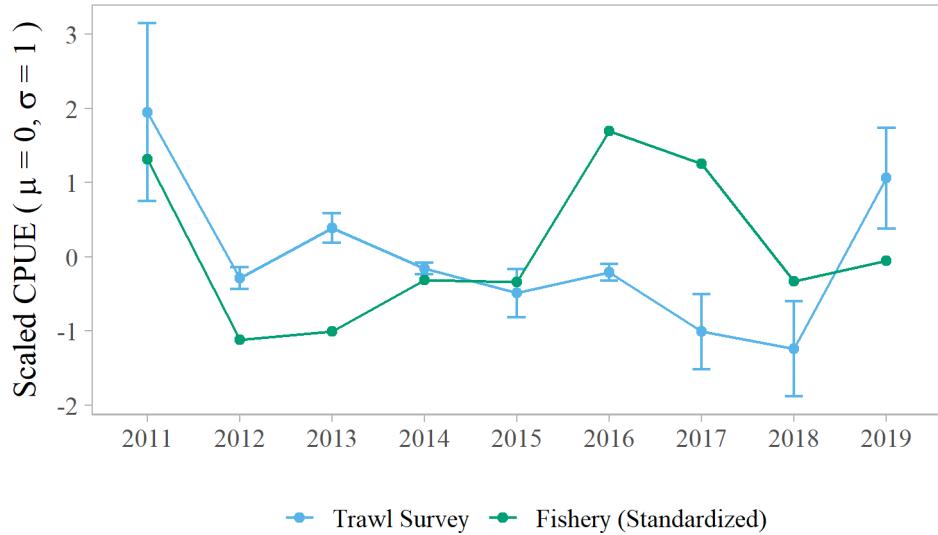


Figure 53: Trawl survey CPUE (+/- 95% confidence interval) (blue) in comparision to standardized fishery CPUE within the KSW district. Both indices are scaled to a standard normal distribution to compare trends.

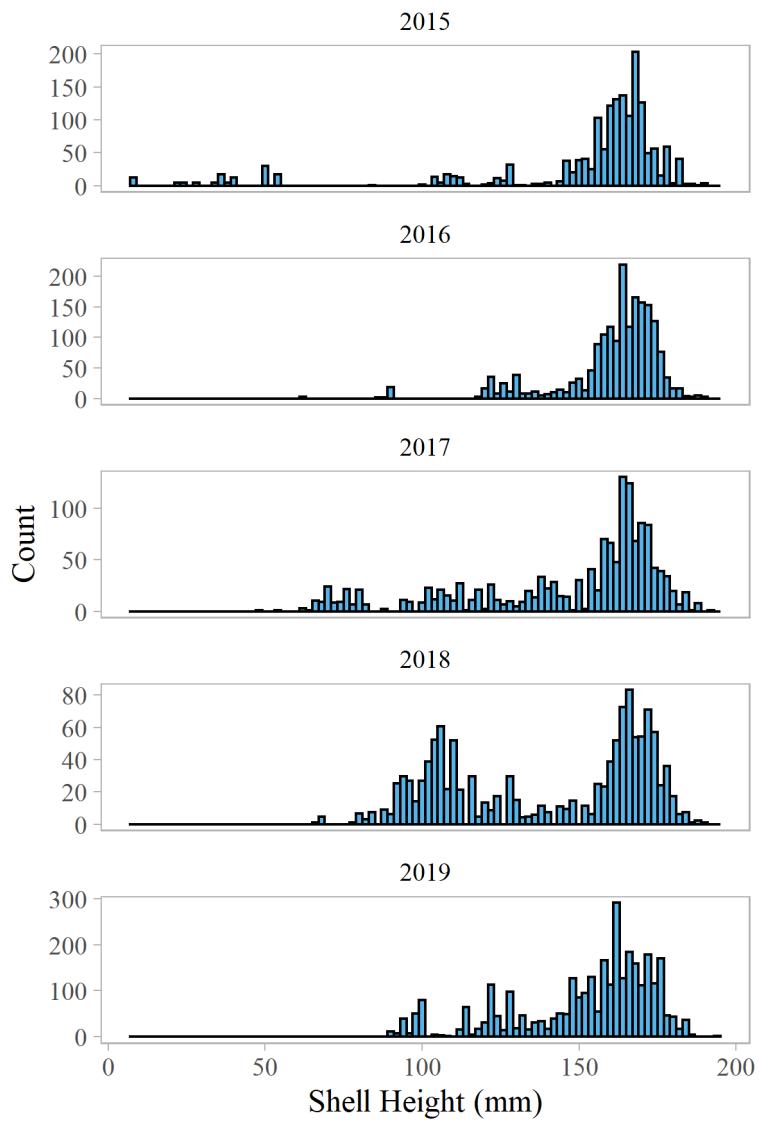


Figure 54: Size composition of scallops caught in the trawl survey from 2015 to 2019 in the KSW district



Figure 55: Trawl survey CPUE (+/- 95% confidence interval) (blue) in comparision to standardized fishery CPUE within the KSE district. Both indices are scaled to a standard normal distribution to compare trends.

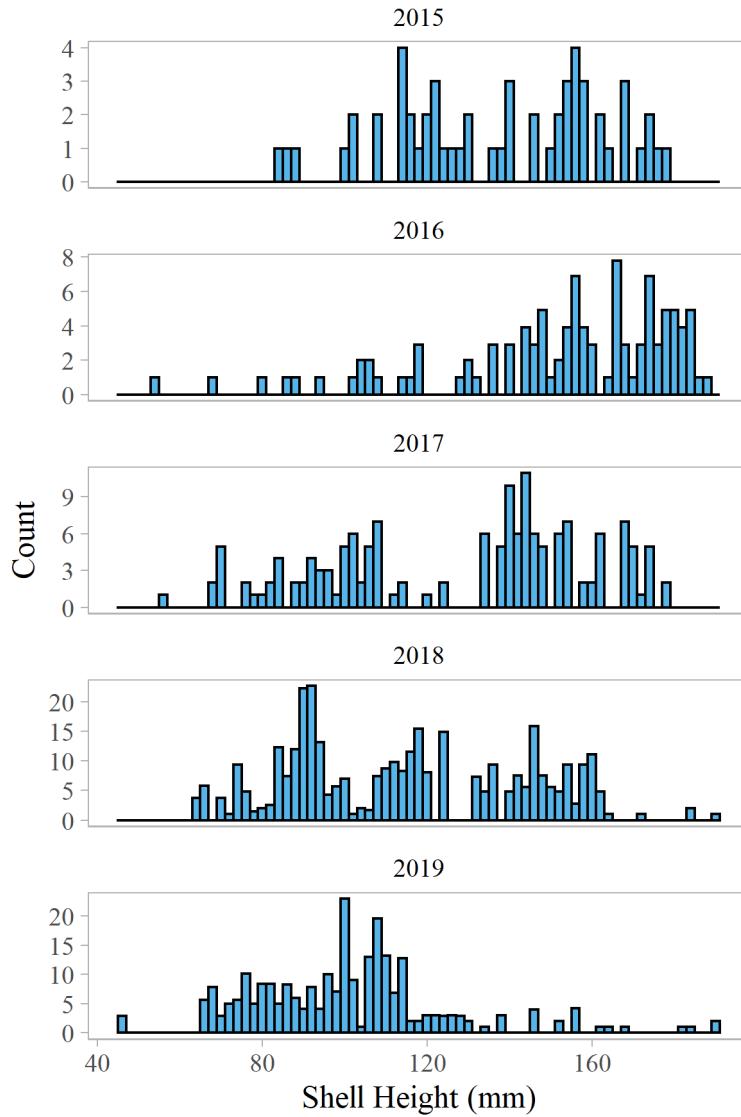


Figure 56: Size composition of scallops caught in the trawl survey from 2015 to 2019 in the KSE district

5 Alaska Peninsula Registration Area (M)

The Alaska Peninsula registration area (M) contains three districts: Unimak Bight (UB), Central (C), and West Chignik (WC). GHLs for the 2019/20 season were set for the UB district (7,500 lbs) and waters between 160°W - 161°W longitude (7,500 lbs), which is within the C district (Table 17). Fishery statistics within area M are presented here with all districts combined, unless otherwise noted. Area M has never been included in the dredge survey, though several trawl survey stations within area M are sampled on an annual basis.

5.1 Fishery performance

The 2019/20 Unimak Bight District scallop fishery opened on July 1, 2019 with a GHL of 7,500 lbs of scallop meats in the Unimak Bight district and waters between 160°W - 161°W longitude. One vessel participated in the fishery harvesting 5,740 lbs scallop meat with a CPUE of 48.7 lbs meat/dredge hour, and the fishery closed prior to achieving the GHL due to high Tanner crab bycatch. All effort occurred in the UB district.

Total round weight of retained scallops was 63,937 lbs with a nominal CPUE of 542 lbs/dredge hour (Table 17). Fishing effort was restricted to a small area within the UB district (Figure 57), and the resulting catch came from the smallest spatial area within the UB district since the 2012/13 season (Figure 58). Round weight CPUE was standardized without a covariate for bed due to inconsistent or limited fishing effort, despite some catch occurring throughout the management area. Despite a slight increase in nominal CPUE from the 2018/19 season, standardized CPUE continues a decreasing trend (Table 18, Figure 60), which may be because fishing occurred during the month of October, the effect of which is negative compared to months July through September (i.e., poorer fishing performance in prior seasons occurred during October, and the model fits the data accordingly) (Figure 59).

Table 17: Area M catch summary. Meat and round weight CPUE represent nominal values.

Year	GHL	Retained catch (lb meat)	Retained catch (lb round)	Dredge hours	Numer hauls	Meat wt cpue ^a	Round wt cpue ^b
1993/94		112,087		1,847	957	61	
1994/95		65,282		1,664	1,115	39	
1995/96	closed						
1996/97	200,000	12,560	128,800	327	177	38	394
1997/98	200,000	51,616	597,546	1,752	1,050	29	341
1998/99	200,000	63,290	617,039	1,612	681	39	383
1999/00	200,000	75,535	778,838	2,025	1,099	37	385
2000/01	33,000	7,660	92,874	320	188	24	290
2001/02	closed						
2002/03	closed						
2003/04	closed						
2004/05	closed						
2005/06	10,000	No Effort					
2006/07	25,000	155	2,936	64	73	2	99
2007/08	10,000	No Effort					
2008/09	10,000	2,460	31,870	154	114	16	207
2009/10	closed						
2010/11	closed						
2011/12	closed						
2012/13	15,000	15,040	217,607	255	248	59	853
2013/14	15,000	15,155	193,106	247	198	61	781
2014/15	22,500	15,000	227,369	294	223	51	775
2015/16	22,500	15,000	207,991	308	166	49	676
2016/17	22,500	15,013	202,806	345	216	43	587
2017/18	22,500	15,250	181,646	328	193	47	555
2018/19	22,500	8,905	119,458	264	146	34	452
2019/20	15,000	5,740	63,937	118	68	49	542

^alb scallop meat wt/dredge hour

^blb scallop round wt/dredge hour

^c2019/20 Inseason closure due to Tanner bycatch

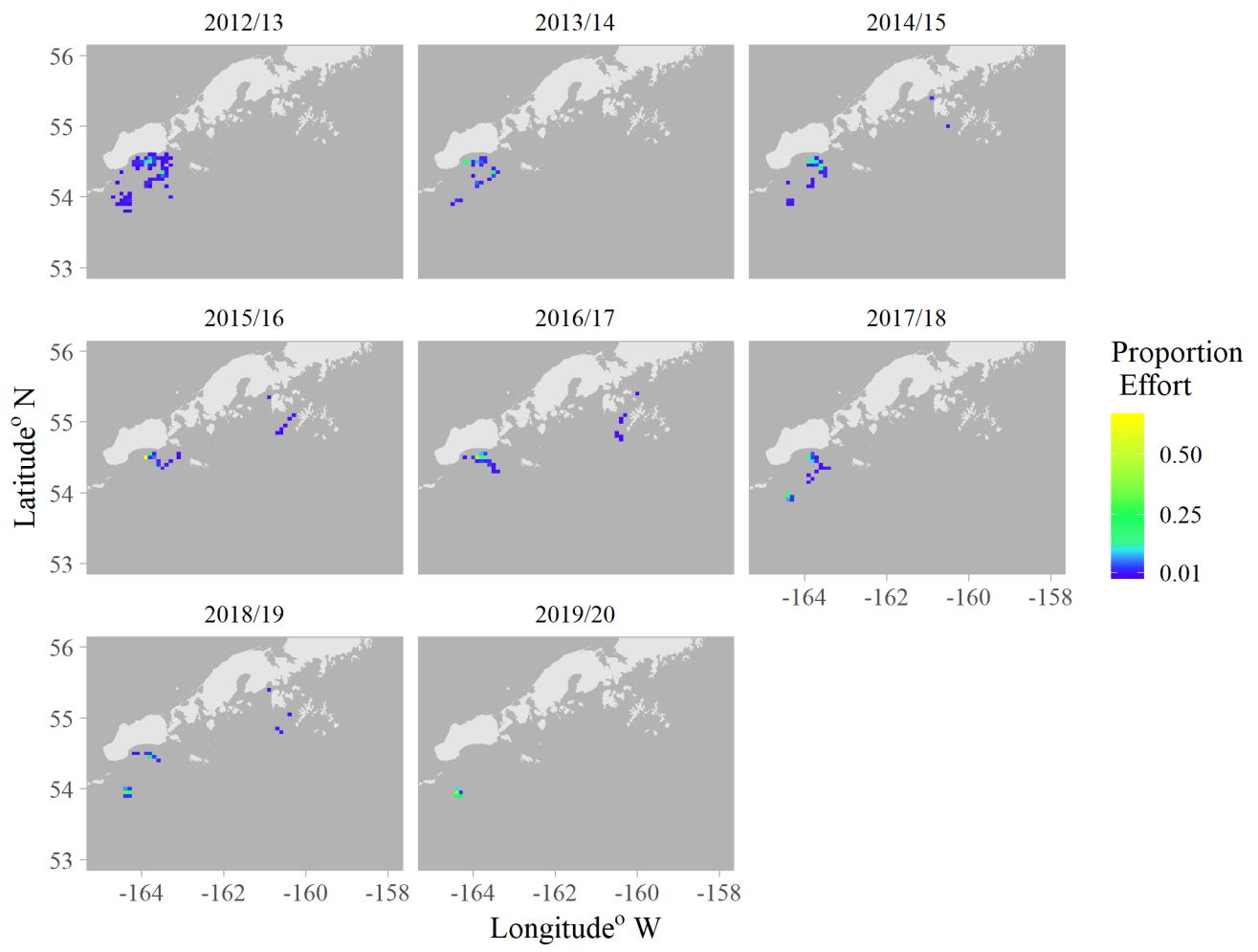


Figure 57: Heat map of fishing effort within area M. Warmer colors indicate areas accounting for a greater proportion of fishing effort.

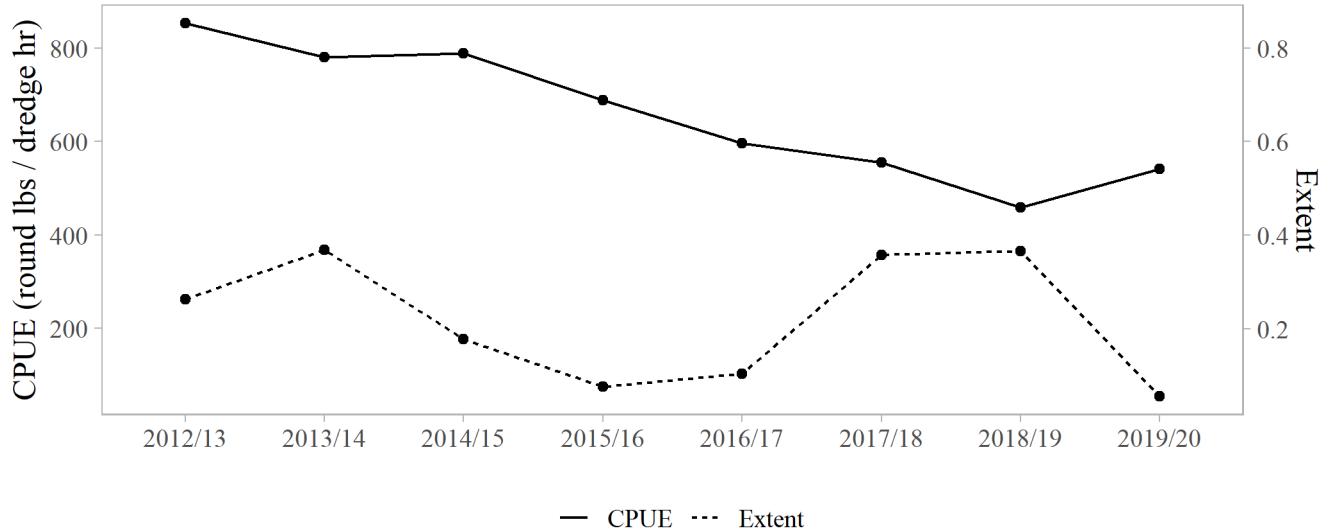


Figure 58: Nominal CPUE (round lbs / dredge hr) (solid line) and relative spatial extent of fishing effort (dotted line) within the UB district by season. The C district did not have enough catch in most years to compute relative extent.

Table 18: Area M district nominal and standardized CPUE estimates (round lbs / dredge hour) by season.

Season	Nominal CPUE			Standardized CPUE
	(total)	(median)	(sd)	
2012/13	852.96	686.80	631.24	1,117.58
2013/14	780.64	718.60	525.11	1,174.37
2014/15	774.52	783.05	439.06	1,129.35
2015/16	675.82	682.77	285.15	797.22
2016/17	587.30	589.15	298.20	801.39
2017/18	554.59	490.96	336.99	539.03
2018/19	452.30	451.86	224.61	433.40
2019/20	541.93	577.01	164.09	305.88

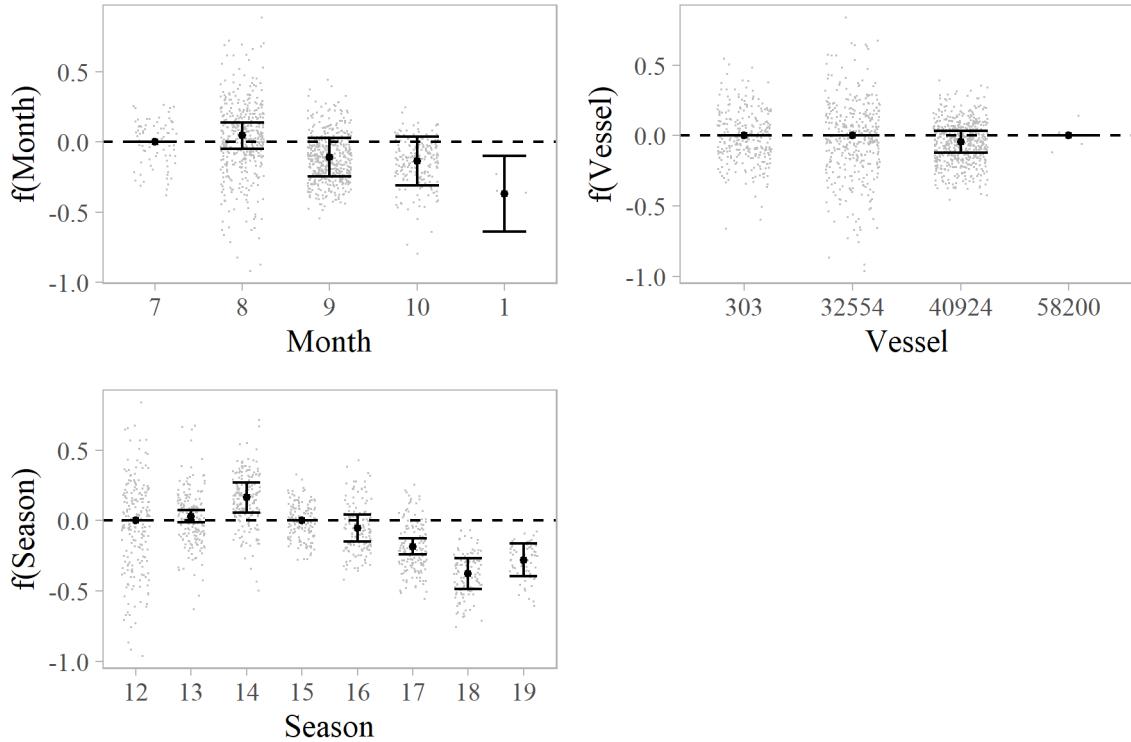


Figure 59: Partial effects of Month, Vessel, Season, and Bed on CPUE within the KNE district. Season values represent the last two digits of the year the fishery opened.

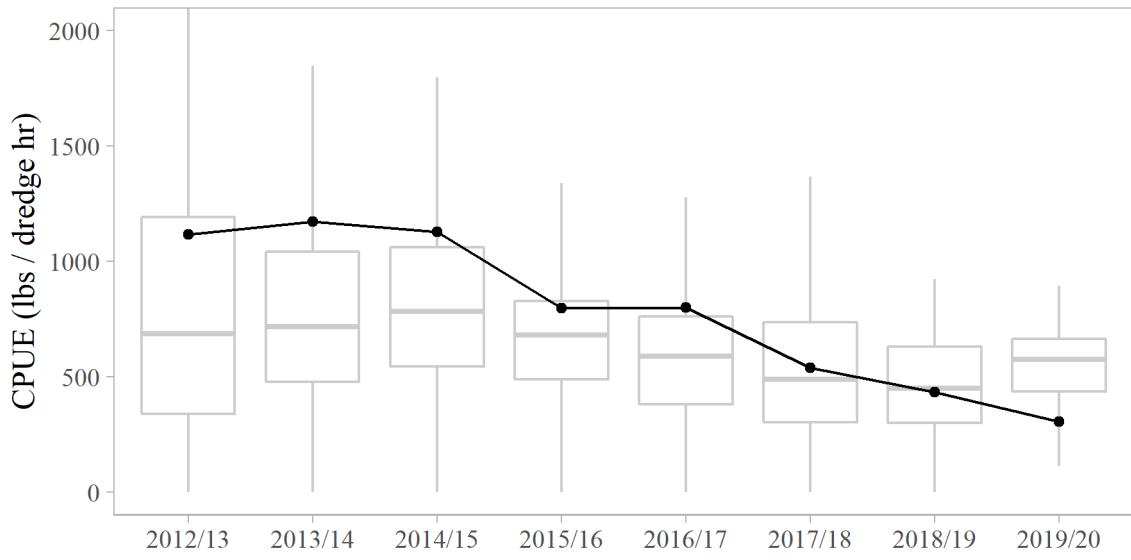


Figure 60: Boxplots of nominal CPUE (round lbs / dredge hr) overlaid with standardized CPUE (round lbs / dredge hr) by season (black line) (top) and standardized CPUE by bed and season (bottom) within the M district.

5.2 Fishery discards

Estimated scallop discards during the 2019/20 season were 25,917 round weight lbs (84,153 scallops) in the UB district (Table 19, Figure 61). The most recent fishing effort in the C district (2018/19 season) saw no retained catch, and 139 round weight lbs of discards (450 scallops) (Table 20). Discard ratio (lbs discarded:lbs retained) in the UB district continued an increasing trend since the 2015/16 season to > 0.4 lbs discards per pound of retained scallops (i.e., close to a 1:2 ratio) in the 2019/20 season (Table 19, Figure 62). The rate of clapper catch nearly tripled from the 2018/19 season (Tables 21 - 22, Figure 63). Intact scallops outweighed broken scallops in all hauls (Figure 64)

Table 19: UB district discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), and associated discard rates (lbs or count per dredge hr).

Season	Retained (lbs)	Discarded (lbs)	Discarded (count)	Discard ratio	Discard rate (lbs)	Discard rate (count)	Discard mortality (lbs)	Discard mortality (count)
2012/13	217,607	26,559	21,423	0.12	104	84	5,312	4,285
2013/14	193,106	16,929	24,347	0.09	68	98	3,386	4,869
2014/15	227,369	19,235	23,455	0.08	67	81	3,847	4,691
2015/16	207,991	9,108	4,393	0.04	30	15	1,822	879
2016/17	202,806	10,698	7,647	0.05	31	23	2,140	1,529
2017/18	181,646	23,457	31,693	0.13	72	97	4,691	6,339
2018/19	119,458	38,278	75,744	0.32	147	291	7,656	15,149
2019/20	63,937	25,917	84,153	0.41	220	713	5,183	16,831

Table 20: C district discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), and associated discard rates (lbs or count per dredge hr). Discard ratio was not computed for seasons with no retained catch.

Season	Retained (lbs)	Discarded (lbs)	Discarded (count)	Discard ratio	Discard rate (lbs)	Discard rate (count)	Discard mortality (lbs)	Discard mortality (count)
2014/15	0	9	14		2	3	2	3
2015/16	0	0	0		0	0	0	0
2016/17	0	49	161		9	29	10	32
2018/19	0	139	450		38	123	28	90

Table 21: UB district clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	Clappers	
		(rate)	(count)
2012/13	255	18.74	4,781
2013/14	247	17.38	4,299
2014/15	288	28.12	8,100
2015/16	302	9.41	2,839
2016/17	340	11.35	3,858
2017/18	328	13.90	4,554
2018/19	260	13.99	3,644
2019/20	118	36.72	4,333

Table 22: C district clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	(rate)	Clappers (count)
2014/15	6	0.00	0
2015/16	6	0.00	0
2016/17	5	6.83	37
2018/19	4	0.00	0

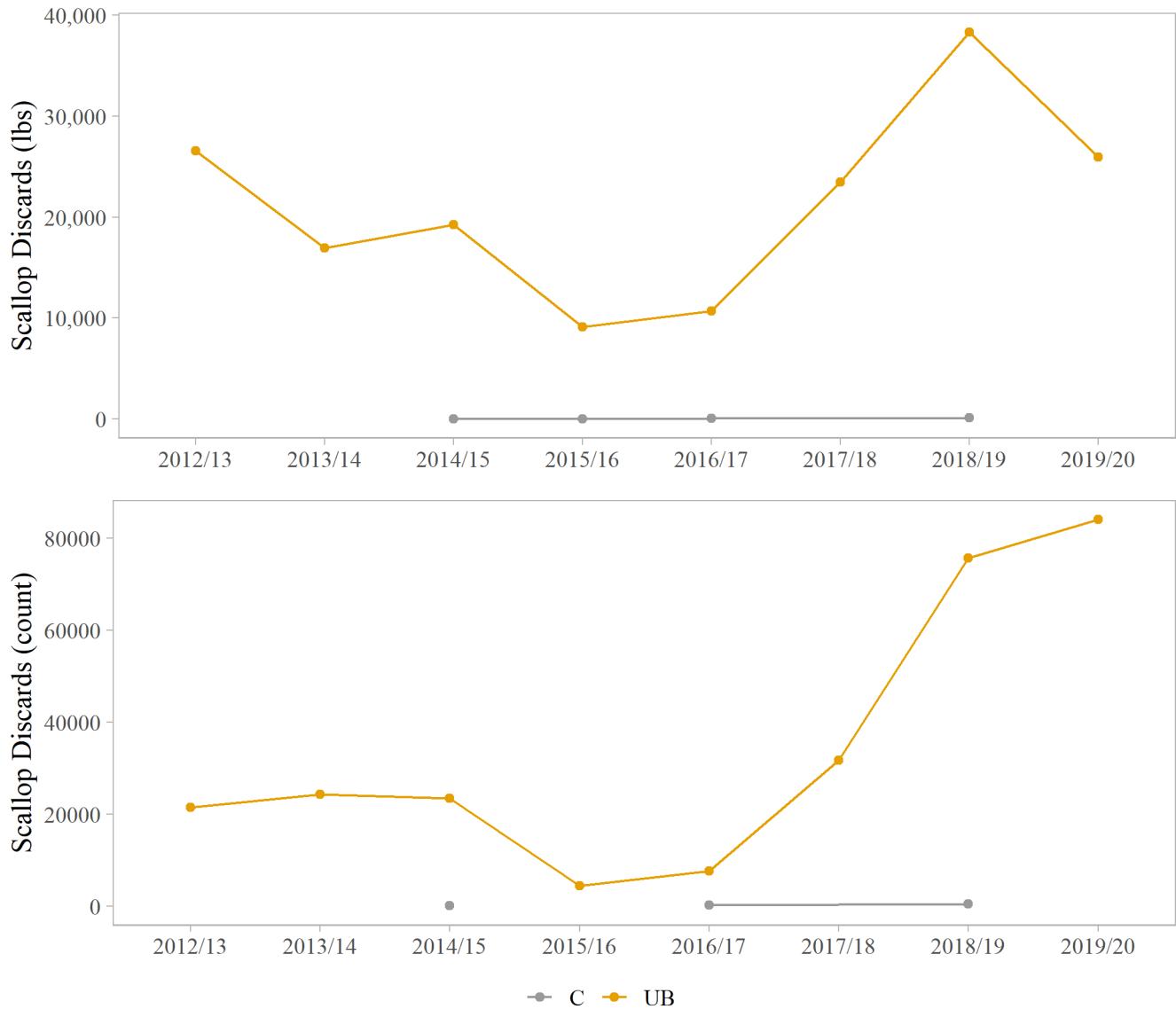


Figure 61: Total discarded scallops as round weight (top) and number of count (bottom) for each district by season.

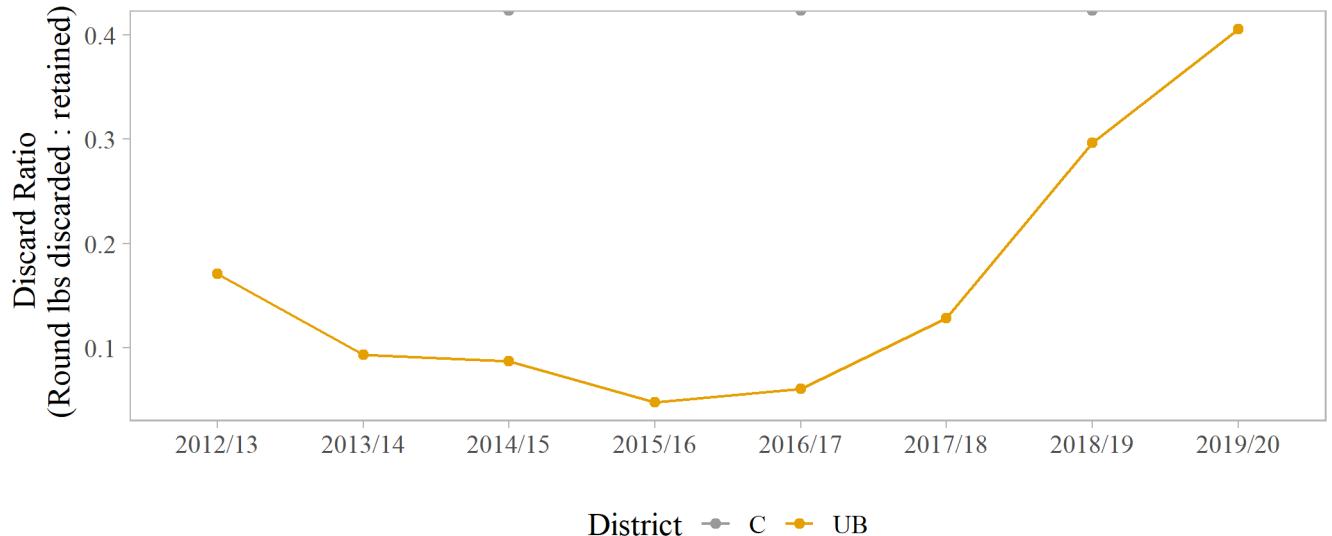


Figure 62: Scallop discard ratio (round weight discarded : retained) for each district by season.

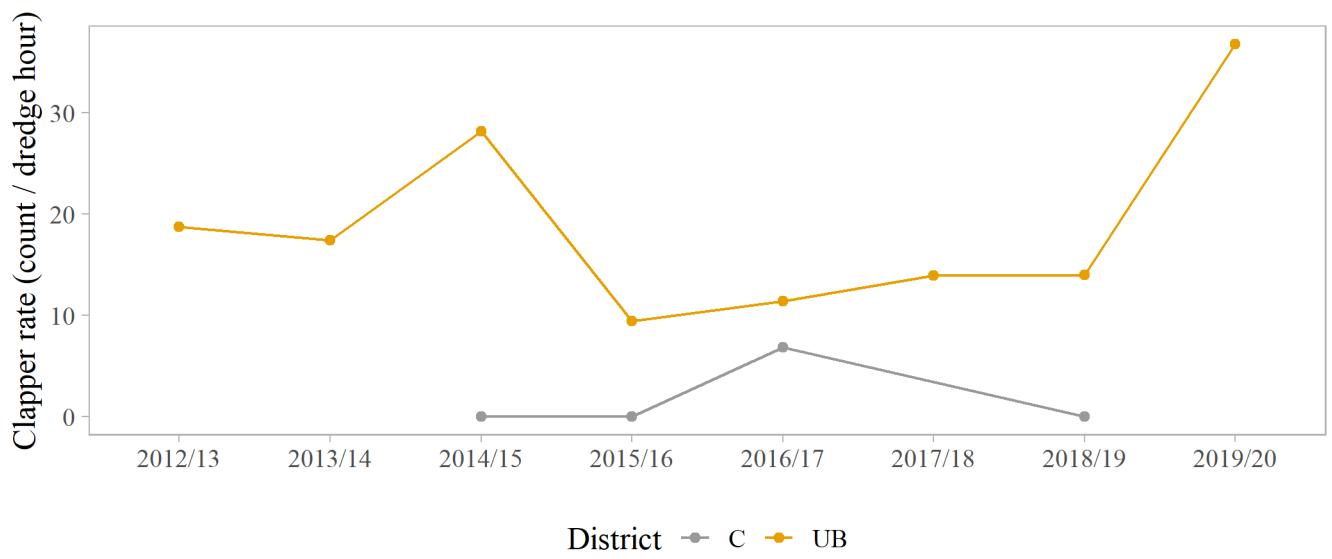


Figure 63: Rate of clapper catch for each district by season in area M.

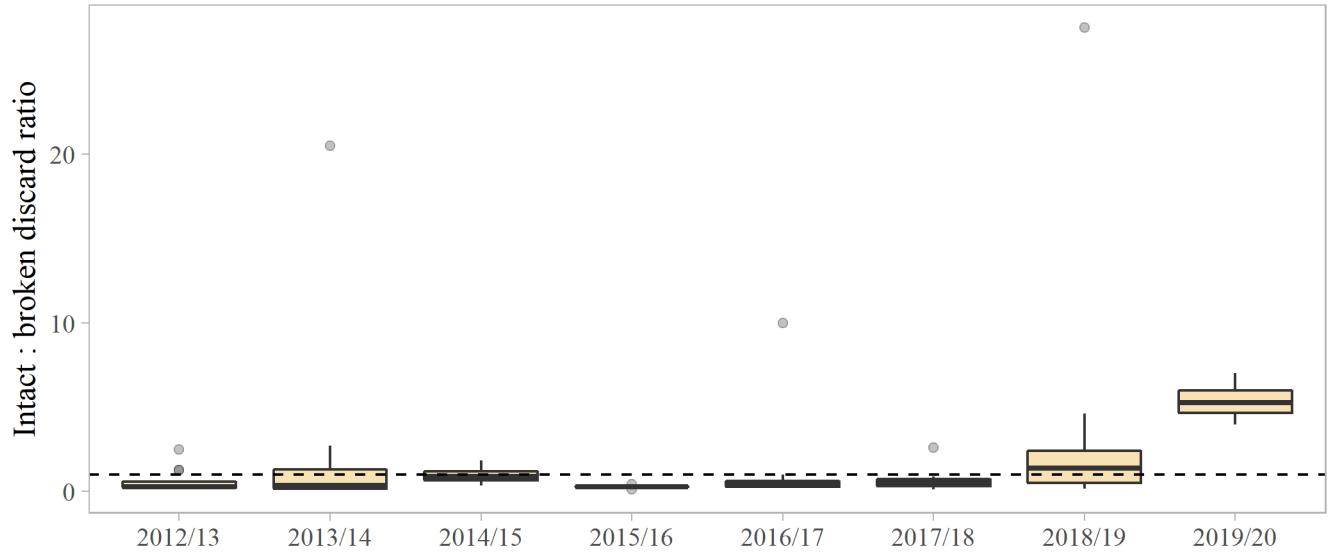


Figure 64: Boxplots of the ratio between intact and broken scallop discards in every haul within area M. The dotted line represents a 1:1 ratio.

5.3 Fishery bycatch

Area M utilizes CBLs for Tanner crab and red king crab. During the 2019/20 season, the Tanner crab CBL was 3,750 crab in both UB district and waters waters between 160°W - 161°W longitude (Table 23). The red king crab CBL for both districts was 25 crab.

Bycatch of Tanner crab and Pacific halibut increased markedly from the 2018/19 season, and no red king crab or Dungeness crab were caught (Table 23, Figure 65 - 66). Four snow crab (3 female, 1 male, < 55 mm) were caught in observer sampled dredges in two consecutive days, though bycatch expansion estimates likely overinflate this occurrence. Bycatch of snow crab in the UB district is certainly odd, but not unfeasible given the proximity of the UB district to the Bering Sea. Species identification was not confirmed by photo, and it is worth noting that sampling protocols do not differentiate between snow crab and snow-Tanner crab hybrids. Tanner crab bycatch exceeded the CBL during the second day (October 5, 2019) of fishing, and the fishery was subsequently closed by emergency order after achieving only 75% of the GHL (Table 23, Figure 67). Crab bycatch (both Tanner and potential snow crab) included mostly small, immature crab, predominately under 50 mm (Figure 68).

Table 23: UB bycatch summary including total number caught for each species. No Dungeness crab or red king crab have been caught in any season since the fishery reopened in the 2012/13.

Season	Scallop GHL	Tanner crab CBL	Tanner crab (total)	Tanner crab (ratio)	Snow crab (total)	Snow crab (ratio)	Pacific halibut (total)	Pacific halibut (ratio)
2012/13	15,000	12,000	8,045	0.53	0	0.00	71	0.00
2013/14	15,000	12,000	3,312	0.22	0	0.00	17	0.00
2014/15	15,000	12,000	14,065	0.94	0	0.00	52	0.00
2015/16	15,000	12,000	6,397	0.43	0	0.00	43	0.00
2016/17	15,000	12,000	4,017	0.27	0	0.00	50	0.00
2017/18	15,000	12,000	5,053	0.33	0	0.00	44	0.00
2018/19	15,000	7,500	4,049	0.45	0	0.00	0	0.00
2019/20	7,500	3,750	10,415	1.81	46	0.01	91	0.02



Figure 65: Total bycatch of Tanner crab, snow crab, and Pacific halibut by fishing season within the UB district.

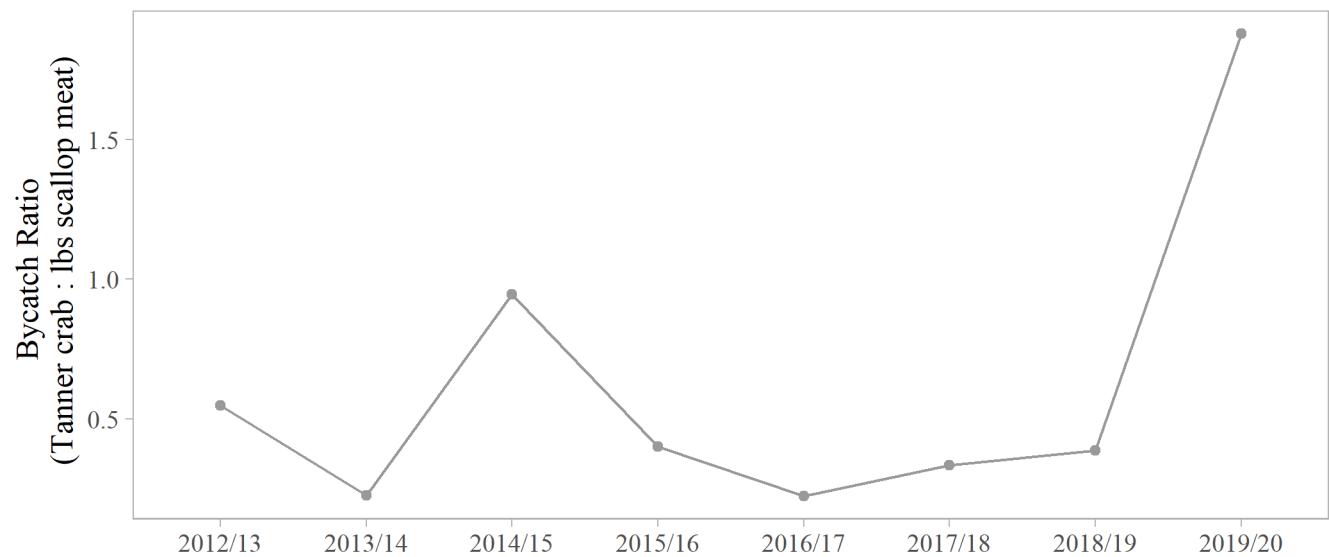


Figure 66: Bycatch ratio, expressed as number of Tanner crab per pound of scallop meat weight, by year and district within the UB district

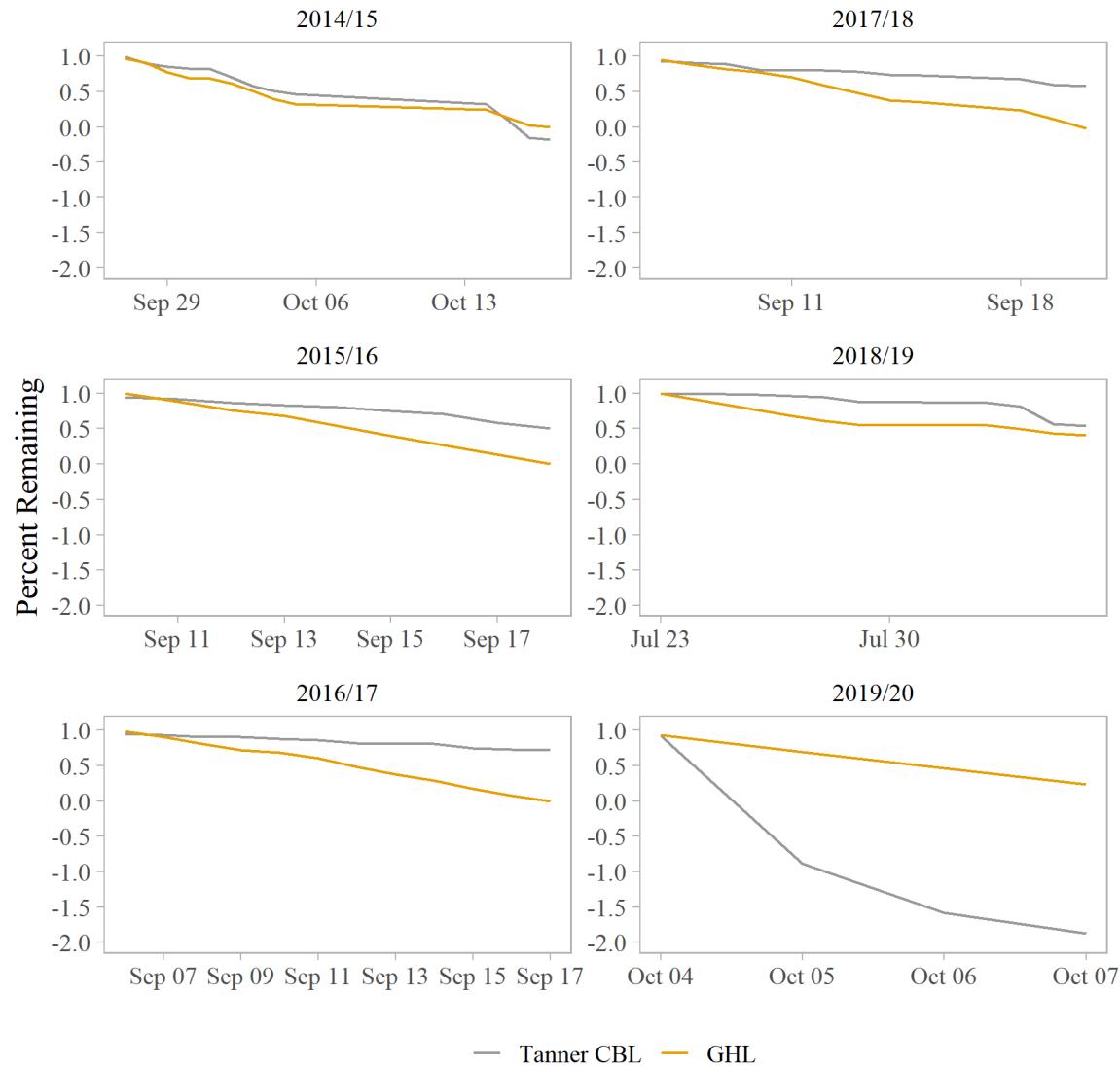


Figure 67: Percent reduction in scallop GHL and Tanner crab CBL throughout recent seasons within the UB district.

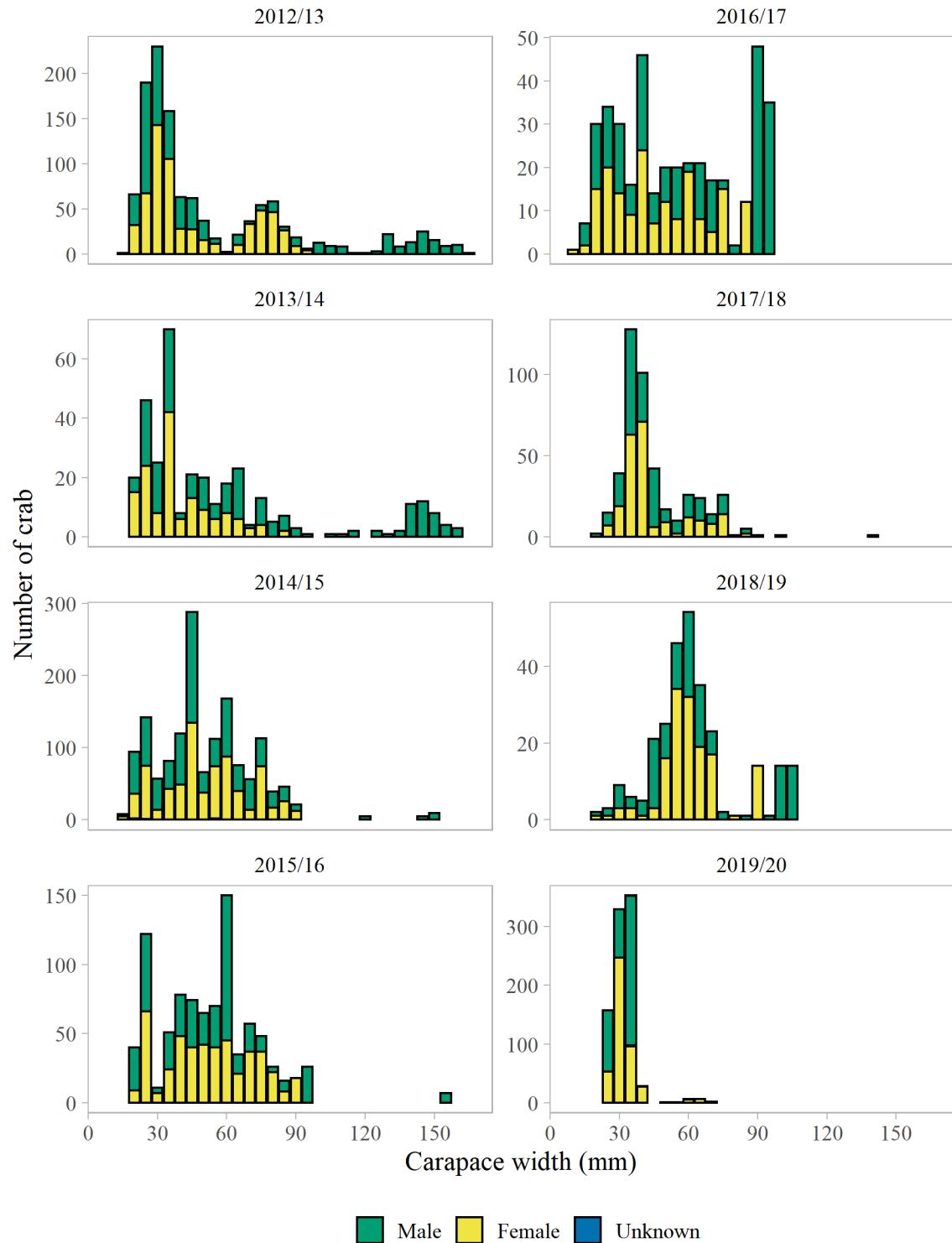


Figure 68: Size frequency histogram of the number of Tanner crab caught by sex during each season in the UB district. Includes four potential snow crab.

5.4 Fishery biological information

Shell height composition of catch in area M (i.e., the UB district) indicated two potential strong cohorts which overlap in shell size. Retained scallops were between $\sim 115 - 160$ mm, and discarded scallops were mostly > 100 mm (Figure 69). Though data from the 2019/20 season were limited, there was no visible difference in the meat weight \sim shell height relationship between seasons (Table 24, Figure 70).

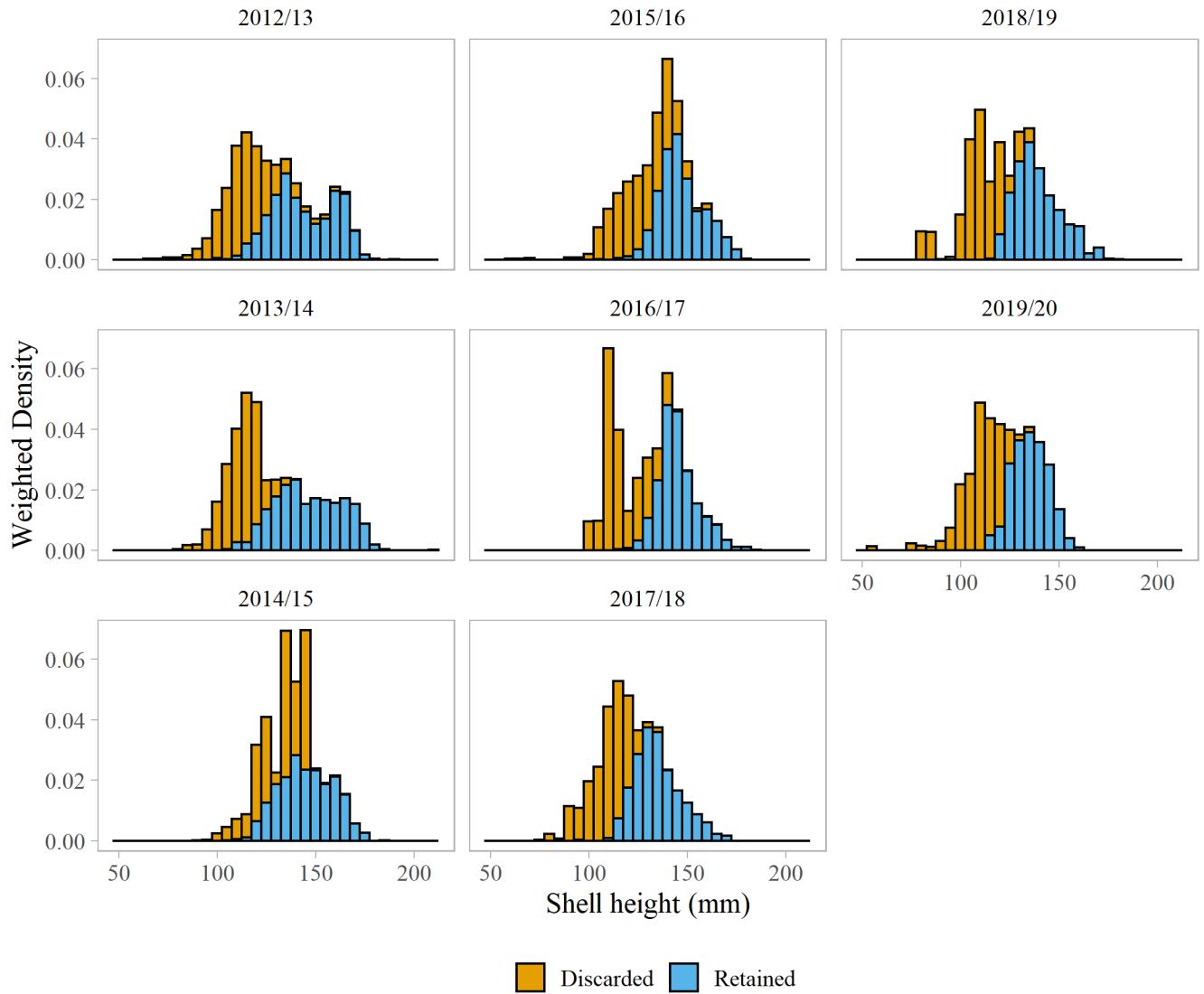


Figure 69: Shell height composition of scallops caught within area M in 5mm bins expressed as a weighted probability density function.

Table 24: Allometric growth parameters characterizing the meat weight, shell height relationship in area M by season.

Season	α	β
All	1.52e-05	2.879

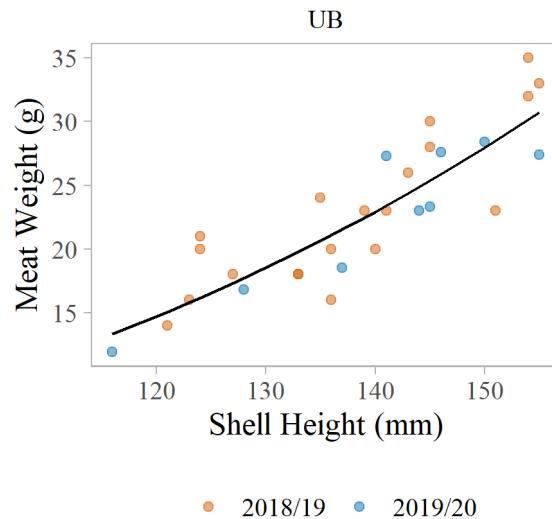


Figure 70: Individual meat weight (g) as a function of shell height (mm) for scallops caught in area M during the 2018/19 and 2019/20 seasons.

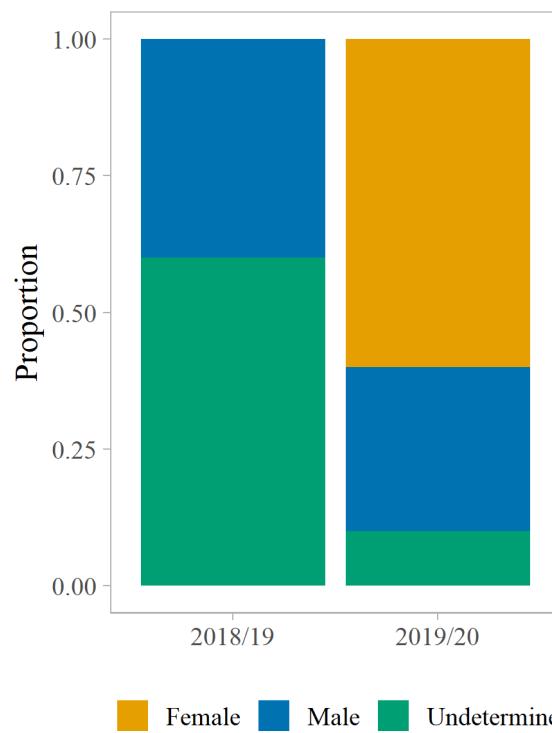


Figure 71: Proportion by sex in area M.

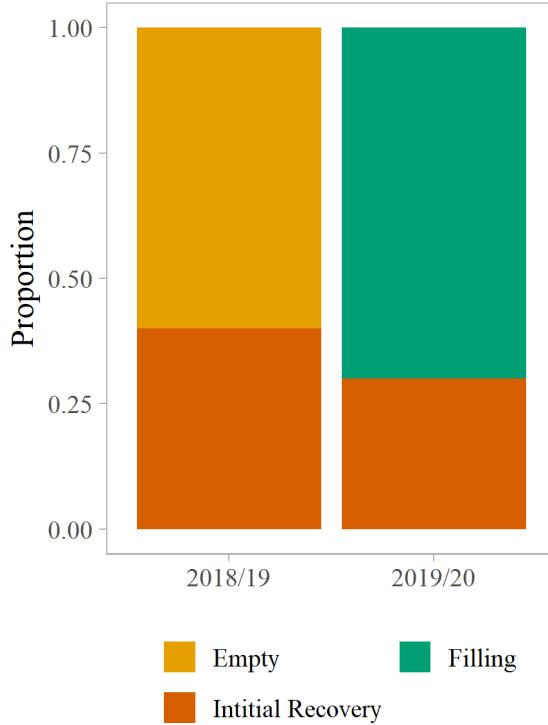


Figure 72: Proportion by gonad condition in area M.

5.5 Fishery independent information

5.5.1 Trawl survey

In 2019, the trawl survey completed 137 hauls within area M (Figure 73). Since scallop catch across the management area is low, C and WC districts were summarized together. The trawl survey does not include any stations in the UB district.

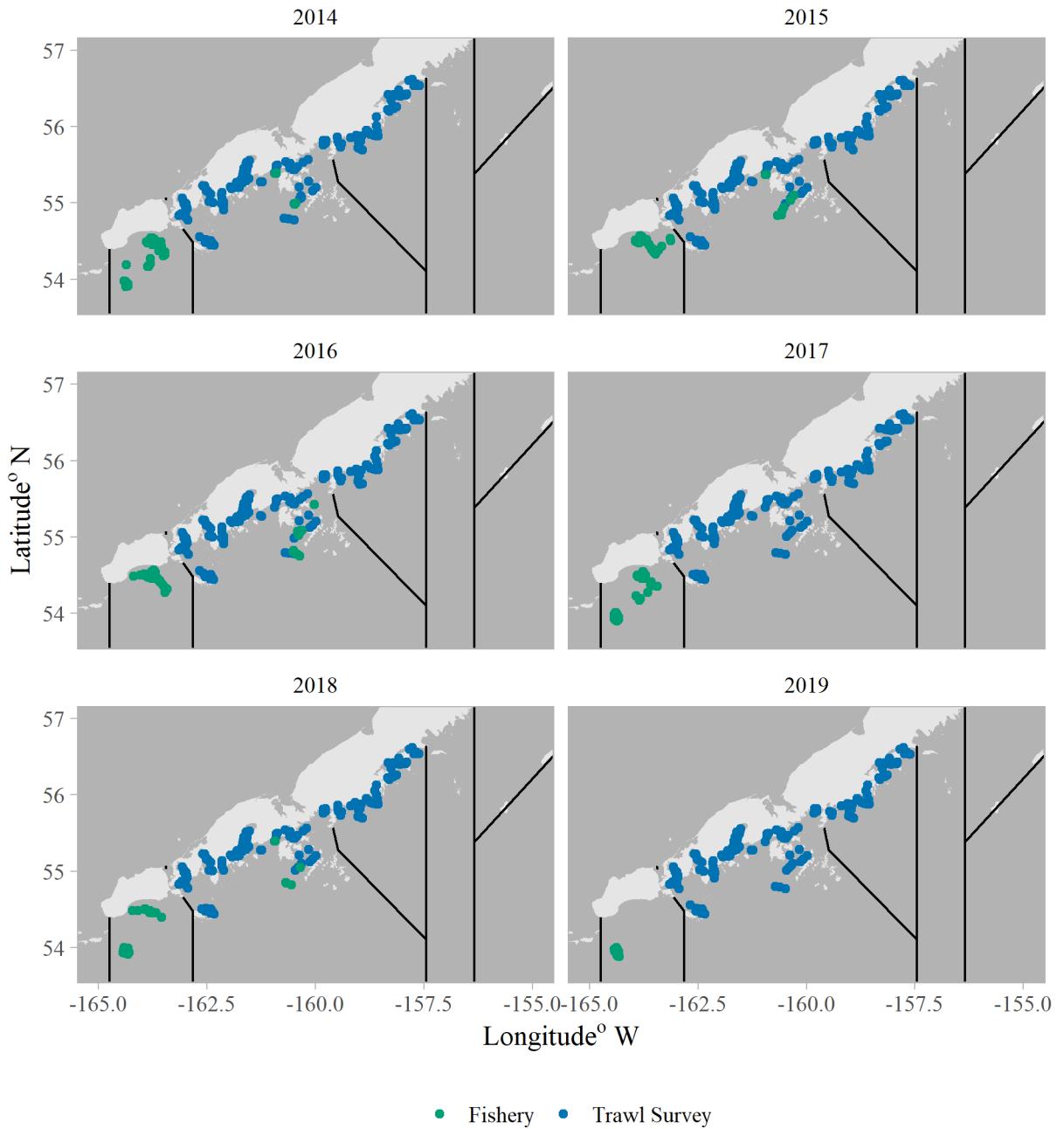


Figure 73: Trawl survey haul locations (blue) in comparison to the location of fishing effort (green) in area M from 2015 - 2019.

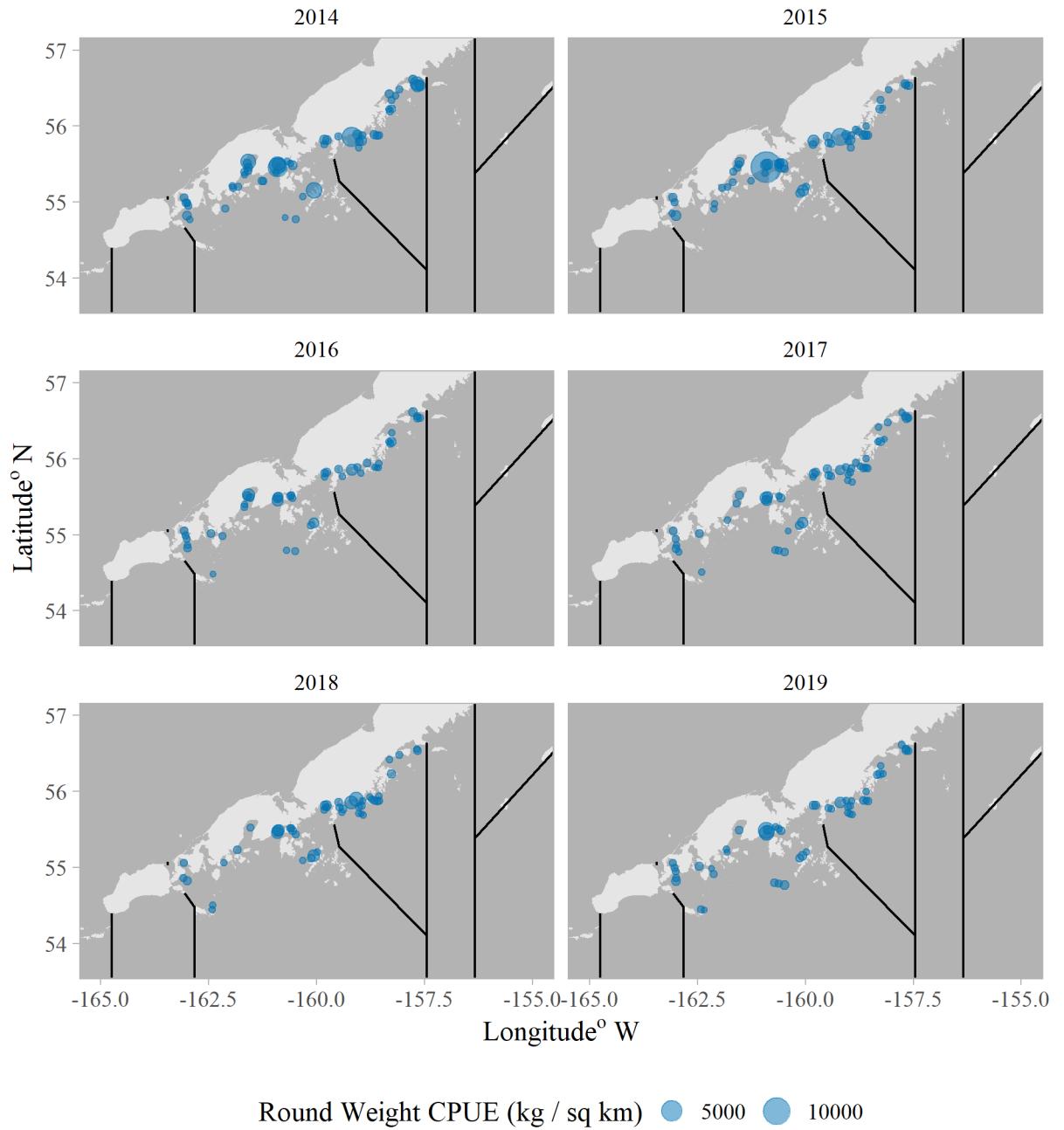


Figure 74: Trawl survey CPUE (kg / sq nm).

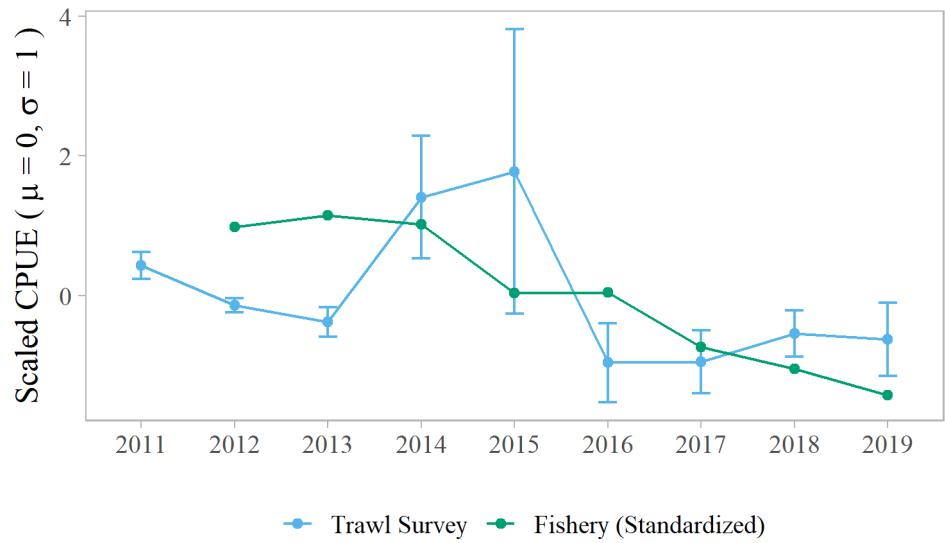


Figure 75: Trawl survey CPUE (+/- 95% confidence interval) (blue) in comparison to standardized fishery CPUE within area M. Both indices are scaled to a standard normal distribution to compare trends.

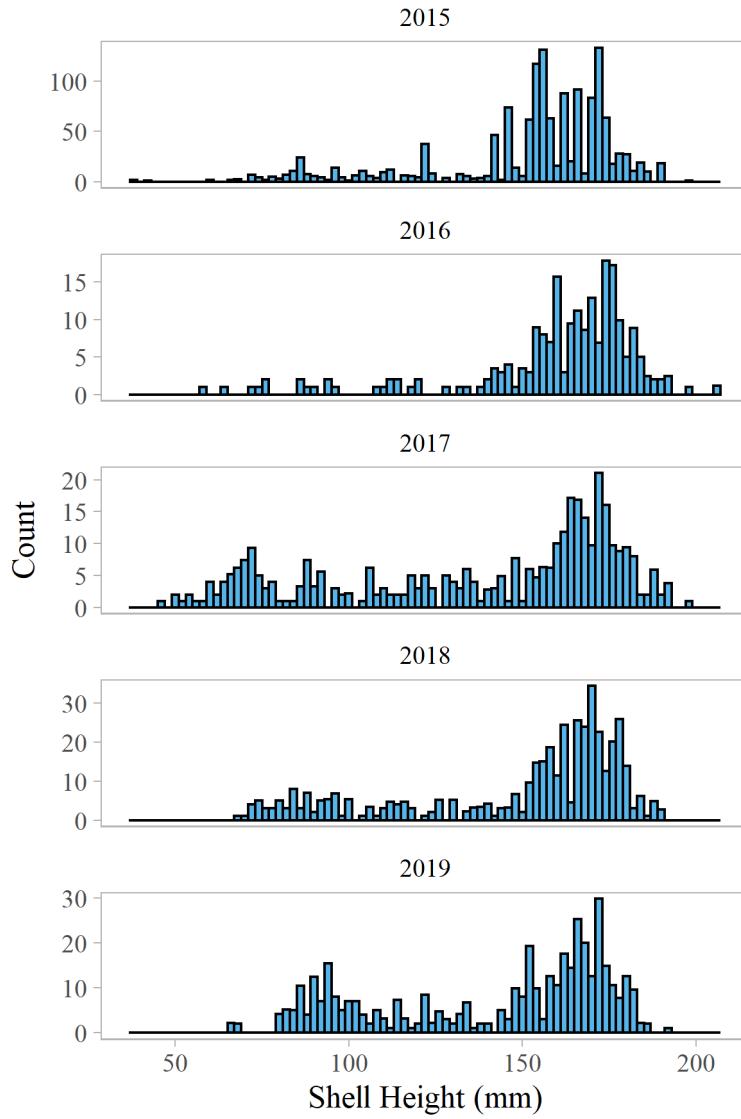


Figure 76: Size composition of scallops caught in the trawl survey from 2015 to 2019 in area M

6 Dutch Harbor Registration Area (O)

The Dutch Harbor registration area (O) consists of a single district, but is managed on the basis of beds, one on the Bering Sea side and one on the Pacific Ocean side of Unalaska Island. During the 2019/20 season, the Pacific Ocean side was closed and the Bering Sea side was fished within a monitoring GHL of 5,000 lbs. During the 2018/19 season the observer did not collect an average whole basket weight, and thus retained round weight could not be extrapolated from the catch with empirical data from that season. Instead, the average basket weight from 2009/10 - 2017/18 (54.1 lbs) was used to estimate retained round weight. Area O has never been included in the dredge survey, though several trawl survey stations within area O are sampled on an annual basis.

6.1 Fishery performance

The 2019/20 Dutch Harbor District scallop fishery opened on July 1, 2019 with a GHL of 5,000 lbs of scallop meats on the Bering Sea side of Unalaska Island. One vessel participated in the fishery harvesting 2,625 lbs scallop meat with a nominal CPUE of 20.1 lbs meat/dredge hour. Total round weight of retained scallops was 24,739 lbs with a nominal CPUE of 189 lbs/dredge hour (Table 25). As during the 2018/19 season, fishing effort was restricted to a single bay on the north side of Unmak Island (Figure 77). Despite geographically restricted effort, the spatial extent of 90% of the retained catch was similar to years with more widespread effort (Figure 78). Round weight CPUE increased from the 2018/19 season, though the long-term trend since the 2013/14 season has been decreasing (Table 26, Figure 79 - 80).

Table 25: Area O catch summary. Meat and round weight CPUE represent nominal values.

Year	GHL	Retained catch (lb meat)	Round weight (lb round)	Dredge hours	Number hauls	Meat wt cpue ^a	Round wt cpue ^b
1993/94	170,000	38,731		838		46	
1994/95	170,000	1,931		81		24	
1995/96	170,000	26,950		1,047		26	
1996/97	170,000						
1997/98	170,000	5,790	55,350	160		36	345
1998/99	110,000	46,462	424,028	941		49	451
1999/00	110,000	6,465	66,420	278		23	268
2000/01	closed						
2001/02	closed						
2002/03	10,000	6,000	59,066	177		33	333
2003/04	closed						
2004/05	closed						
2005/06	closed						
2006/07	closed						
2007/08	closed						
2008/09	10,000	10,040	93,077	191		53	488
2009/10	10,000	6,080	54,882	104	77	59	528
2010/11	10,000	5,640	42,177	83	53	68	506
2011/12	10,000	5,570	45,513	77	60	73	593
2012/13	5,000	5,100	37,730	64	60	79	588
2013/14	5,000	5,225	44,572	56	28	94	798
2014/15	5,000	5,160	41,323	73	57	70	563
2015/16	10,000	5,040	45,215	157	97	32	288
2016/17	10,000	5,050	39,181	104	81	48	376
2017/18	10,000	285	2,250	24	18	12	93
2018/19	5,000	325	3,571	24	12	14	152
2019/20	5,000	2,625	24,739	131	65	20	189

^alb scallop meat/dredge hour

^blb scallop round/dredge hour

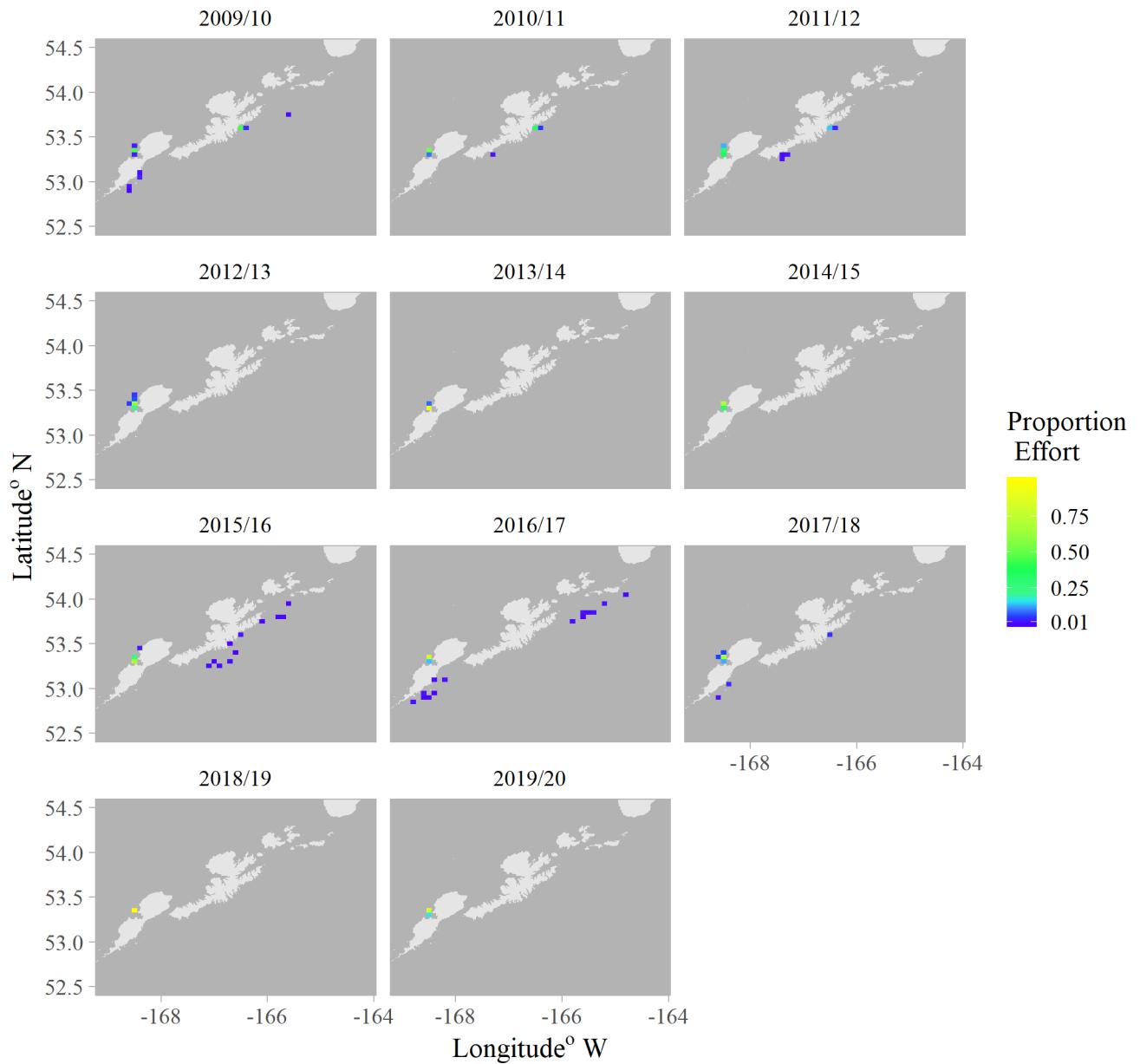


Figure 77: Heat map of fishing effort within area O. Warmer colors indicate areas accounting for a greater proportion of fishing effort.

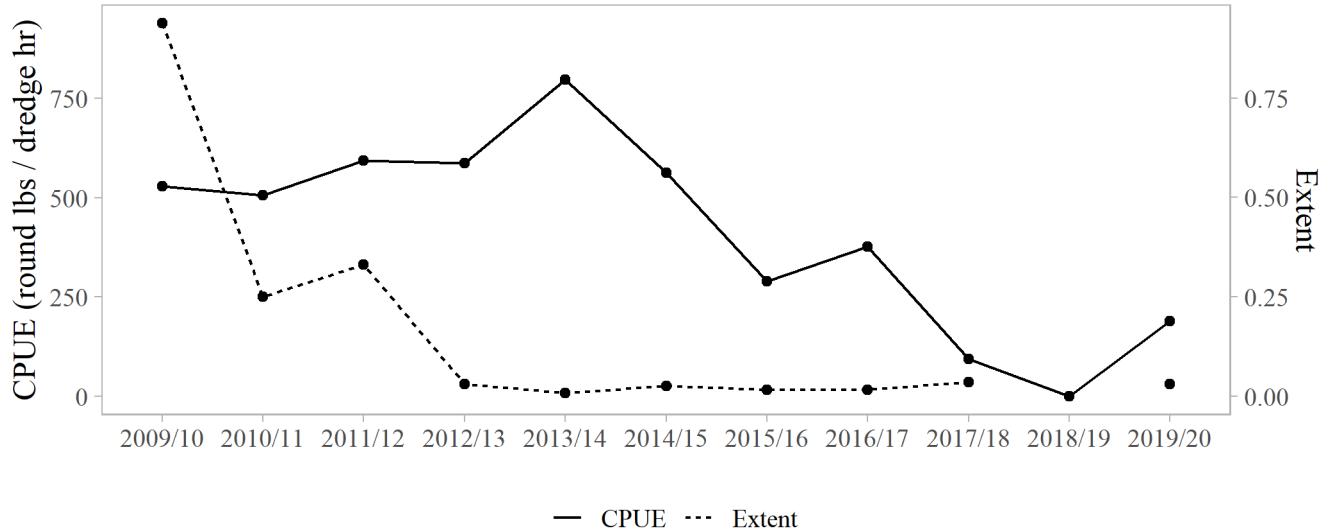


Figure 78: Nominal CPUE (round lbs / dredge hr) (solid line) and relative spatial extent of fishing effort (dotted line) within the UB district by season

Table 26: Area O nominal and standardized CPUE estimates (round lbs / dredge hour) by season.

Season	Nominal CPUE			Standardized CPUE
	(total)	(median)	(sd)	
2009/10	528.47	363.33	362.40	258.32
2010/11	505.53	475.33	345.33	665.99
2011/12	592.85	530.29	344.01	740.30
2012/13	587.79	622.20	367.23	646.48
2013/14	798.06	799.02	183.72	779.52
2014/15	563.21	541.60	164.75	580.06
2015/16	288.43	296.83	130.71	299.17
2016/17	376.16	388.27	217.42	453.16
2017/18	92.75	83.33	64.07	92.45
2018/19	151.94	171.32	69.15	166.60
2019/20	189.22	182.65	79.23	216.93

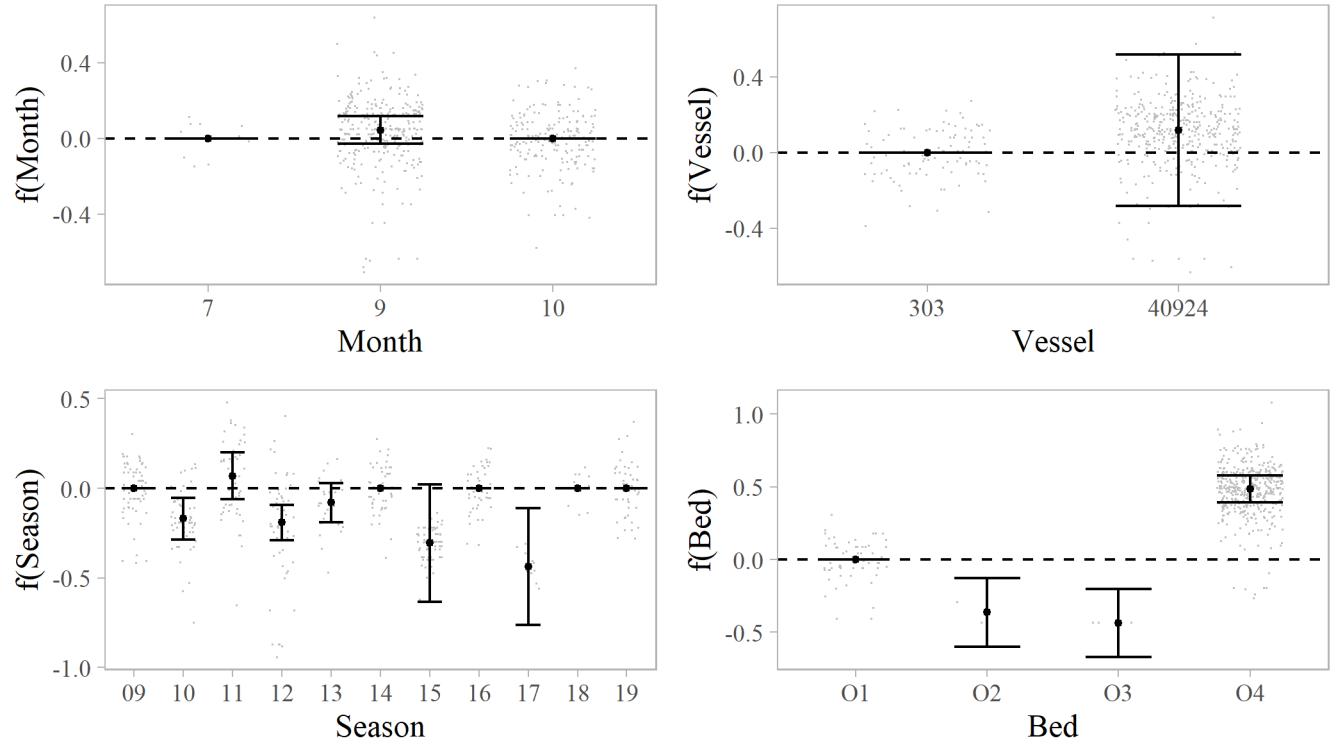


Figure 79: Partial effects of Month, Vessel, Season, and Bed on CPUE within area O. Season values represent the last two digits of the year the fishery opened.

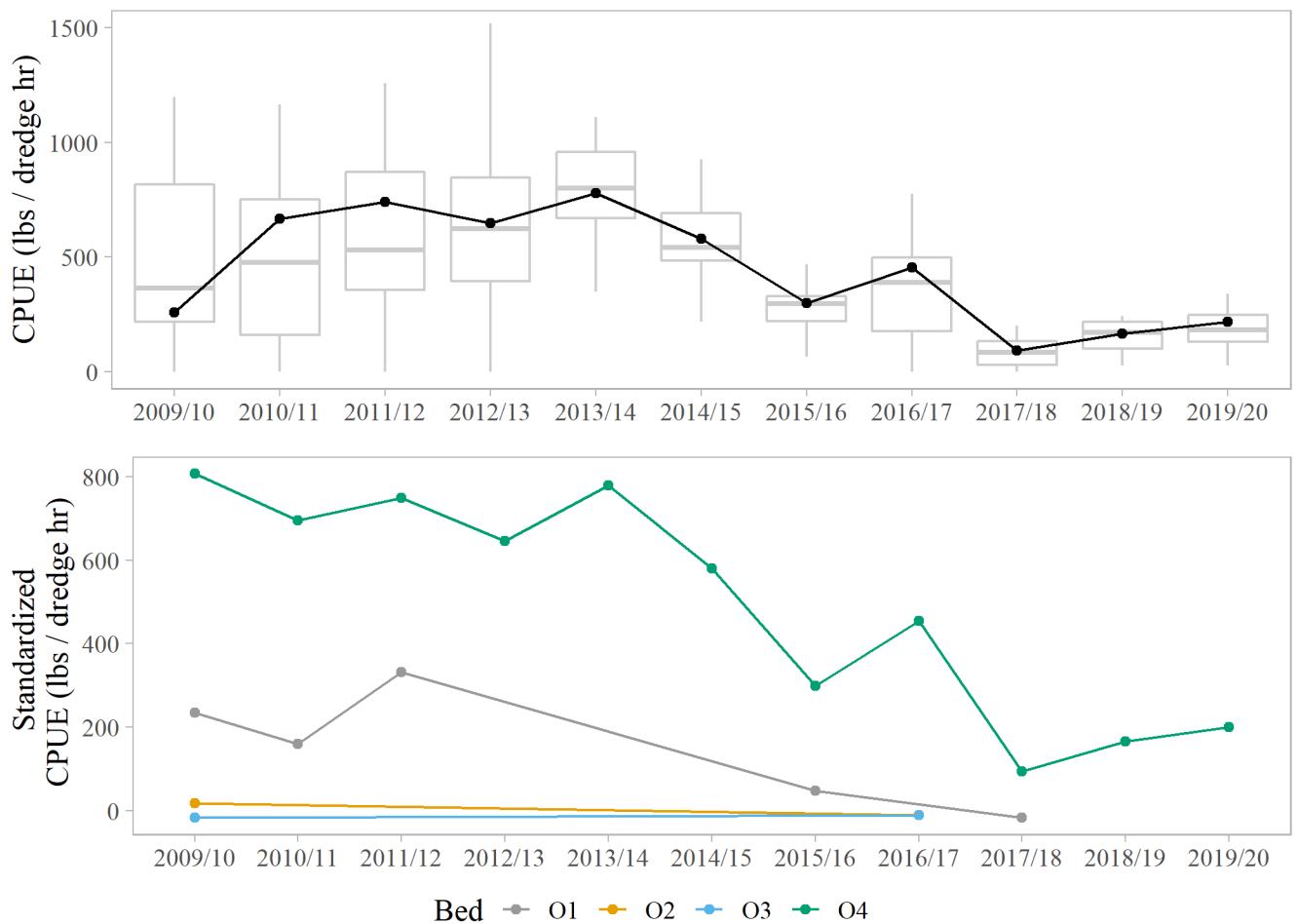


Figure 80: Boxplots of nominal CPUE (round lbs / dredge hr) overlaid with standardized CPUE (round lbs / dredge hr) by season (black line) (top) and standardized CPUE by bed and season (within area O) (bottom).

6.2 Fishery discards

Estimated scallop discards during the 2019/20 season were 3,199 round weight lbs (3,250 scallops) in area O (Table 27, Figure 81). Discard ratio (lbs discarded:lbs retained, 0.13) saw a substantial increase since the previous season with retained catch (2017/18) and was the highest observed value since the 2009/10 season (Table 27, Figure 82). The rate of clapper catch was comparable to the 2018/19 season (Tables 28, Figure 83). Intact discards outweighed broken discards in most hauls (Figure 84).

Table 27: Area O discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), associated discard rates (lbs or count per dredge hr), and estimated discard mortality.

Season	Retained (lbs)	Discarded (lbs)	Discarded (count)	Discard ratio	Discard rate (lbs)	Discard rate (count)	Discard mortality (lbs)	Discard mortality (count)
2009/10	54,882	2,082	823	0.04	20	8	416	165
2010/11	42,177	3,266	2,979	0.08	39	36	653	596
2011/12	45,513	2,567	2,586	0.06	33	34	513	517
2012/13	37,730	2,714	2,120	0.07	42	33	543	424
2013/14	44,572	4,434	2,004	0.10	79	36	887	401
2014/15	41,323	3,916	5,739	0.09	53	78	783	1,148
2015/16	45,215	3,447	2,384	0.08	22	15	689	477
2016/17	39,181	1,281	1,011	0.03	12	10	256	202
2017/18	2,250	31	0	0.01	1	0	6	0
2018/19	3,571	35	18	0.01	2	1	7	4
2019/20	24,739	3,199	3,250	0.13	24	25	640	650

Table 28: Area O clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	Clappers	
		(rate)	(count)
2009/10	104	2.48	257
2010/11	83	16.35	1,364
2011/12	77	18.22	1,399
2012/13	64	68.78	4,415
2013/14	56	42.69	2,385
2014/15	73	85.10	6,243
2015/16	157	6.17	967
2016/17	104	4.97	517
2017/18	24	3.15	77
2018/19	24	5.50	129
2019/20	131	4.35	569

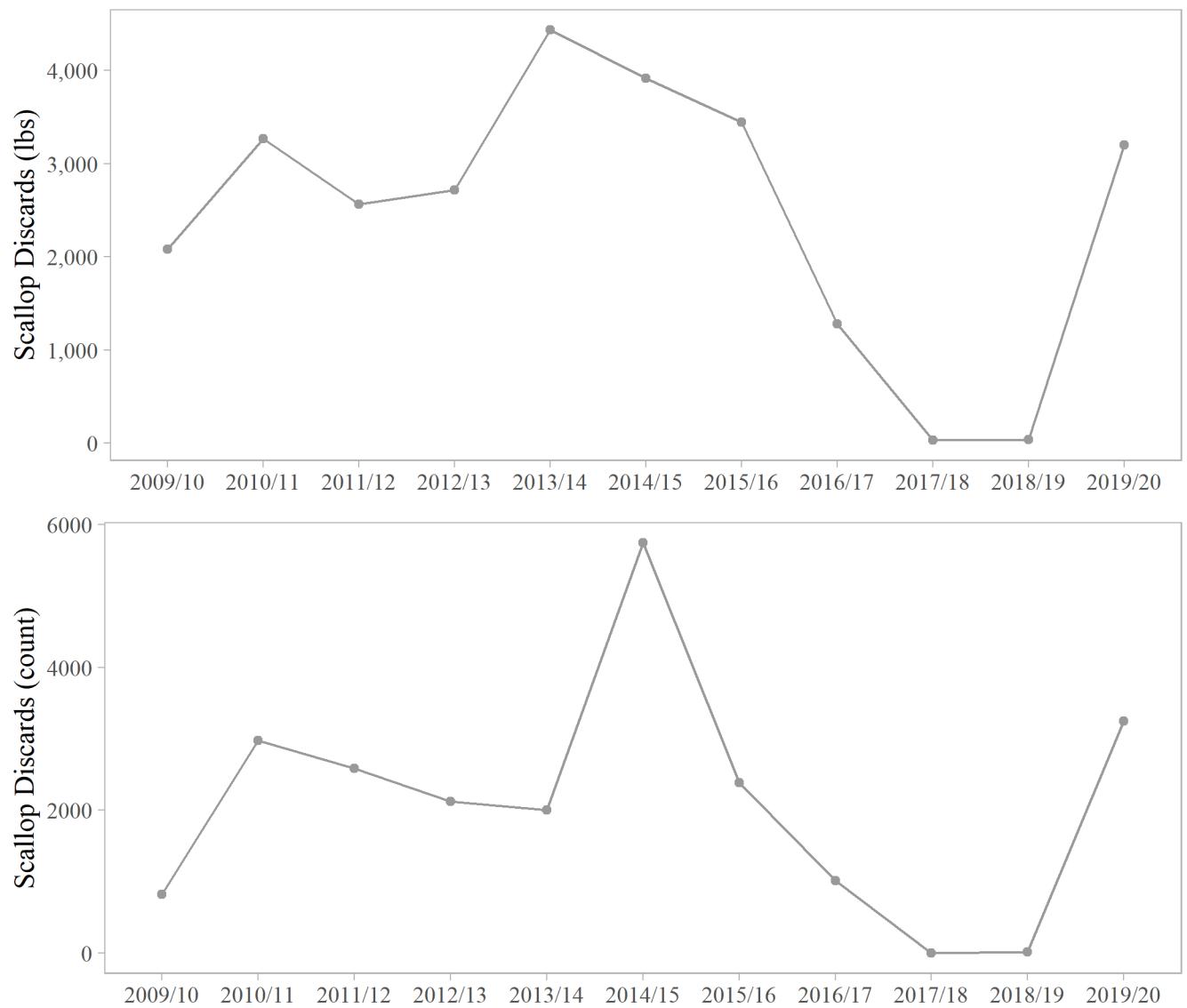


Figure 81: Total discarded scallops as round weight (top) and number of count (bottom) for each district by season.

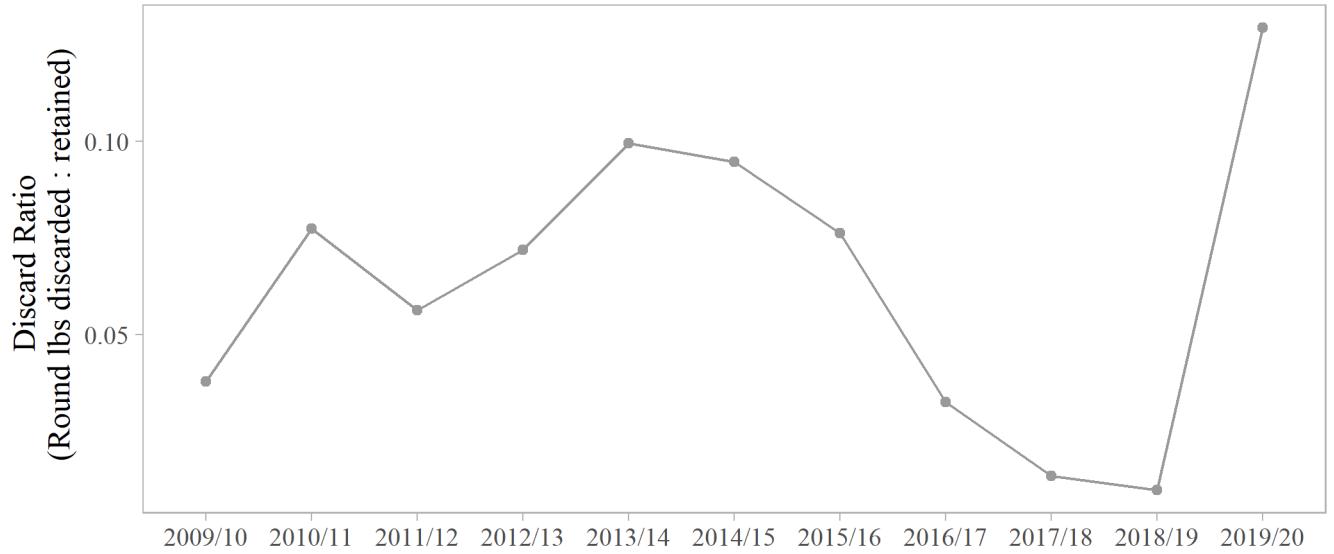


Figure 82: Scallop discard ratio (round weight discarded : retained) for each district by season.

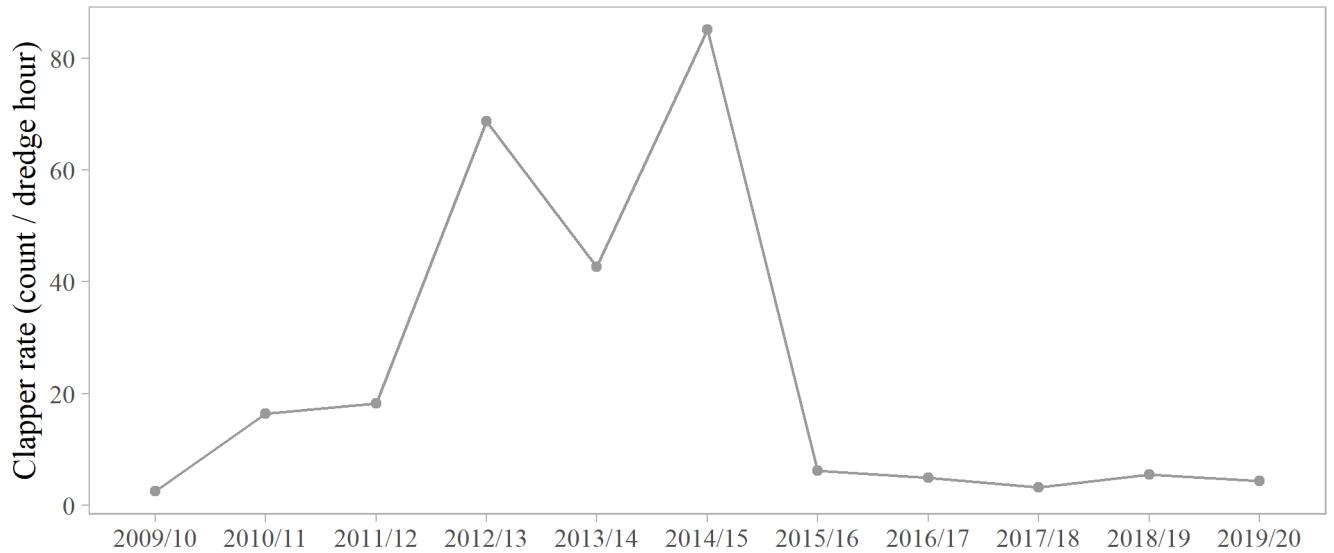


Figure 83: Rate of clapper catch by season in area O.

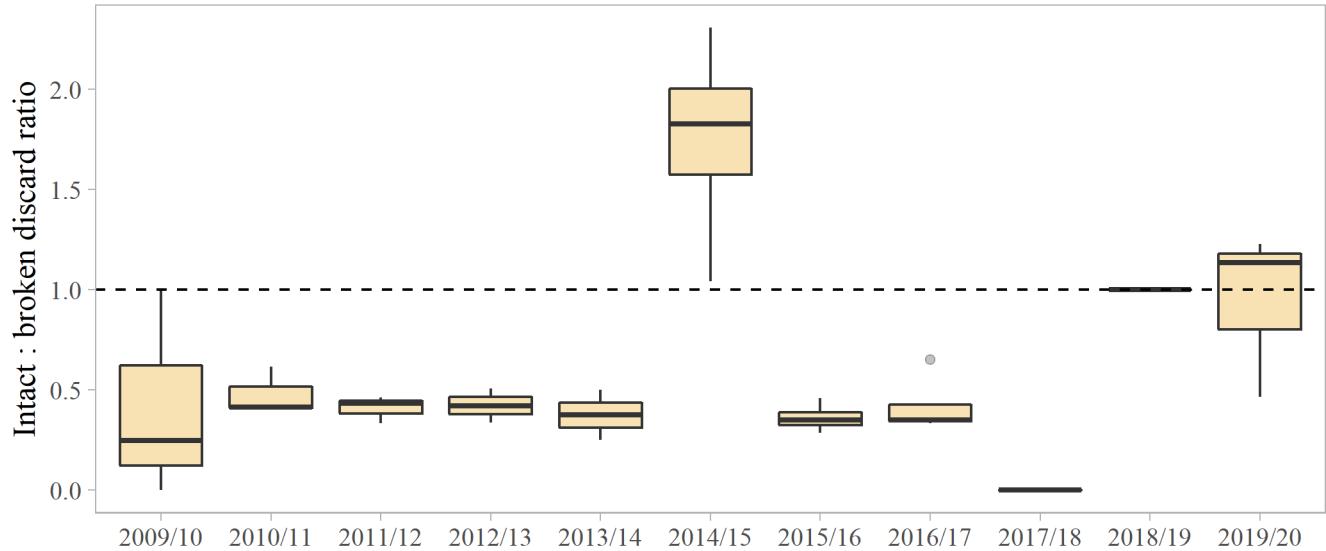


Figure 84: Boxplots of the ratio between intact and broken scallop discards in every haul within area O. The dotted line represents a 1:1 ratio.

6.3 Fishery bycatch

Area O utilizes CBLs for Tanner crab and red king crab. During the 2019/20 season, CBLs on the Pacific Ocean side of Unalaska Island were 5,000 Tanner crab and 10 red king crab (Table 29). Bycatch of Tanner crab increased from the 2018/19 season, though the ratio of Tanner crab caught to scallop meats retained decreased (Table 29, Figure 85 - 86). Bycatch of Pacific halibut decreased, and no red king crab or Dungeness crab were caught (Table 29, Figure 85). Progress towards achieving the GHL remained ahead the remaining Tanner crab CBL for the entire season (Figure 87). Tanner crab bycatch included mostly crab between 60 - 90 mm, and some smaller crab less than 50 mm (Figure 88).

Table 29: Area O bycatch summary including total number caught for each species.

Season	Scallop GHL	Tanner crab CBL	Tanner crab (total)	Tanner crab (ratio)	Red King crab (total)	Red King crab (ratio)	Dungeness crab (total)	Dungeness crab (ratio)	Pacific halibut (total)	Pacific halibut (ratio)
2009/10	10,000	10,000	26	0.00	0	0.00	0	0.00	0	0.00
2010/11	10,000	10,000	909	0.16	0	0.00	0	0.00	51	0.01
2011/12	10,000	10,000	617	0.11	0	0.00	0	0.00	16	0.00
2012/13	5,000	5,000	746	0.15	0	0.00	0	0.00	12	0.00
2013/14	5,000	5,000	1,206	0.23	0	0.00	0	0.00	18	0.00
2014/15	5,000	5,000	1,037	0.20	0	0.00	0	0.00	0	0.00
2015/16	10,000	10,000	326	0.06	0	0.00	10	0.00	0	0.00
2016/17	10,000	10,000	271	0.05	2	0.00	16	0.00	32	0.01
2017/18	10,000	10,000	8	0.03	0	0.00	0	0.00	0	0.00
2018/19	5,000	5,000	306	0.94	0	0.00	0	0.00	12	0.04
2019/20	5,000	5,000	885	0.34	0	0.00	0	0.00	0	0.00

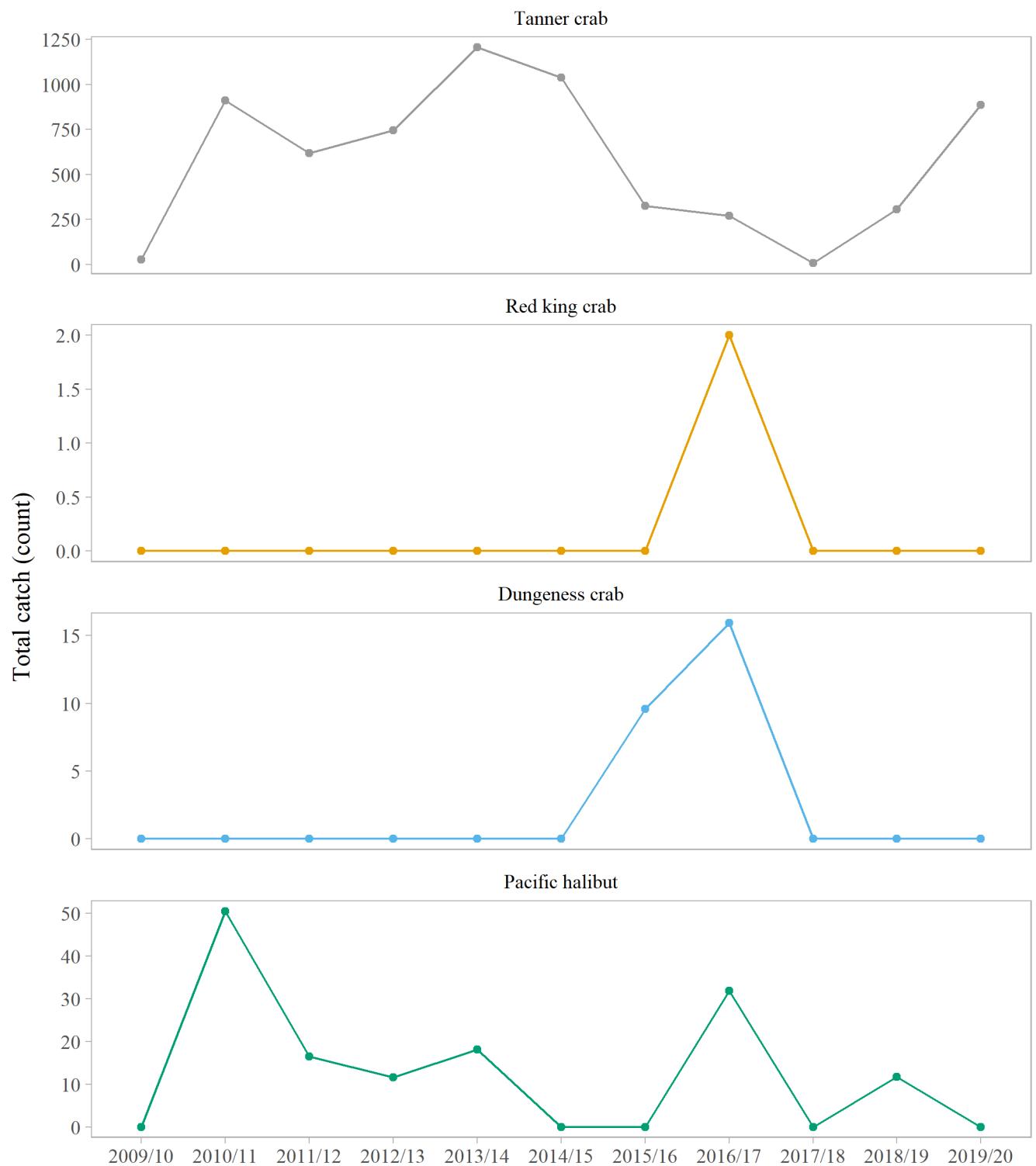


Figure 85: Total bycatch of Tanner crab, red king crab, Dungeness crab, and Pacific halibut by fishing season within area O.

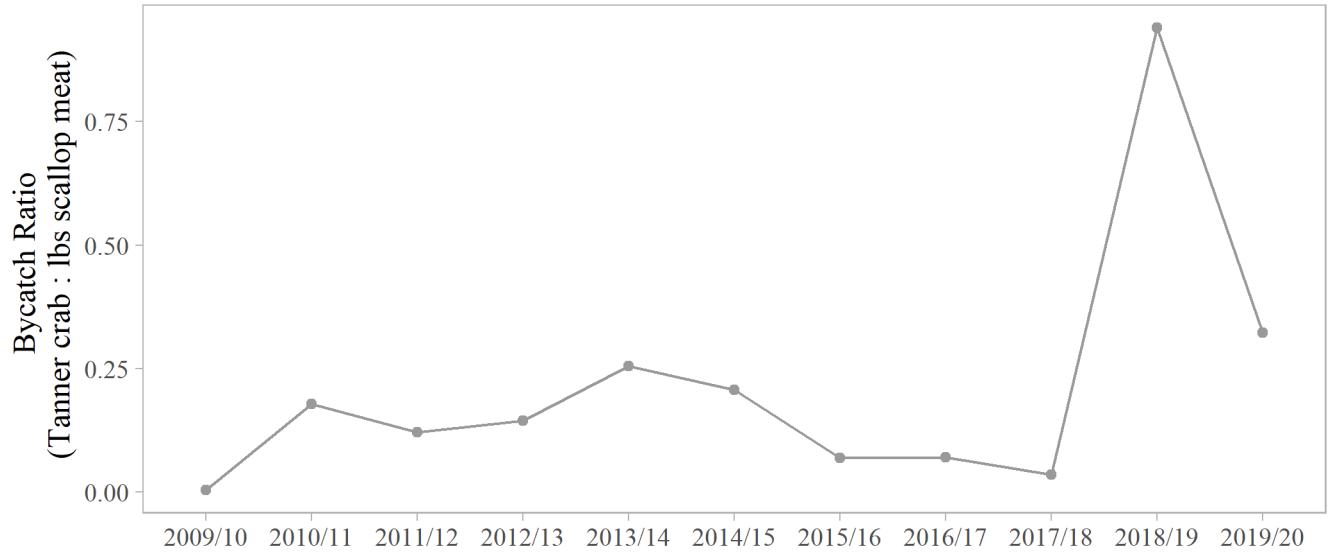


Figure 86: Bycatch ratio, expressed as number of Tanner crab per pound of scallop meat weight, by year and district within area O



Figure 87: Percent reduction in scallop GHL and Tanner crab CBL throughout recent seasons within area O. Area O was only fished a single day during the 2018/19 season.

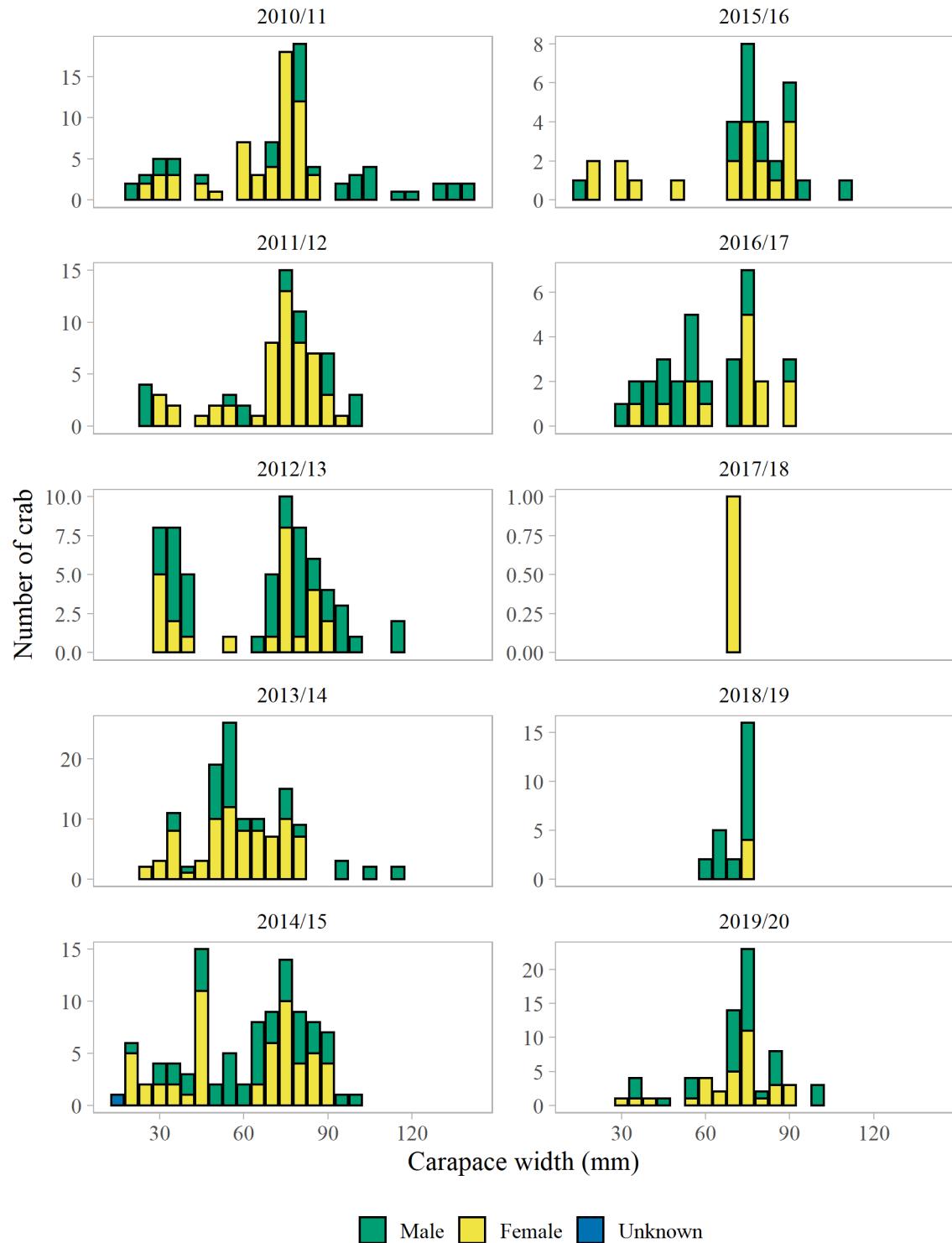


Figure 88: Size frequency histogram of the number of Tanner crab caught by sex during each season in area O.

6.4 Fishery biological information

Retained scallops in area O were all 150 mm shell height or larger, and nearly all discarded scallops were larger than 100 mm (Figure 89). Individual meat weight data was limited in both 2018/19 and 2019/20, but there doesn't appear to be any shift in the meat weight ~ shell height relationship between seasons (Table 30, Figure 90).

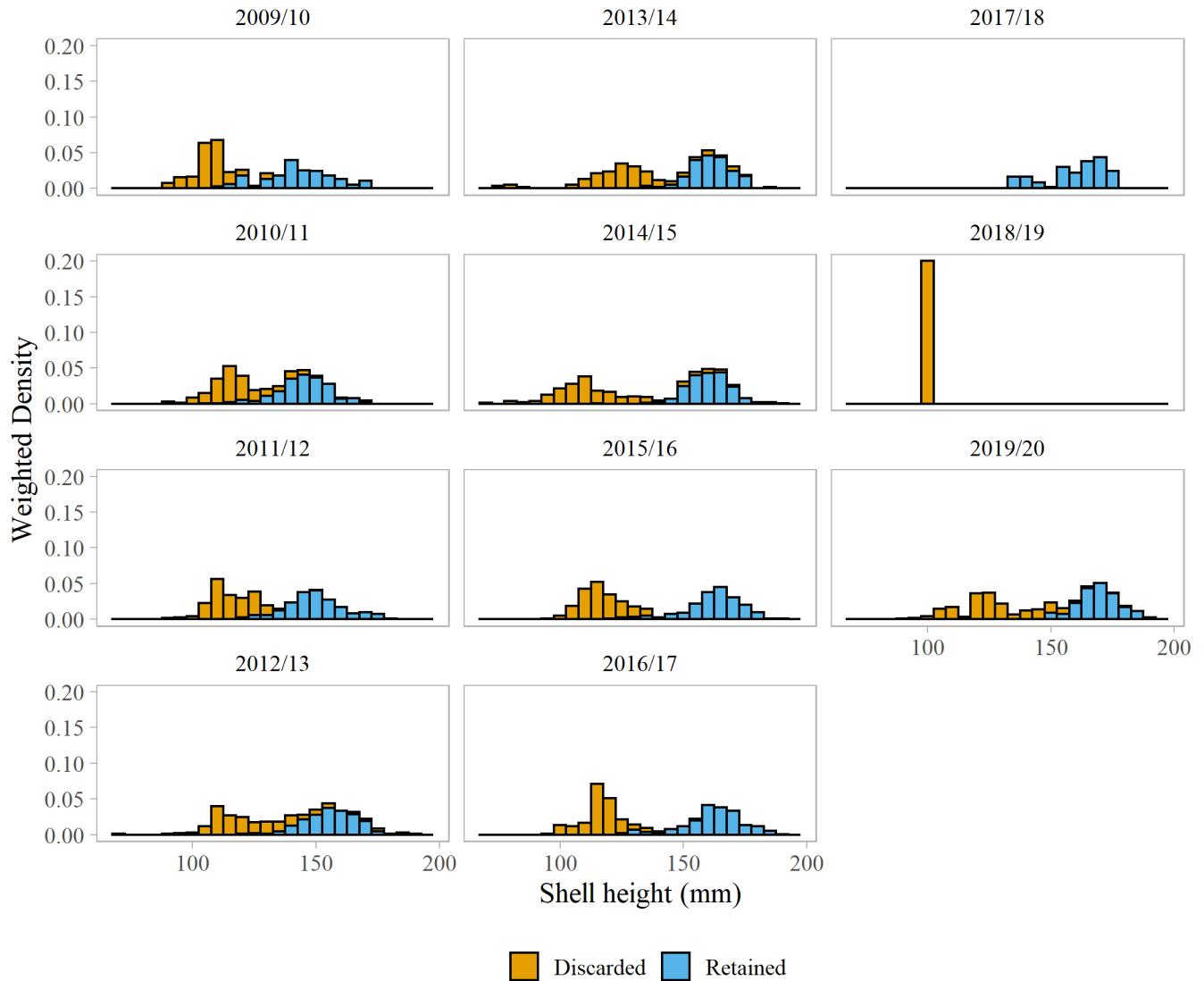


Figure 89: Shell height composition of scallops caught within area O in 5mm bins expressed as a weighted probability density function.

Table 30: Allometric growth parameters characterizing the meat weight, shell height relationship in area O by season.

Season	α	β
All	1.99e-08	4.227

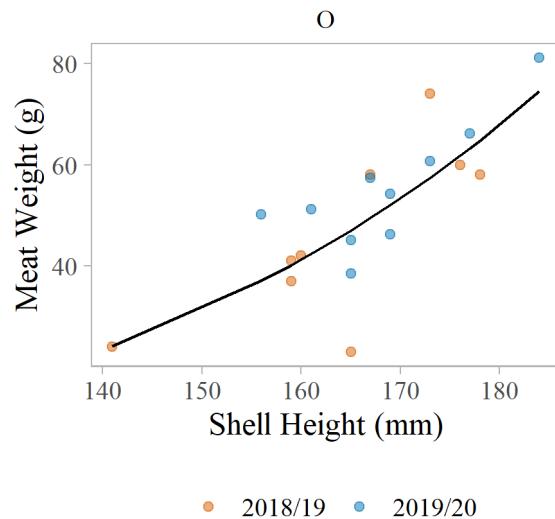


Figure 90: Individual meat weight (g) as a function of shell height (mm) for scallops caught in area O during the 2018/19 and 2019/20 seasons.

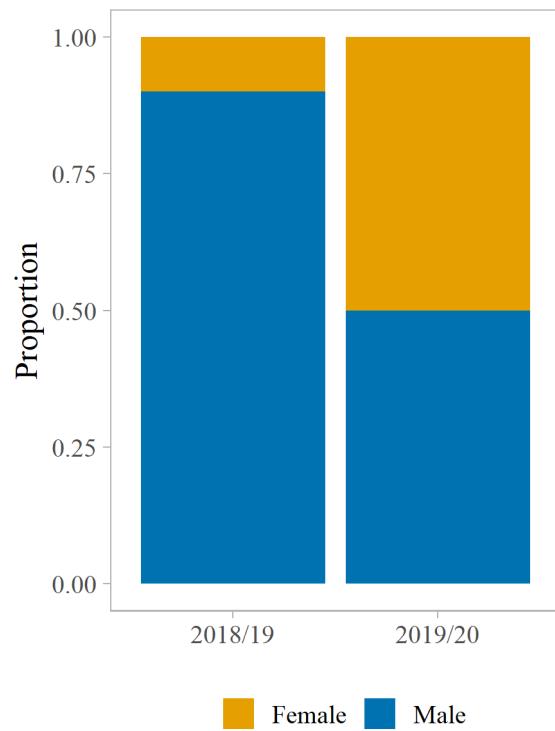


Figure 91: Proportion by sex in area O.

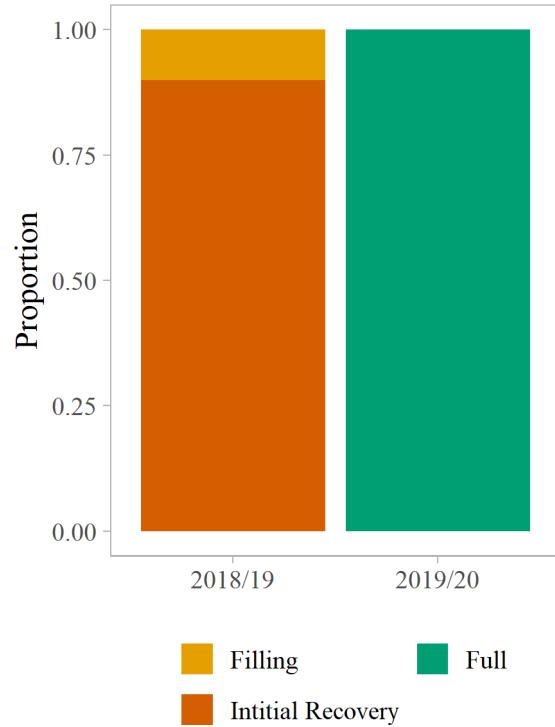


Figure 92: Proportion by gonad condition in area O.

6.5 Fishery independent information

6.5.1 Trawl survey

The trawl survey does not typically overlap with scallop fishing grounds in area O, and catches very few scallops (i.e., only 4 in 2019) (Figure 93 - 94).

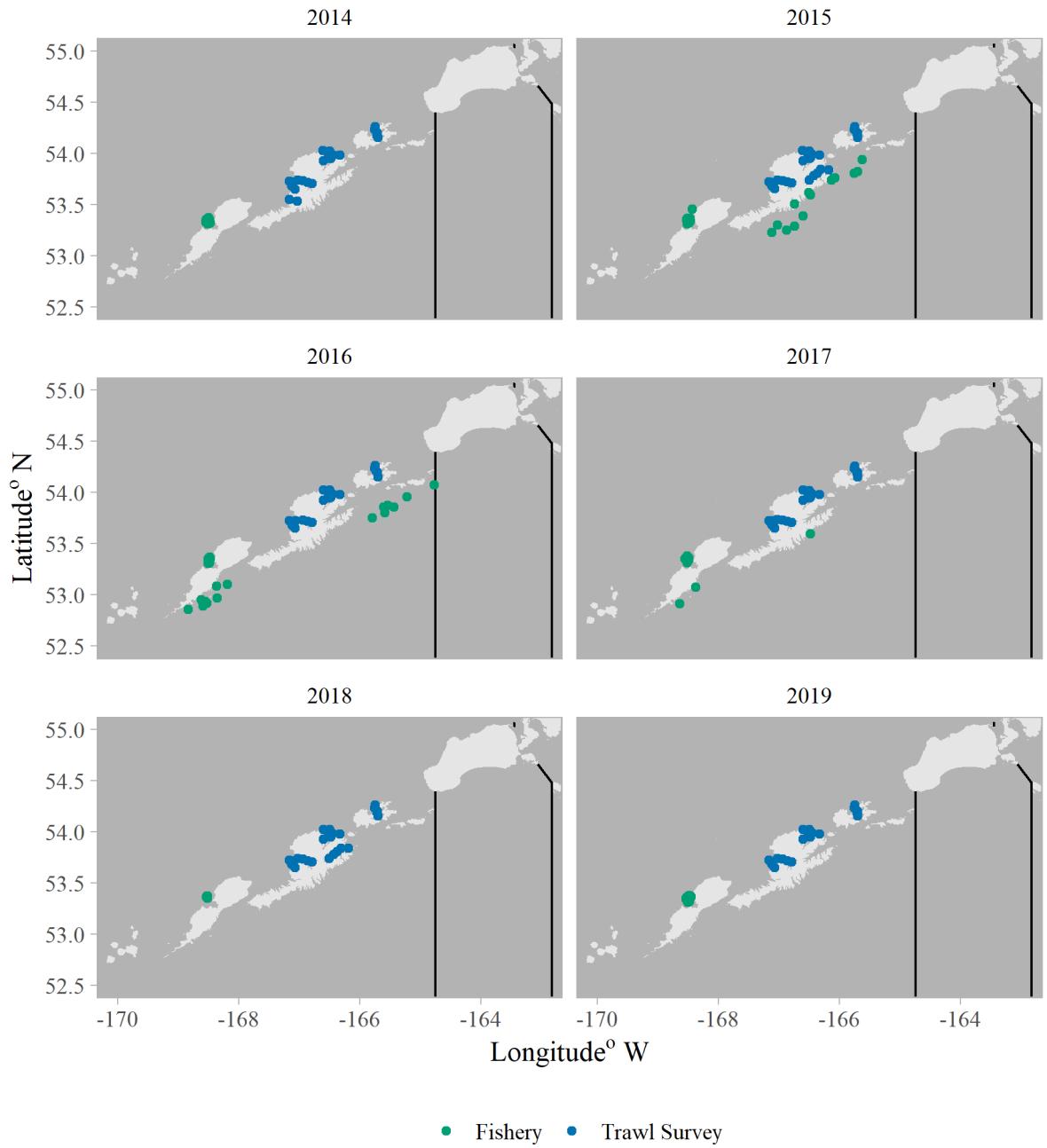


Figure 93: Trawl survey haul locations (blue) in comparison to the location of fishing effort (green) in area O from 2015 - 2019.

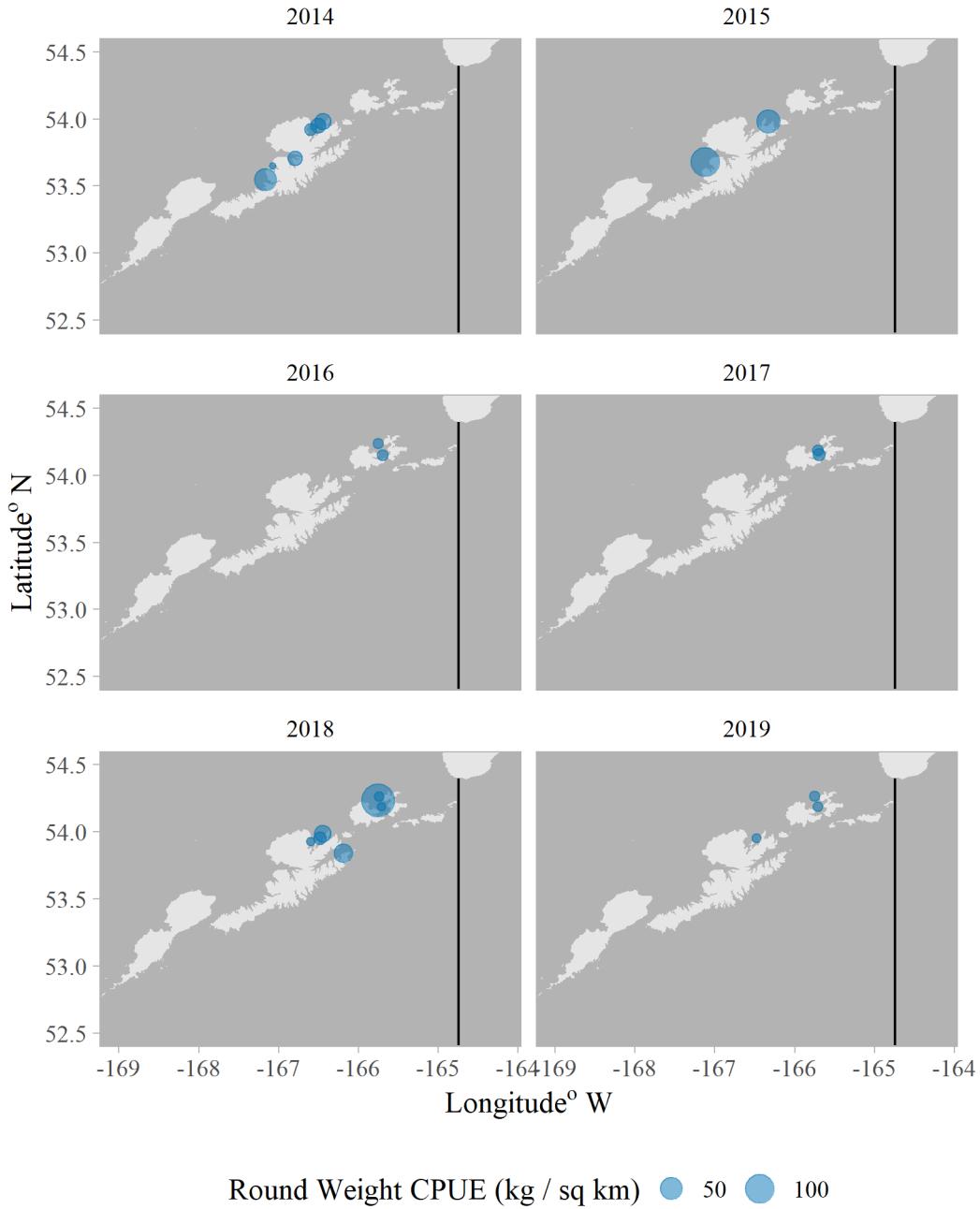


Figure 94: Trawl survey CPUE (kg / sq nm).

7 Bering Sea Registration Area (Q)

The Bering Sea registration area (Q) consists of a single district, with fishing effort predominately occurring north of Unimak Island. Area Q used to contribute a substantial proportion of the statewide harvest until the 2014/15 season, when scallop meat quality began suffering from weak meats. Since then, minimal GHL's have been used to maintain availability of fishery data. The GHL for the 2019/20 survey was 7,500 lbs. The NMFS RACE EBS shelf bottom trawl survey is conducted in this district on an annual basis, but area Q has never been included in the dredge survey.

7.1 Fishery performance

The 2019/20 Bering Sea scallop fishery opened on July 1, 2019 with a GHL of 7,500 lbs of scallop meats. One vessel participated in the fishery harvesting 7,130 lbs scallop meat with a CPUE of 19.5 lbs meat/dredge hour. Total round weight of retained scallops was 106,177 lbs with a nominal CPUE of 291 lbs/dredge hour (Table 31). Fishing effort was the most concentrated it has been since the 2009/10 season, and as a result had the smallest spatial extent of catch during that time period (Figures 95 - 96). Round weight CPUE continued on a long term decline since the 2012/13 season (Table 32, Figures 97 - 98).

Table 31: Area Q catch summary. Meat and round weight CPUE represent nominal values.

Year	GHL	Retained catch (lb meat)	Dredge (lb round)	Number hours	Meat wt hauls	Round wt cpue ^a	Round wt cpue ^b
1993/94		284,414		5,764	3,326	49	
1994/95		505,439		11,113	6,508	45	
1995/96	closed						
1996/97	600,000	150,295	1,428,060	2,313	951	65	620
1997/98	600,000	97,002	1,077,150	2,246	1,280	43	492
1998/99	400,000	96,795	1,189,021	2,319	1,178	42	526
1999/00	400,000	164,481	1,844,765	3,294	1,514	50	563
2000/01	200,000	205,520	2,376,601	3,355	1,564	61	710
2001/02	200,000	140,871	1,700,500	3,072	1,401	46	559
2002/03	105,000	92,240	951,938	2,038	1,010	44	468
2003/04	105,000	42,590	537,552	1,020	517	41	527
2004/05	50,000	10,050	128,128	275	145	37	475
2005/06	50,000	23,220	231,700	602	303	39	386
2006/07	50,000	48,246	529,590	1,138	583	43	466
2007/08	50,000	49,995	697,288	1,084	540	46	647
2008/09	50,000	49,995	502,450	960	642	52	525
2009/10	50,000	48,921	595,602	1,275	726	38	467
2010/11	50,000	50,100	547,302	972	597	52	563
2011/12	50,000	50,275	529,235	984	626	51	538
2012/13	50,000	50,045	564,787	943	695	53	599
2013/14	50,000	49,989	561,033	1,086	719	46	517
2014/15	50,000	12,445	227,196	525	330	24	432
2015/16	7,500	7,500	107,337	307	157	24	350
2016/17	7,500	7,575	108,191	275	174	28	393
2017/18	7,500	7,535	105,668	316	185	24	334
2018/19	7,500	7,540	125,978	357	179	21	353
2019/20	7,500	7,130	106,177	365	184	20	291

^alb scallop meat wt/dredge hour

^blb scallop round wt/dredge hour

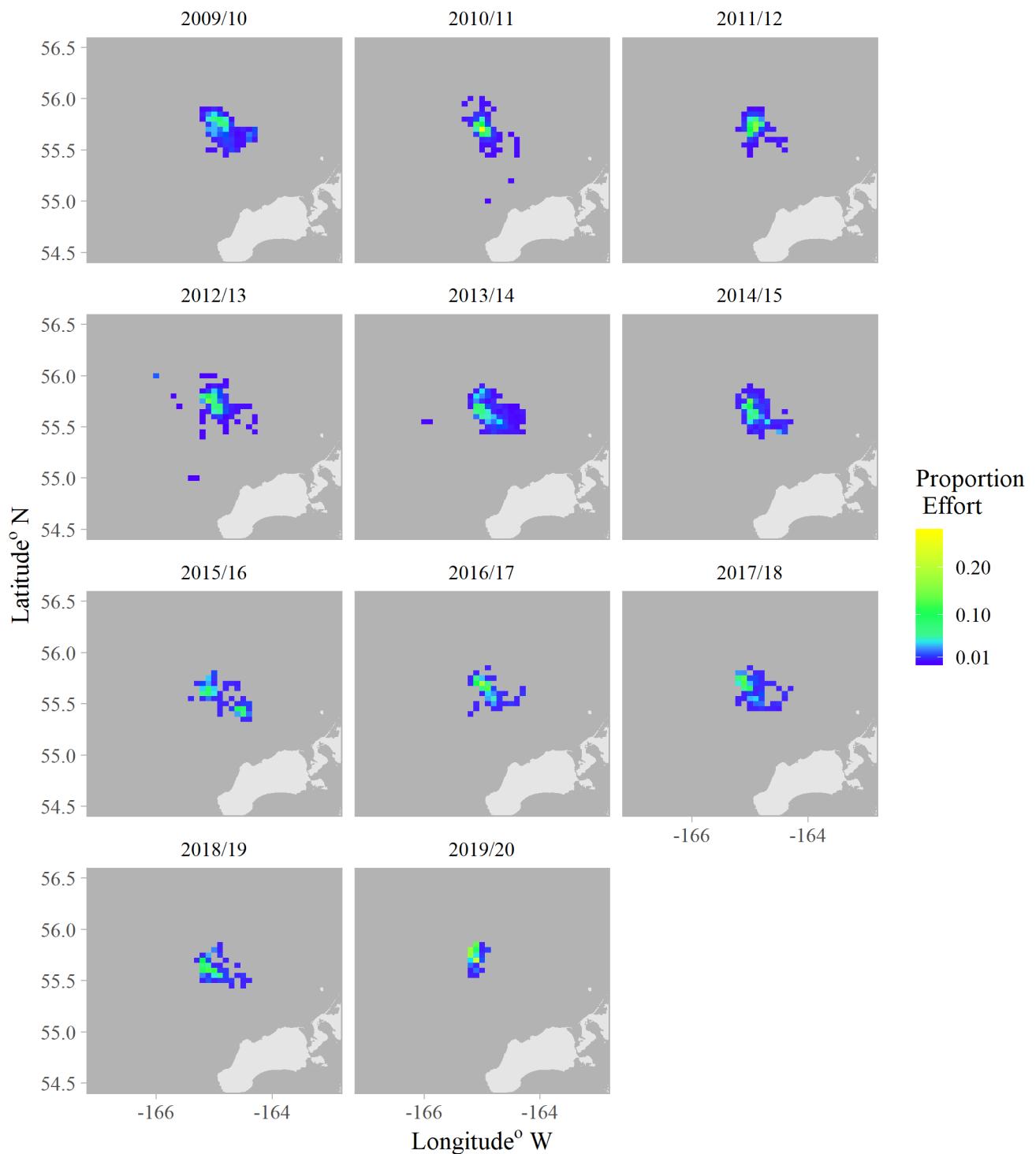


Figure 95: Heat map of fishing effort within area Q. Warmer colors indicate areas accounting for a greater proportion of fishing effort.

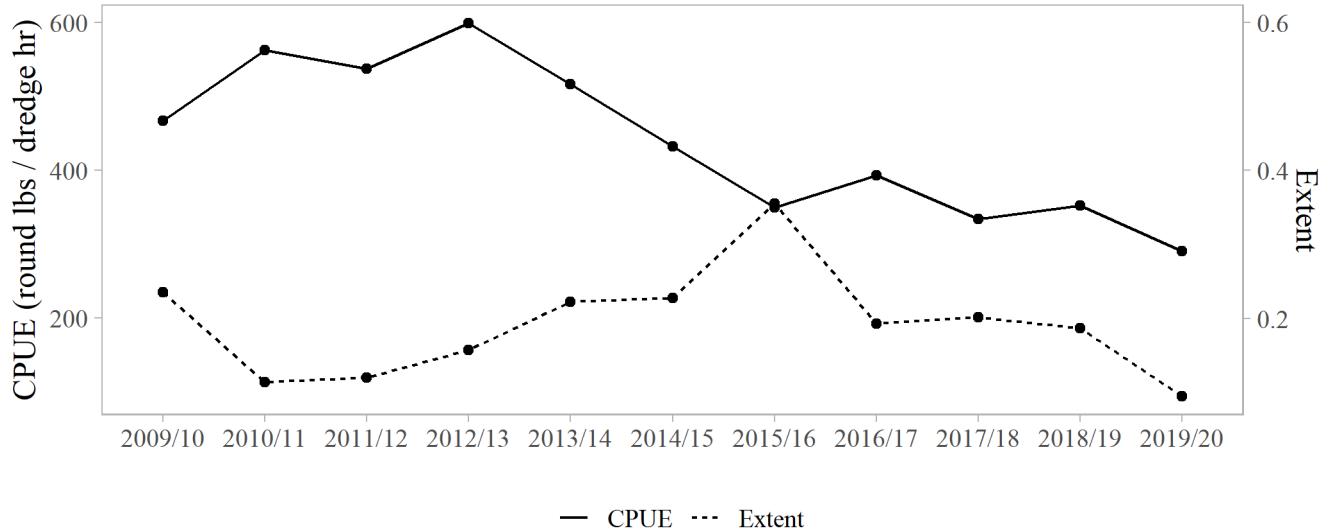


Figure 96: Nominal CPUE (round lbs / dredge hr) (solid line) and relative spatial extent of fishing effort (dotted line) within area Q by season

Table 32: Area Q nominal and standardized CPUE estimates (round lbs / dredge hour) by season.

Season	Nominal CPUE			
	(total)	(median)	(sd)	Standardized CPUE
2009/10	467.24	459.93	153.23	510.14
2010/11	563.34	572.40	196.80	630.95
2011/12	537.82	529.10	135.20	593.82
2012/13	599.10	606.33	208.29	618.27
2013/14	516.61	521.20	127.10	564.24
2014/15	432.48	434.13	94.84	492.60
2015/16	349.79	377.95	81.62	404.42
2016/17	393.48	387.60	119.80	447.78
2017/18	334.15	329.20	114.49	355.33
2018/19	352.72	350.70	78.79	403.58
2019/20	290.81	284.30	83.36	268.71

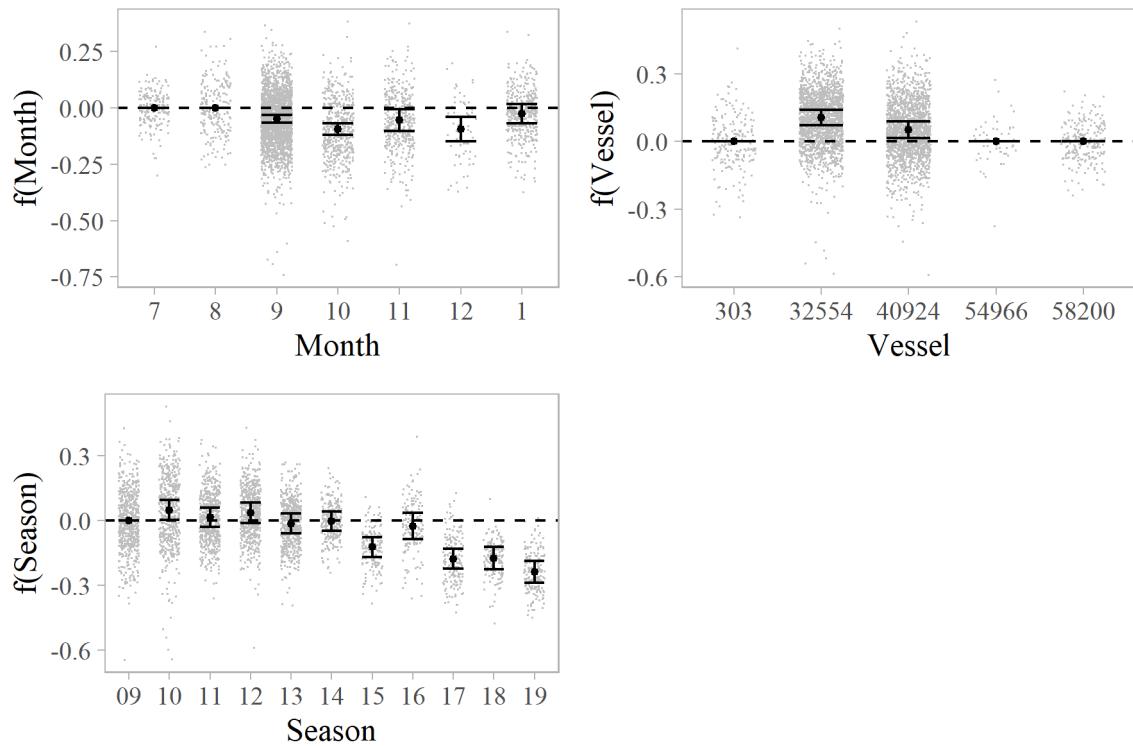


Figure 97: Partial effects of Month, Vessel, Season, and Bed on CPUE within area Q. Season values represent the last two digits of the year the fishery opened.

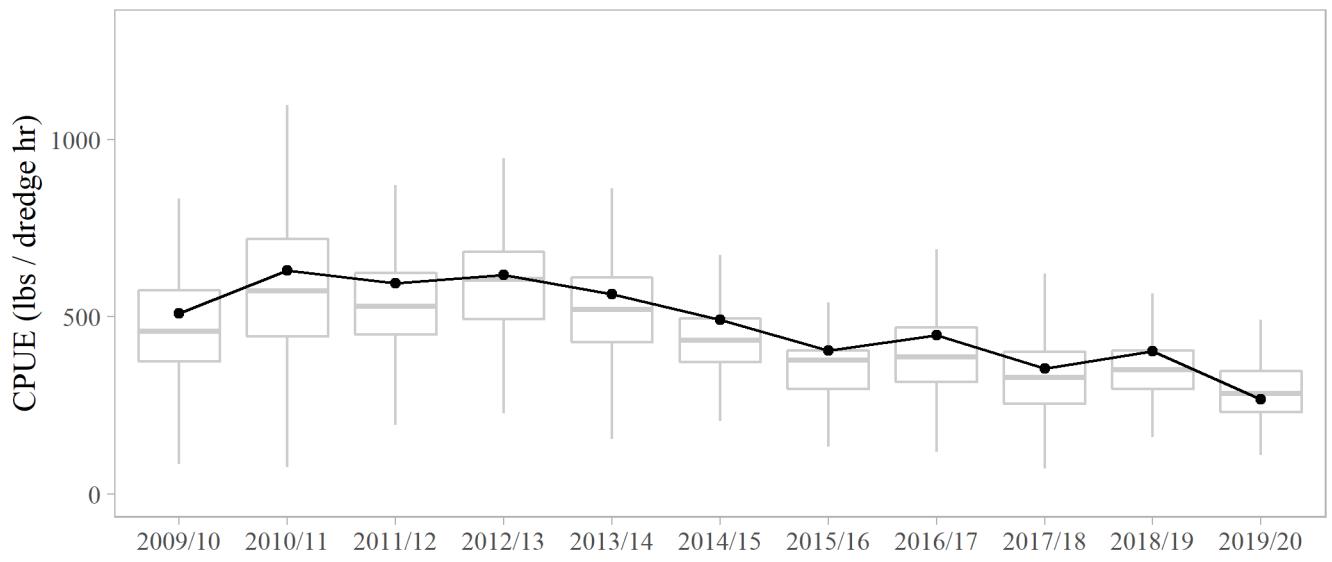


Figure 98: Boxplots of nominal CPUE (round lbs / dredge hr) overlaid with standardized CPUE (round lbs / dredge hr) by season (black line) (top) and standardized CPUE by bed and season (bottom) within area Q.

7.2 Fishery discards

Estimated scallop discards during the 2019/20 season were 6,139 round weight lbs (4,973 scallops) in area Q (Table 33, Figure 99). Discard ratio (lbs discarded:lbs retained, 0.06) increased from the 2018/19 season (0.03) (Table 33, Figure 100). The rate of clapper catch continued an increase from the 2017/18 season (Tables 34, Figure 101). Broken discards outweighed intact discards in all hauls (Figure 102).

Table 33: Area Q discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), associated discard rates (lbs or count per dredge hr), and estimated discard mortality.

Season	Retained (lbs)	Discarded (lbs)	(count)	Discard ratio	Discard rate (lbs)	(count)	Discard mortality (lbs)	(count)
2009/10	595,602	53,900	72,230	0.09	42	57	10,780	14,446
2010/11	547,302	71,702	109,024	0.13	74	112	14,340	21,805
2011/12	529,235	30,971	34,436	0.06	31	35	6,194	6,887
2012/13	564,787	37,899	10,460	0.07	40	11	7,580	2,092
2013/14	561,033	21,108	5,927	0.04	19	5	4,222	1,185
2014/15	227,196	7,961	2,404	0.04	15	5	1,592	481
2015/16	107,337	4,626	4,096	0.04	15	13	925	819
2016/17	108,191	6,671	8,459	0.06	24	31	1,334	1,692
2017/18	105,668	3,906	2,099	0.04	12	7	781	420
2018/19	125,978	3,746	4,430	0.03	10	12	749	886
2019/20	106,177	6,139	4,973	0.06	17	14	1,228	995

Table 34: Area Q clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	Clappers	
		(rate)	(count)
2009/10	1,275	4.27	5,442
2010/11	972	8.57	8,326
2011/12	984	5.79	5,700
2012/13	943	9.32	8,784
2013/14	1,086	11.28	12,253
2014/15	525	11.37	5,975
2015/16	307	13.67	4,196
2016/17	275	7.85	2,159
2017/18	316	6.25	1,977
2018/19	357	10.60	3,786
2019/20	365	15.81	5,772

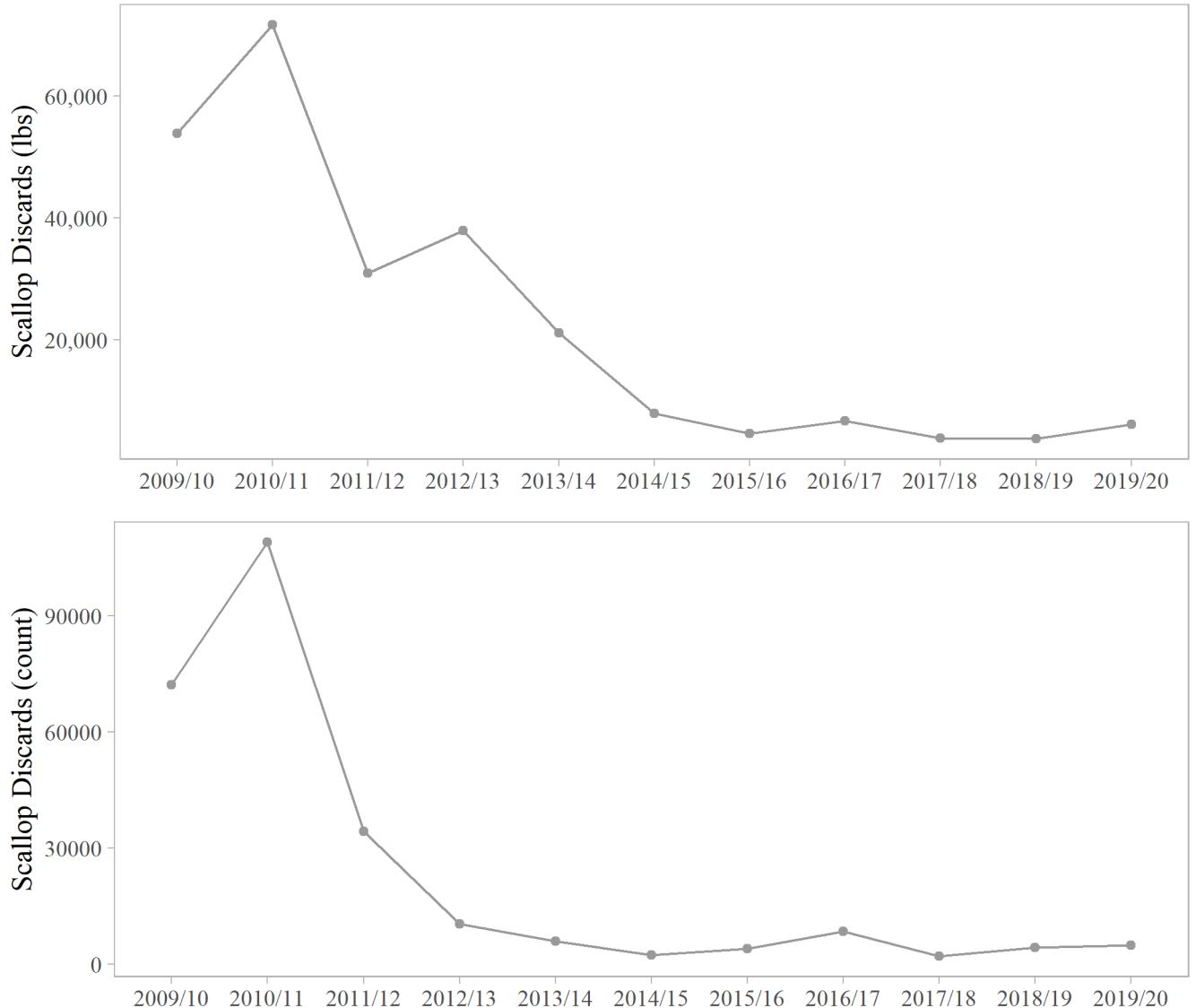


Figure 99: Total discarded scallops as round weight (top) and number of count (bottom) for each district by season.

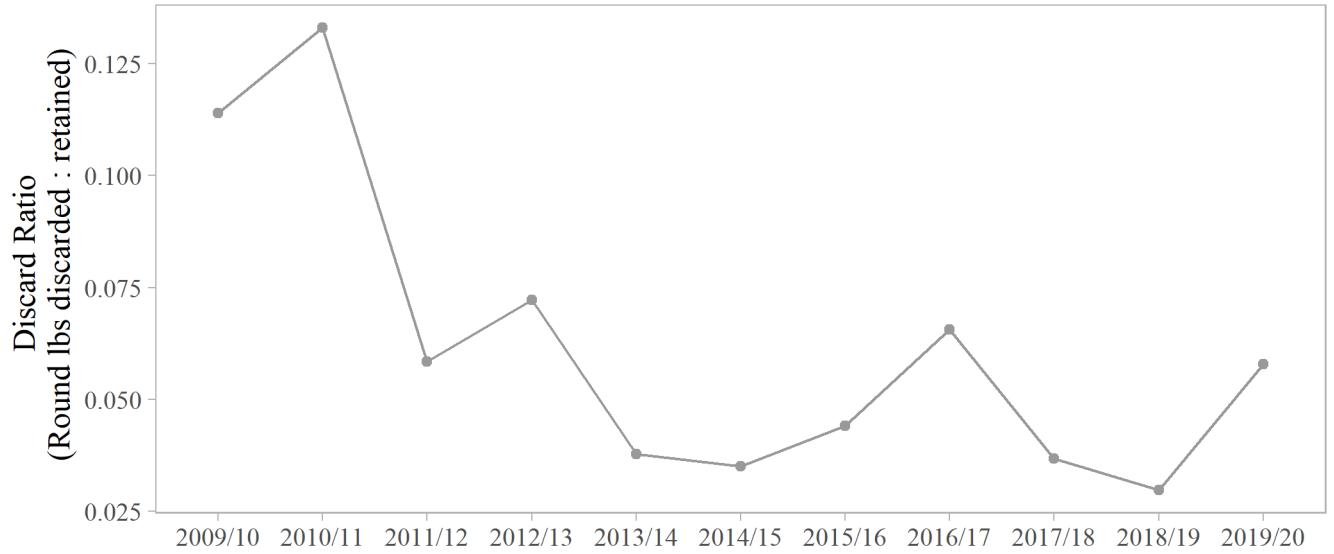


Figure 100: Scallop discard ratio (round weight discarded : retained) for each district by season.

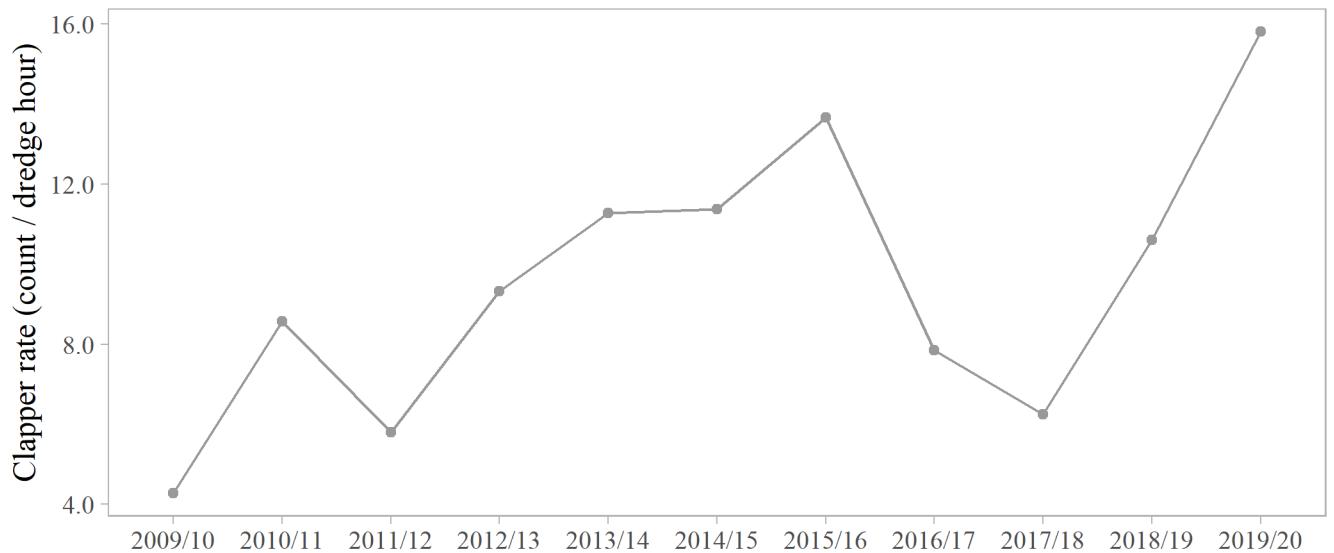


Figure 101: Rate of clapper catch by season in area Q.

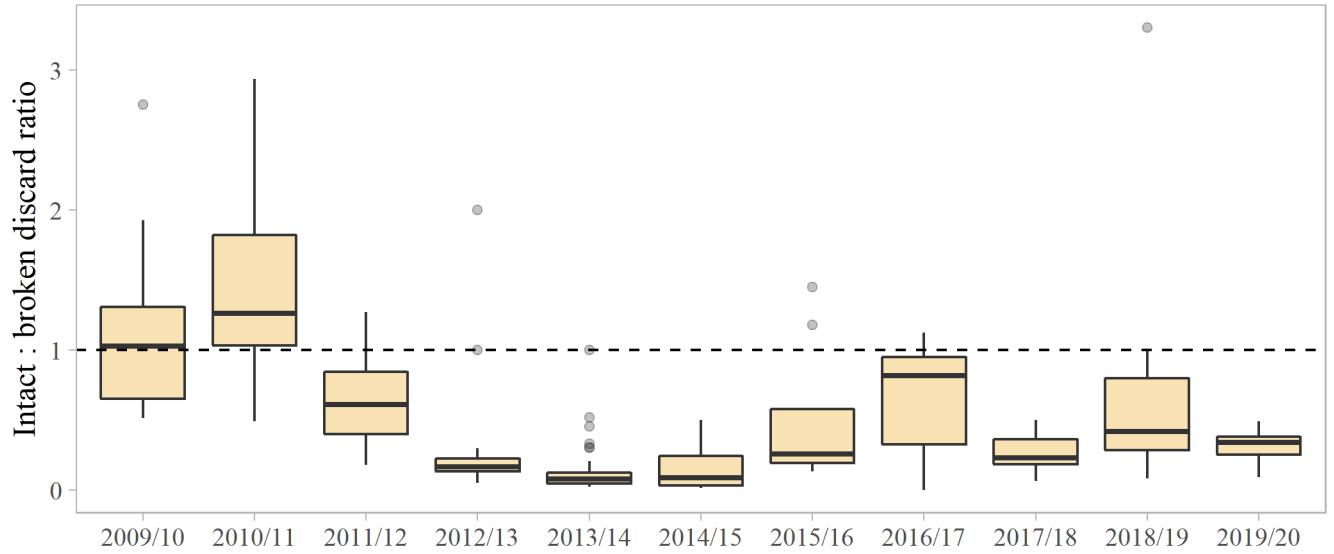


Figure 102: Boxplots of the ratio between intact and broken scallop discards in every haul within area Q. The dotted line represents a 1:1 ratio.

7.3 Fishery bycatch

Area Q utilizes CBLs for Tanner crab, snow crab (including snow-Tanner hybrids), and red king crab. During the 2019/20 season, CBLs were 65,000 Tanner crab, 300,000 snow crab, and 500 red king crab (Table 35).

Bycatch of Tanner crab was similar to the 2018/19 season, while snow crab bycatch increased (Table 35, Figure 103 - 104). Bycatch of Pacific halibut decreased, and no red king crab were caught for the third consecutive season (Table 35, Figure 103). Crab bycatch rates never exceeded progress towards achieving the GHL at any point in the season (Figure 105). Tanner crab bycatch included all size classes, though was dominated by crab less than 100 mm (Figure 106). The same is true for snow crab, though proportionately, more commercially targeted males were caught (Figure 107).

Table 35: Area Q bycatch summary including total number caught for each species.

Season	Scallop GHL	Tanner crab CBL	Snow crab CBL	Tanner crab (total)	Tanner crab (ratio)	Snow crab (total)	Snow crab (ratio)	Red king crab (total)	Red king crab (ratio)	Pacific halibut (total)	Pacific halibut (ratio)
2009/10	50,000	260,000	300,000.00	27,998	0.57	31,022	0.63	106	0.00	0	0.00
2010/11	50,000	130,000	300,000.00	61,791	1.23	18,998	0.38	33	0.00	10	0.00
2011/12	50,000	65,000	300,000.00	17,504	0.35	13,509	0.27	135	0.00	28	0.00
2012/13	50,000	65,000	300,000.00	36,070	0.72	15,720	0.31	75	0.00	10	0.00
2013/14	50,000	260,000	300,000.00	88,655	1.77	29,254	0.59	19	0.00	25	0.00
2014/15	50,000	260,000	300,000.00	24,943	2.00	9,868	0.79	23	0.00	19	0.00
2015/16	7,500	260,000	300,000.00	22,339	2.98	8,355	1.11	68	0.01	23	0.00
2016/17	7,500	260,000	300,000.00	11,571	1.53	68,103	8.99	35	0.00	49	0.01
2017/18	7,500	65,000	300,000.00	7,323	0.97	4,565	0.61	0	0.00	24	0.00
2018/19	7,500	65,000	300,000.00	16,287	2.16	2,156	0.29	0	0.00	13	0.00
2019/20	7,500	65,000	300,000.00	15,138	2.12	3,406	0.48	0	0.00	11	0.00



Figure 103: Total bycatch of Tanner crab, snow crab, red king crab, and Pacific halibut by fishing season within area Q.

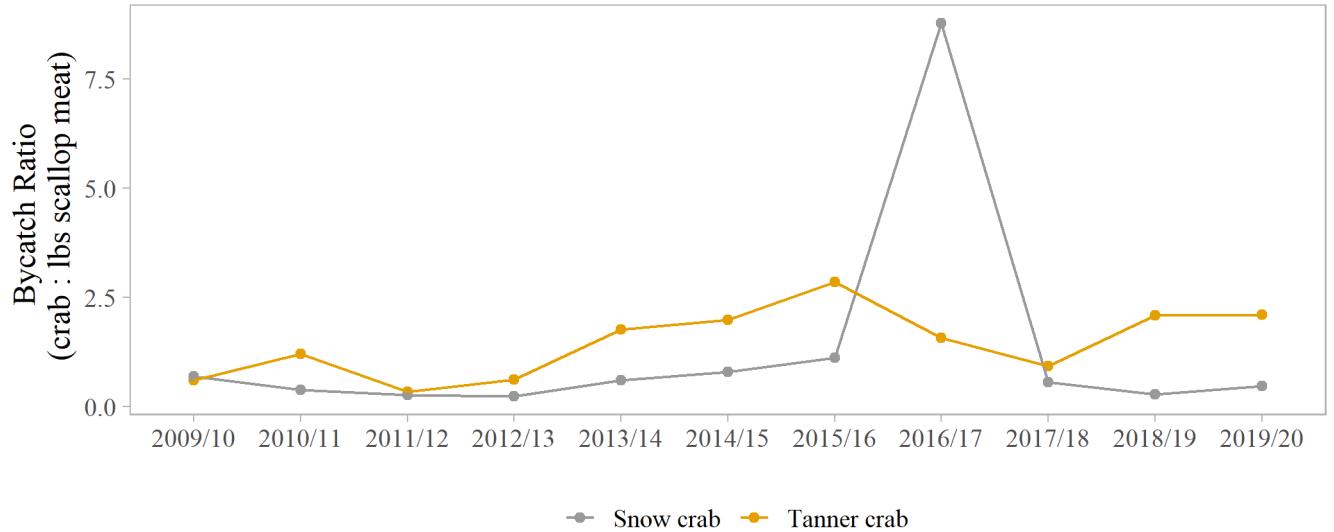


Figure 104: Bycatch ratio, expressed as number of Tanner or snow crab per pound of scallop meat weight, by year and district within area Q

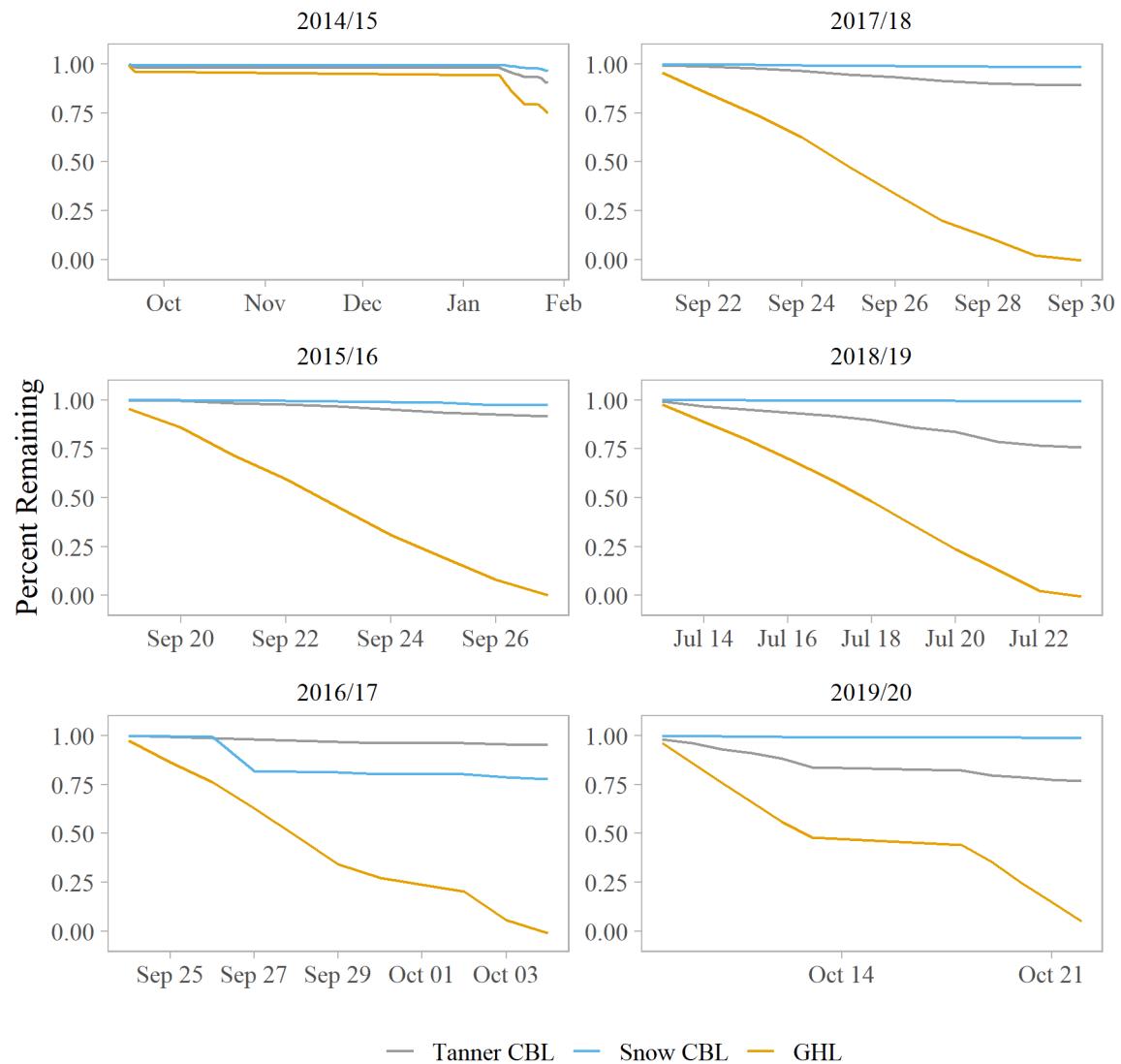


Figure 105: Percent reduction in scallop GHL and Tanner or snow crab CBL throughout recent seasons within area Q.

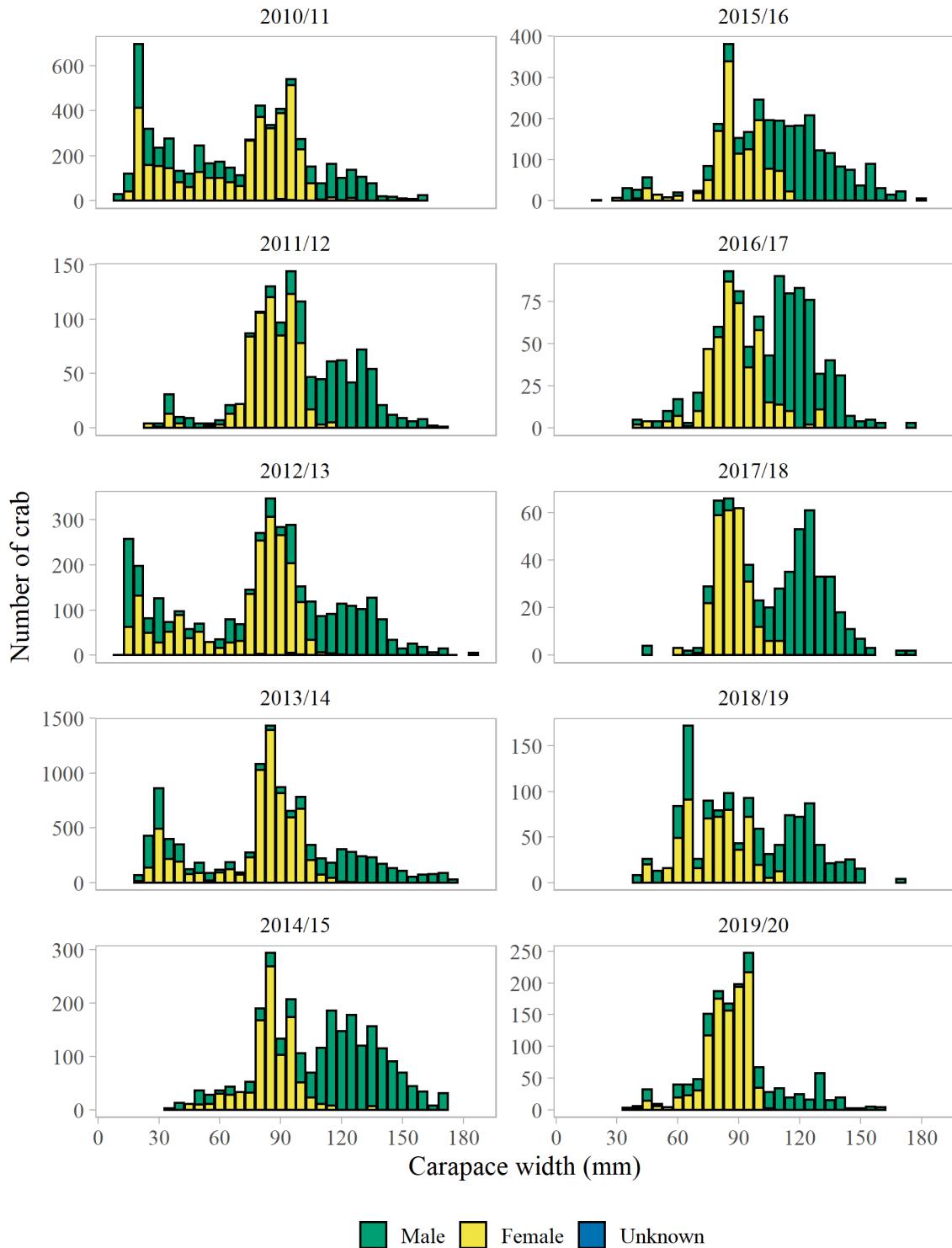


Figure 106: Size frequency histogram of the number of Tanner crab caught by sex during each season in area Q.

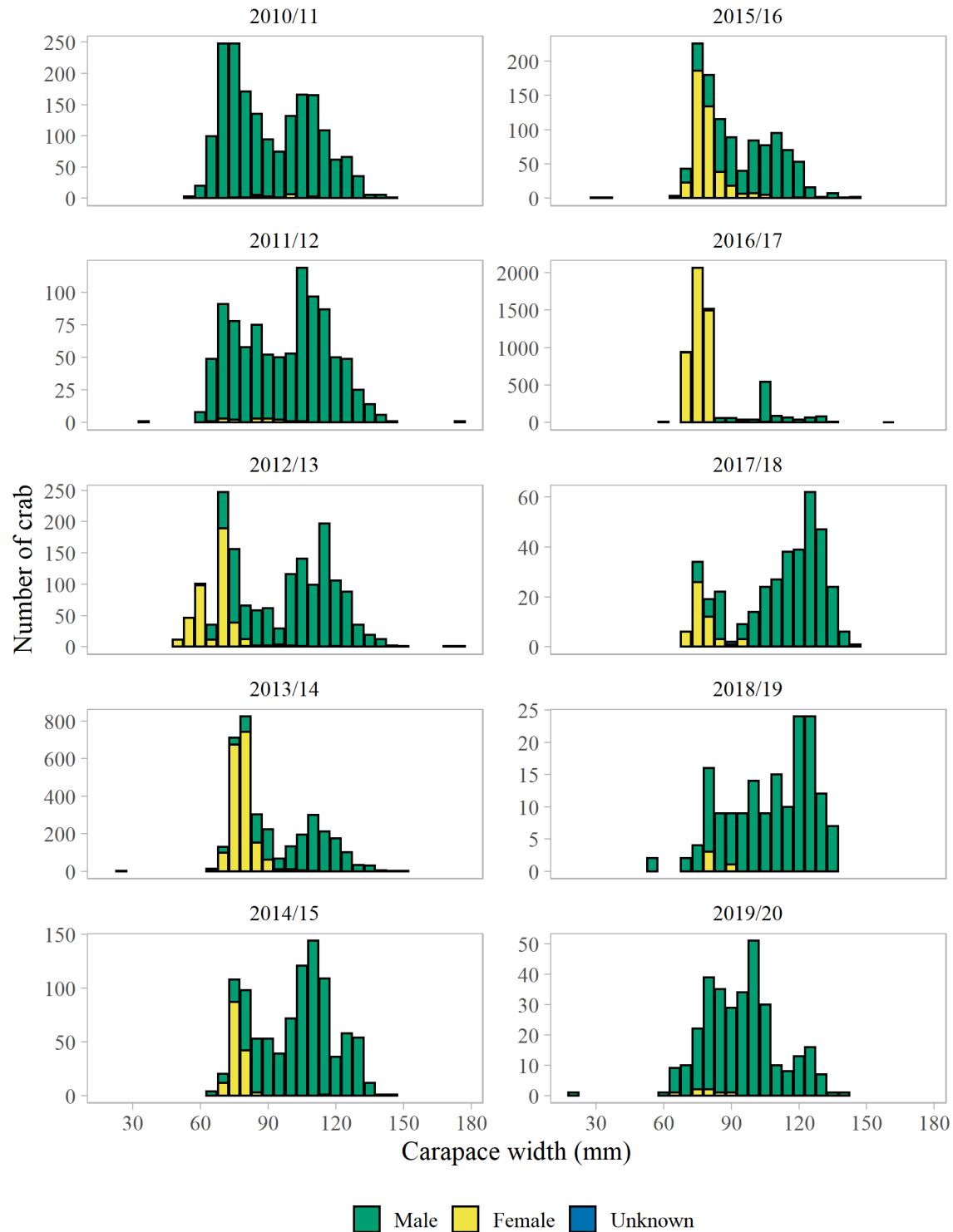


Figure 107: Size frequency histogram of the number of snow crab caught by sex during each season in area Q.

7.4 Fishery biological information

Retained scallops in area Q appear to consist of a single strong cohort 150 mm shell height or larger. Most discarded scallops were larger than 100 mm (Figure 108). There doesn't appear to be any shift in the meat weight ~ shell height relationship between seasons (Table 36, Figure 109).

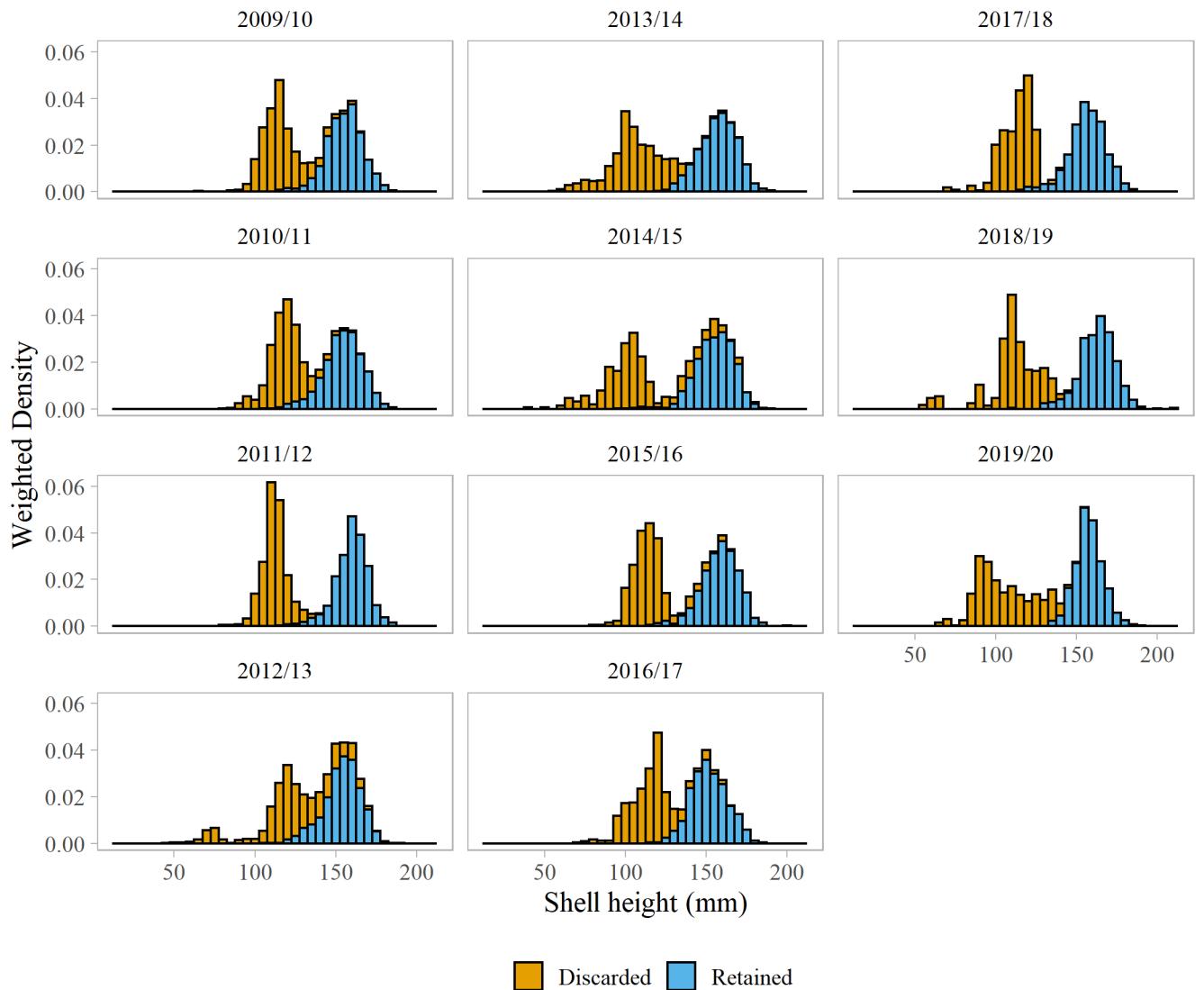


Figure 108: Shell height composition of scallops caught within area Q in 5mm bins expressed as a weighted probability density function.

Table 36: Allometric growth parameters characterizing the meat weight, shell height relationship in area Q by season.

Season	α	β
All	4.26e-04	2.199

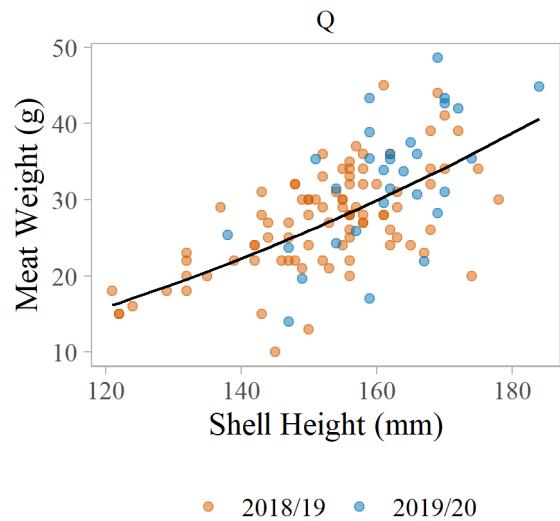


Figure 109: Individual meat weight (g) as a function of shell height (mm) for scallops caught in area Q during the 2018/19 and 2019/20 seasons.

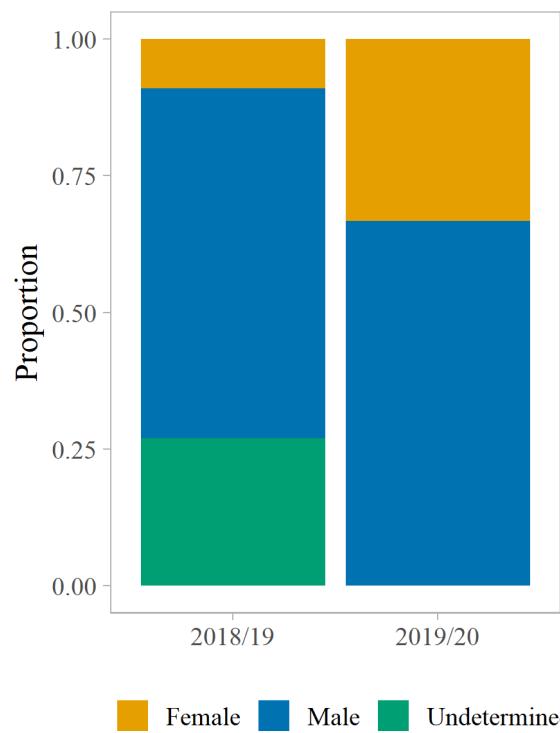


Figure 110: Proportion by sex in area Q.

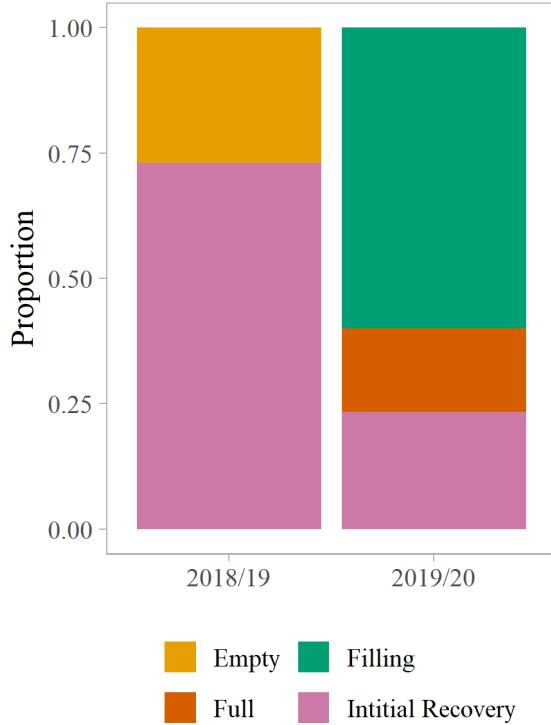


Figure 111: Proportion by gonad condition in area Q.

7.5 Fishery independent information

7.5.1 Trawl survey

The EBS trawl survey overlaps the area Q fishing grounds (Figure 112), but also includes a much broader geographic range over which scallops are not typically encountered. The survey takes place annually, sampling 376 stations. Shell height composition of scallops caught is not collected.

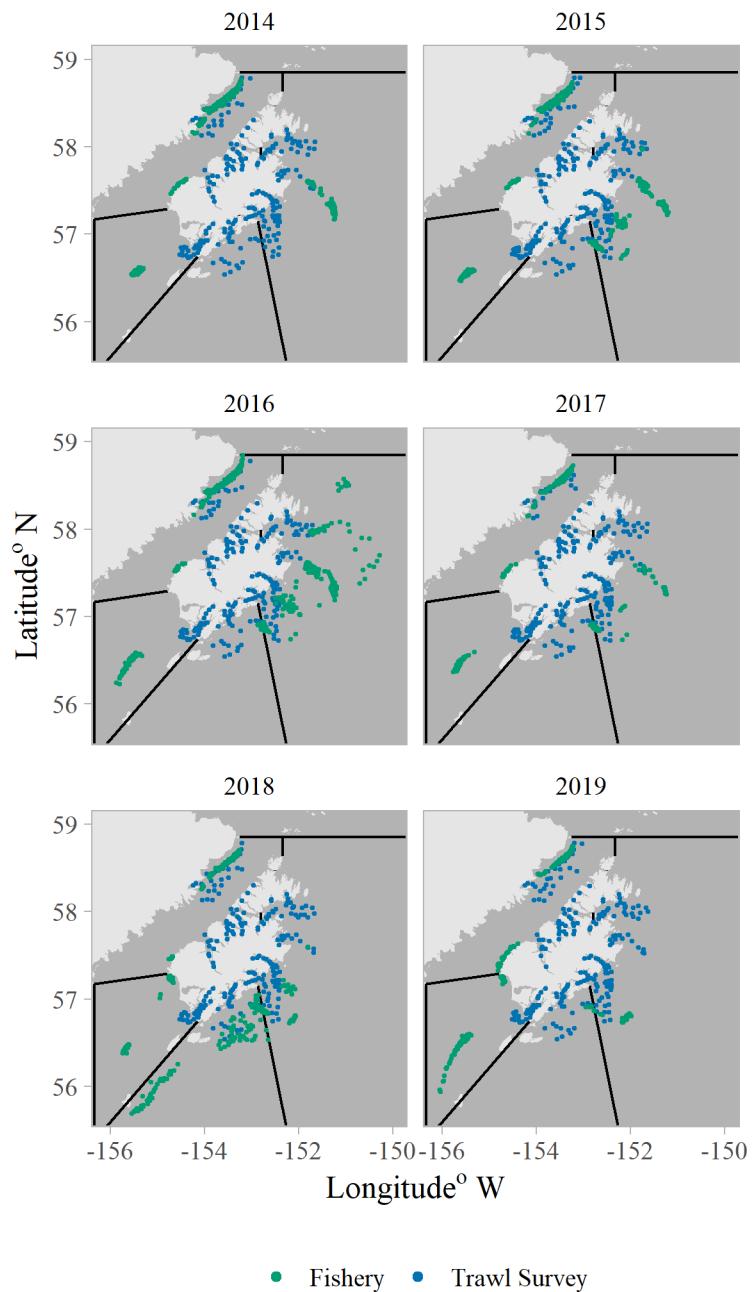


Figure 112: Trawl survey haul locations (blue) in comparison to the location of fishing effort (green) in area Q from 2015 - 2019.



Figure 113: Trawl survey CPUE (kg / sq nm).



Figure 114: Trawl survey CPUE (+/- 95% confidence interval) (blue) in comparision to standardized fishery CPUE within area Q. Both indices are scaled to a standard normal distribution to compare trends.

8 Cook Inlet Registration Area H

The Cook Inlet Registration Area (H) consists of two beds: Kamishak North (KAMN) and South (KAMS). KAMN has been closed since the 2018 season (with no effort occurring under a 10,000 lbs GHL in the 2017 season). KAMS has been effectively closed since the 2005 season (with no effort occurring under a 5,000 lbs GHL in the 2007 - 2008 seasons). A dredge survey is conducted in area H on an annual basis. In this document, only results from the 2019 survey are presented.

8.1 Fishery independent information

8.1.1 Dredge survey

ADF&G Central Region staff began a dredge survey of KAMN from September 13 - 14, 2019 and finished the survey on October 12, 2019. The survey covered 29 stations (Figure 115). The estimated density of large (> 100 mm) scallops was 11,842 scallops / nm² with a coefficient of variation (CV) of 18%, while the density of small (< 100 mm) scallops was 16,449 scallops / nm² with a CV of 35%. Large scallop abundance and biomass were estimated to be 1,068,248 scallops [708,610, 1,481,044] and 505.1 t [340.5, 682.2], respectively. Small scallop abundance and biomass were estimated to be 1,483,839 scallops [570,035, 2,548,580] and 45.7 t [8.1, 107.4], respectively (Table 37 - 38, Figure 116). Shell height composition indicate five potential distinct size classes present in KAMN, with the most abundant being under 50 mm or over 150 mm (Figure 117). Individual meat weight followed the anticipated allometric relationship with shell height (Figure 118), though estimation of growth parameters (α and β) is hindered by the lack of data collected on scallops between approximately 125 mm - 150 mm, thus estimates should be interpreted as *approximate* (Table 39). The relationship between individual meat weight and round weight varied around 10% and appears to asymptote at around 400 g (Figure 119). Additional biological information (e.g., meat condition, gonad condition, mud blisters, shell shell worm presence) will be presented in a forthcoming 2019-2020 statewide dredge survey Fishery Data Series report.

Table 37: Estimated scallop density (scallops/nm²), coefficient of variation (CV), and abundance a 95% confidence interval computed via bootstrap resampling ($i = 1,000$).

Size group	Density (count/nm ²)	CV	Abundance	Lower 95% CI	Upper 95% CI
Large	11,841.79	0.18	1,068,248	708,610	1,481,044
Small	16,448.73	0.35	1,483,840	570,036	2,548,580

Table 38: Estimated scallop density (t/nm²), coefficient of variation (CV), and biomass (t) a 95% confidence interval computed via bootstrap resampling ($i = 1,000$).

Size group	Density (t/nm ²)	CV	Biomass (t)	Lower 95% CI	Upper 95% CI
Large	5.60	0.18	505.1	340.5	682.2
Small	0.51	0.64	45.7	8.1	107.4

Table 39: Allometric growth parameters characterizing the meat weight, shell height relationship estimated from 2019 survey data.

$$\begin{array}{cc} \alpha & \beta \\ \hline 1.00e+00 & 13.557 \end{array}$$

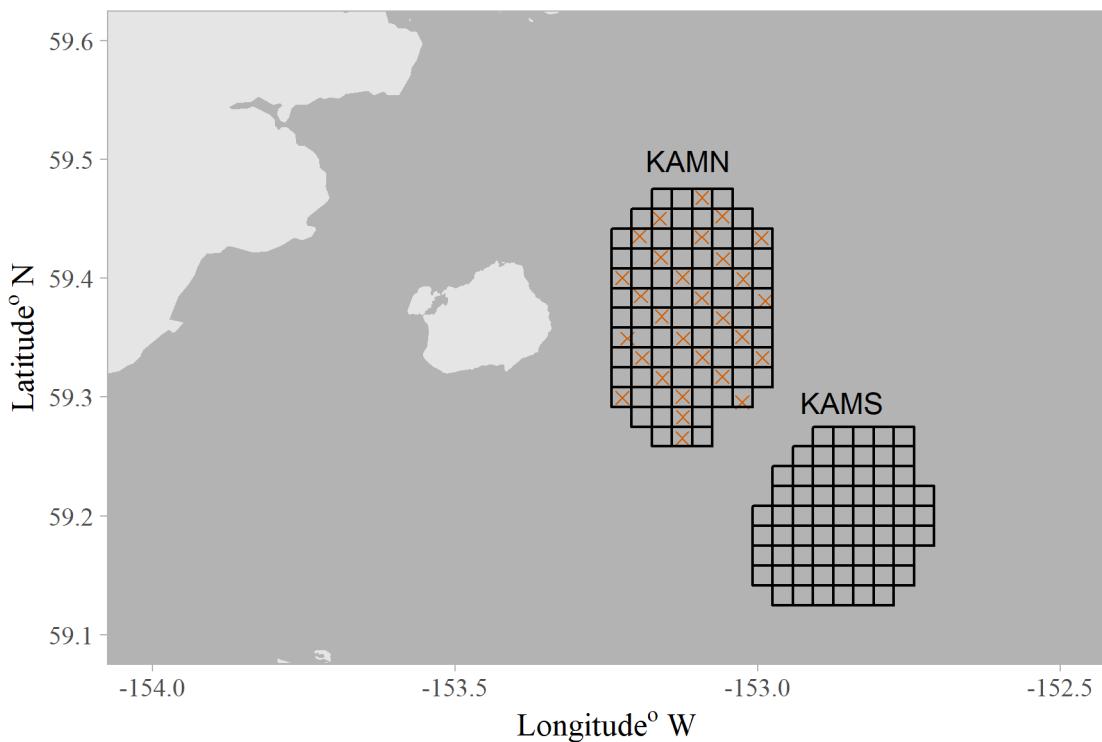


Figure 115: Map of area H bed survey grids. Red X's mark stations within the KAMN bed that were sampled in 2019.

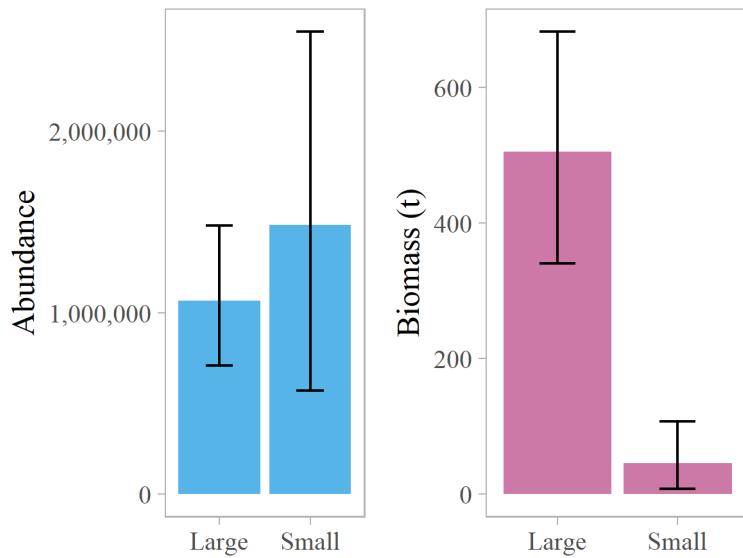


Figure 116: Abundance and biomass (t) estimates for KAMN in 2019. Error bars represent 95% confidence intervals constructed via bootstrapping.

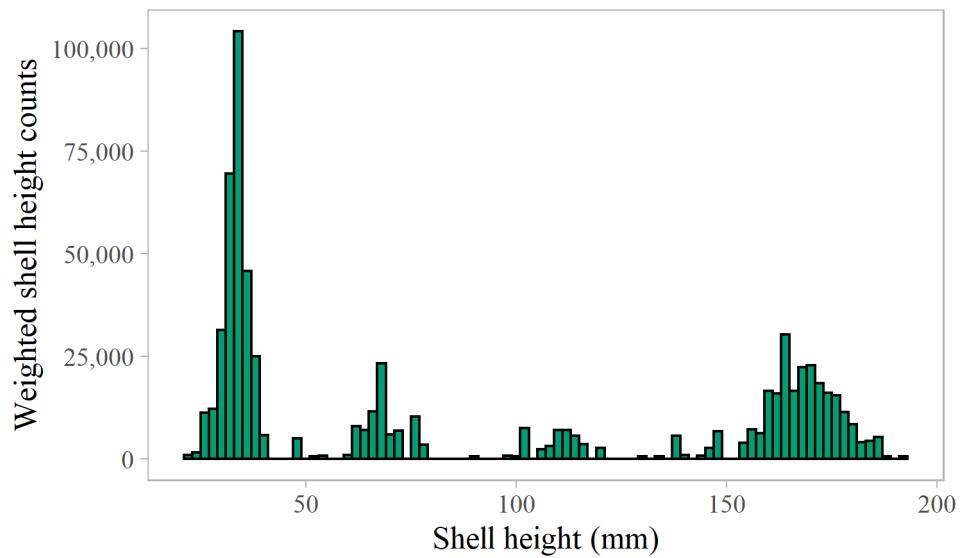


Figure 117: Shell height (mm) composition of scallops caught during the 2019 KAMN dredge survey.

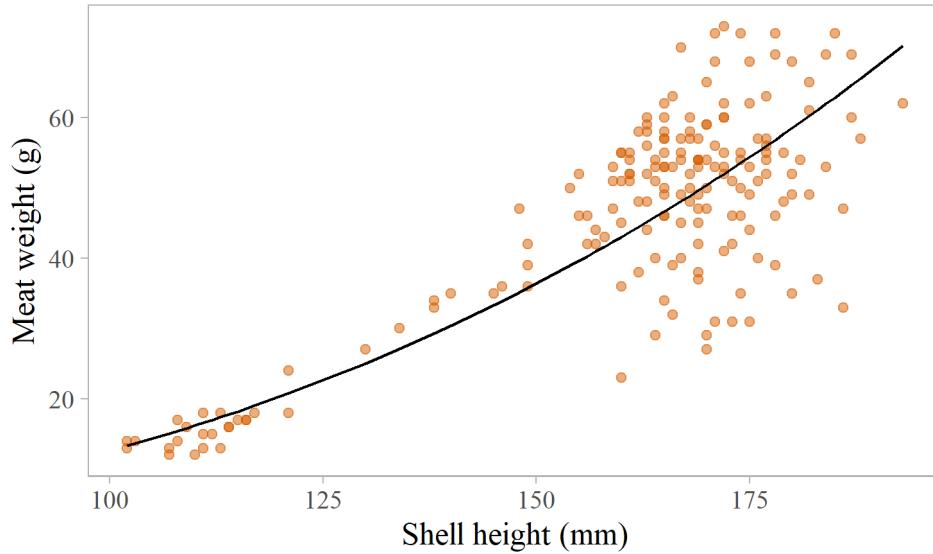


Figure 118: individual meat weight (g) as a function of shell height (mm) for scallops caught during the 2019 KAMN dredge survey.

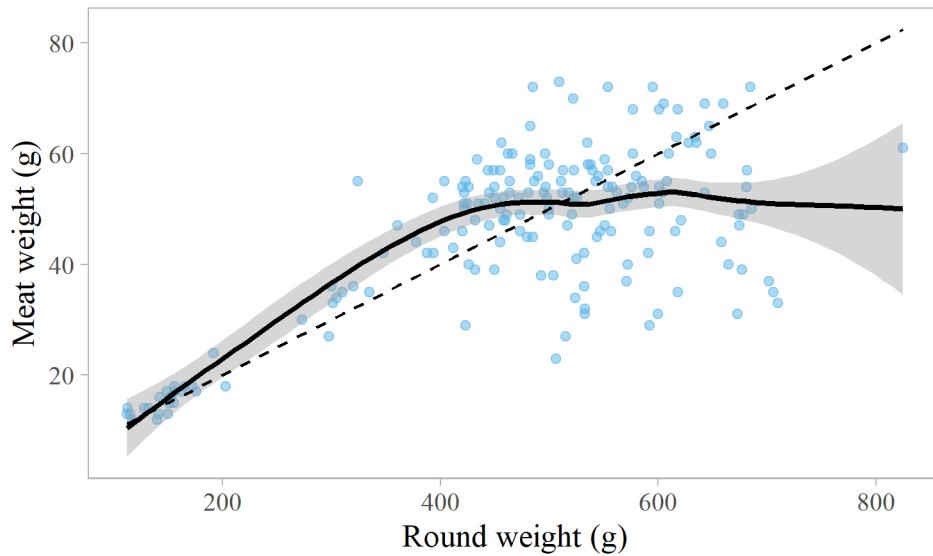


Figure 119: individual meat weight (g) as a function of round weight (g) for scallops caught during the 2019 KAMN dredge survey. The dotted line represents a 10% meat:round weight ratio, and the solid line is a LOESS curve fitting the data.

9 Prince William Sound Registration Area (E)

The Prince William Sound Registration area (E) consists of the West Kayak Island (WKI) and East Kayak Island (EKI) Subsections. Both subsections were closed during the 2019/20 season. WKI was sampled during the 2019 dredge survey, results can be found in the 2020 Weathervane Scallop SAFE report (NPFMC 2020).

10 Yakutat Registration Area (D)

The Yakutat Registration Area (D) is historically consisted of two districts (D16 and D), but was combined into a single unit for management purposes in 2018. Area D was fished within the GHLS during the 2019/20 season. The dredge survey was conducted in area D from 2017 - 2019 within select beds.

10.1 Fishery performance

The 2019/20 Yakutat scallop fishery opened on July 1, 2019 with a GHL of 155,000 lbs of scallop meats. Two vessels participated in the fishery harvesting 144,245 lbs scallop meat with a CPUE of 43.8 lbs meat/dredge hour. Total round weight of retained scallops was 1,989,202 lbs with a nominal CPUE of 604 lbs/dredge hour (Table 40). Fishing effort was spread throughout much of the district, though most occurred within beds YAK4 and YAK5 (Figure 120), and the spatial extent of the catch was considerably lower than the preceding seasons (Figure 121). Round weight CPUE decreased from the 2018/19 season across all beds, except for YAKB (Table 41, Figures 122 - 123).

Table 40: Yakutat District catch summary. Meat and round weight CPUE represent nominal values.

Year	GHL	Retained catch (lb meat)	Dredge (lb round)	Number hours	Meat wt hauls	Round wt cpue ^a	Round wt cpue ^b
1995		242,491	3,214,968	4,712	2,597	51	682
1996		238,736	3,195,254	3,982	2,102	60	802
1997/98		242,940	3,282,860	3,956	1,958	61	830
1998/99		241,678	3,475,996	4,192	2,193	58	830
1999/00		249,681	3,119,103	3,840	1,720	65	812
2000/01	250,000	195,699	2,734,559	4,241	2,111	46	645
2001/02	200,000	103,800	1,521,537	2,406	1,096	43	632
2002/03	200,000	122,718	1,541,867	2,439	1,243	50	632
2003/04	200,000	160,918	1,939,004	3,358	1,716	48	577
2004/05	200,000	86,950	1,262,499	2,134	1,194	41	592
2005/06	200,000	199,351	2,662,031	5,089	2,585	39	523
2006/07	150,000	150,041	1,771,229	2,817	1,533	54	629
2007/08	150,000	125,960	1,593,223	2,601	1,416	48	613
2008/09	150,000	150,289	2,053,912	3,286	1,825	46	625
2009/10	185,000	170,016	2,514,004	4,385	2,879	39	573
2010/11	185,000	159,268	2,163,050	3,578	2,074	45	605
2011/12	185,000	158,240	2,380,618	4,655	2,754	34	511
2012/13	145,000	143,395	1,989,071	4,038	2,367	36	493
2013/14	145,000	147,400	1,853,114	3,025	1,716	49	613
2014/15	145,000	129,493	1,555,495	3,159	1,837	41	492
2015/16	145,000	120,690	1,708,707	2,571	1,370	47	665
2016/17	125,000	120,380	1,637,710	2,109	1,260	57	777
2017/18	145,000	145,080	1,841,714	2,899	1,643	50	635
2018/19	145,000	145,083	1,777,744	2,267	1,370	64	784
2019/20	155,000	144,245	1,989,202	3,293	2,025	44	604

^alb scallop meat/dredge hour

^blb scallop round/dredge hour

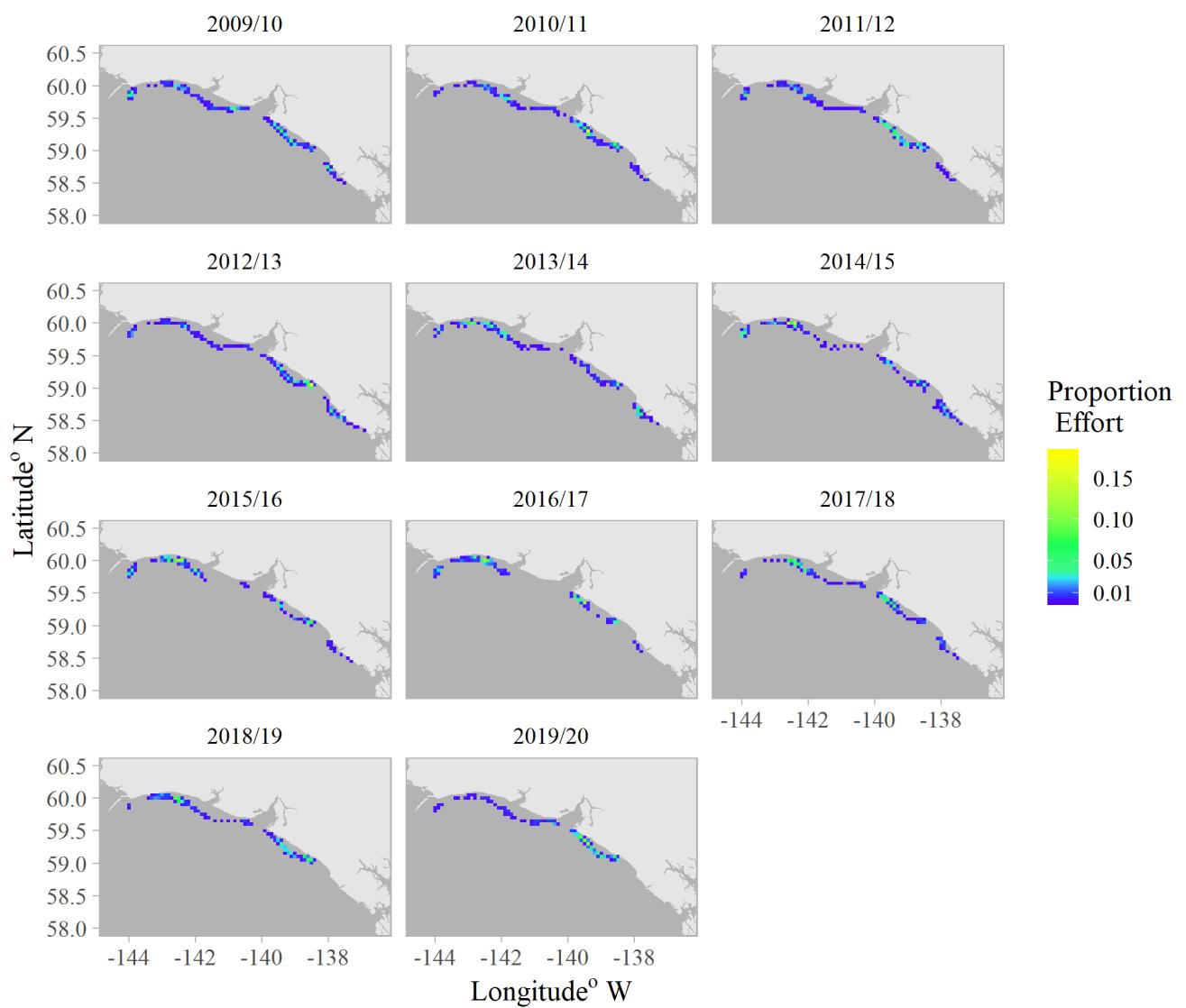


Figure 120: Heat map of fishing effort within area D. Warmer colors indicate areas accounting for a greater proportion of fishing effort.

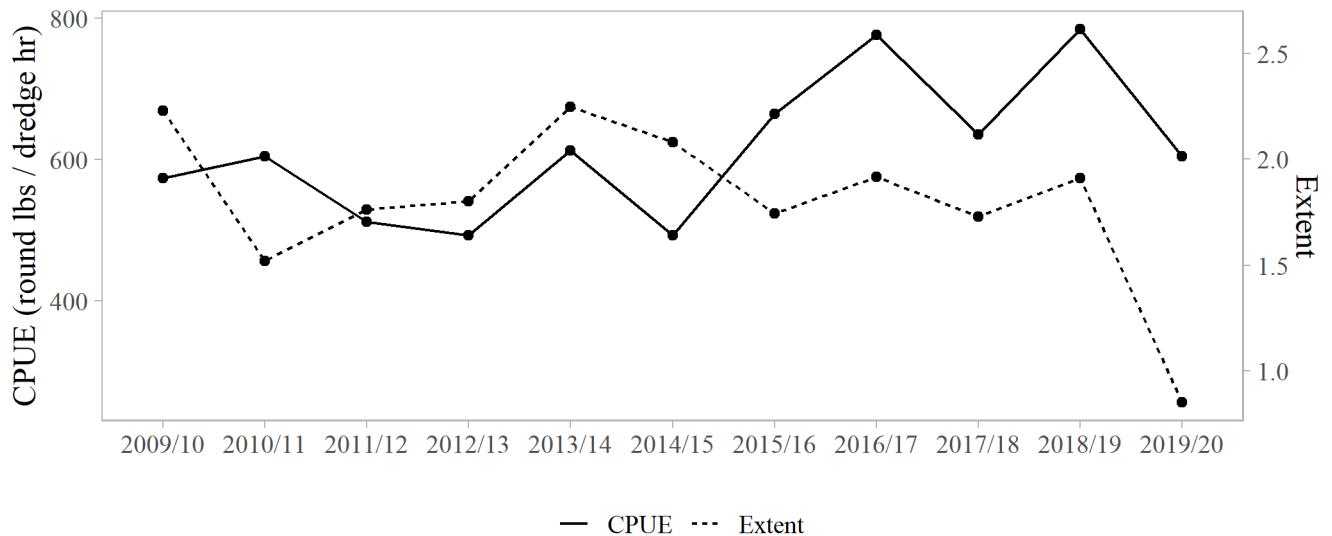


Figure 121: Nominal CPUE (round lbs / dredge hr) (solid line) and relative spatial extent of fishing effort (dotted line) within area D district by season

Table 41: Area D nominal and standardized CPUE estimates (round lbs / dredge hour) by season.

Season	Nominal CPUE			Standardized CPUE
	(total)	(median)	(sd)	
2009/10	573.32	552.33	264.64	607.43
2010/11	604.57	566.67	254.66	566.73
2011/12	511.42	508.25	203.78	482.90
2012/13	492.56	465.93	224.61	498.38
2013/14	612.56	593.93	267.74	656.45
2014/15	492.36	473.85	213.31	590.31
2015/16	664.56	643.50	249.46	760.85
2016/17	776.56	678.93	354.23	873.43
2017/18	635.24	594.93	286.71	685.97
2018/19	784.12	767.22	369.04	864.20
2019/20	604.04	577.60	237.04	631.45

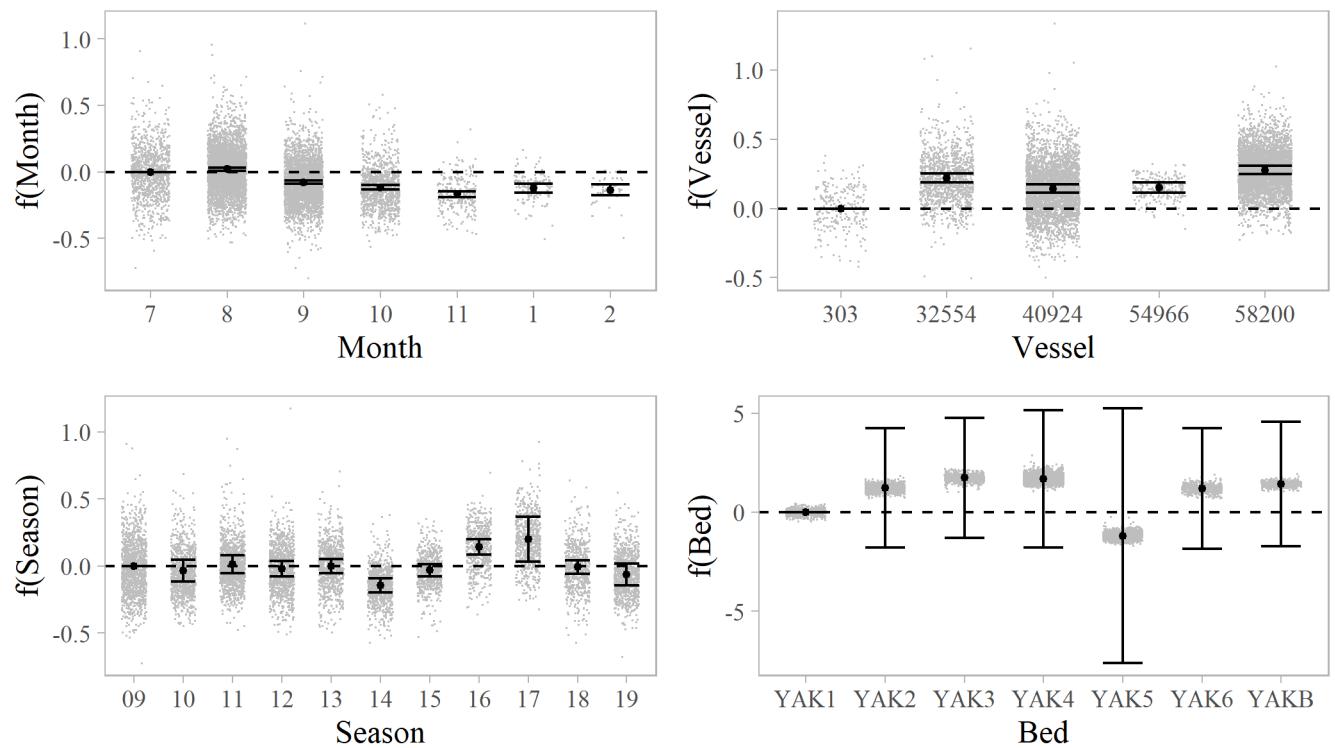


Figure 122: Partial effects of Month, Vessel, Season, and Bed on CPUE within area D. Season values represent the last two digits of the year the fishery opened.

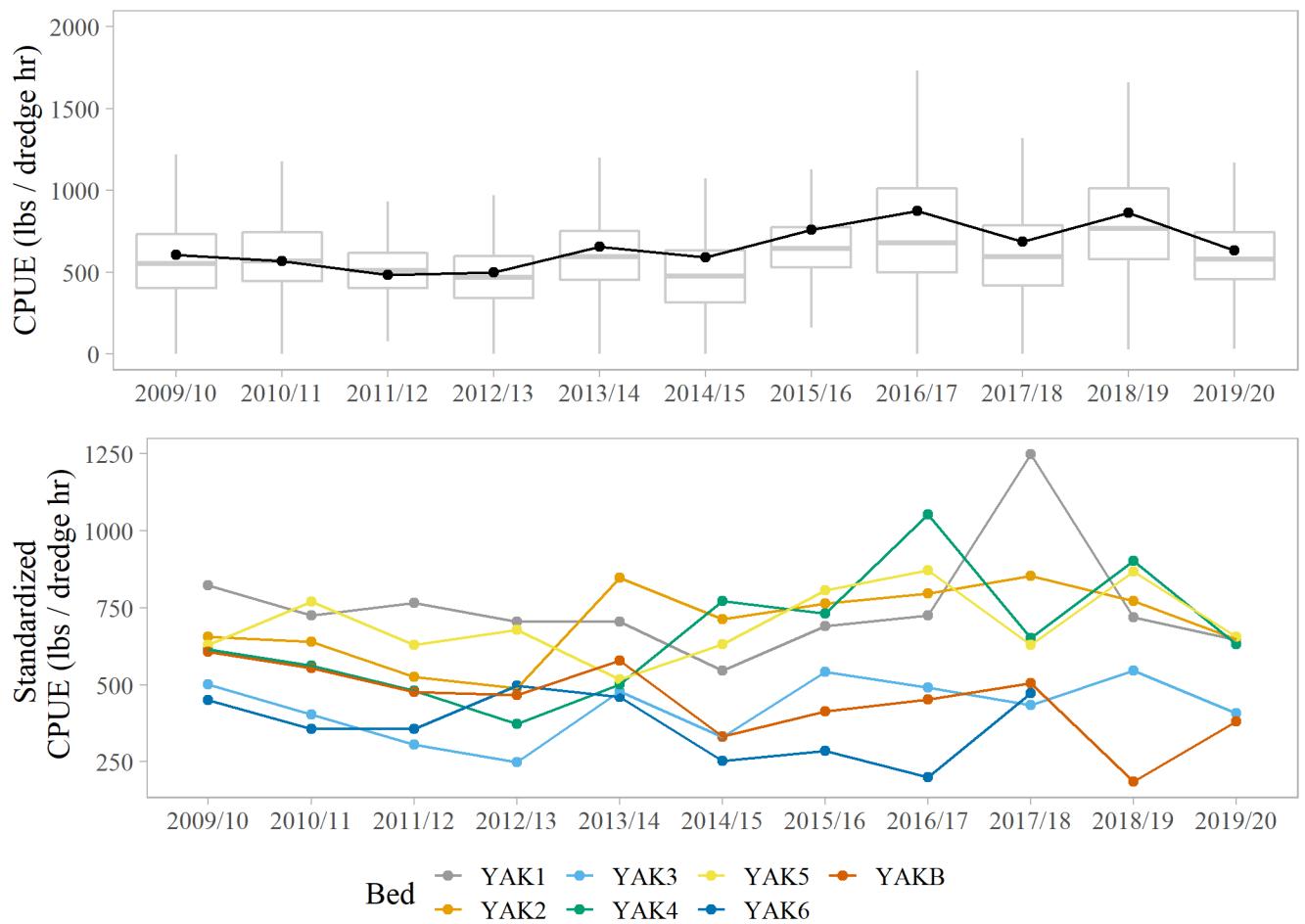


Figure 123: Boxplots of nominal CPUE (round lbs / dredge hr) overlaid with standardized CPUE (round lbs / dredge hr) by season (black line) (top) and standardized CPUE by bed and season (bottom) within area D.

10.2 Fishery discards

Estimated scallop discards during the 2019/20 season were 564,085 round weight lbs (1,704,553 scallops) in area D (Table 42, Figure 124). Discard ratio (lbs discarded:lbs retained, 0.28) doubled from the 2018/19 season (0.11) (Table 42, Figure 125). The rate of clapper catch increased substantially from the 2018/19 season (Tables 43, Figure 126). Intact discards outweighed broken discards in most hauls (Figure 127).

Table 42: Area D discard summary including total retained catch (round weight), total estimated discards (round weight and count), discard ratio (lbs discarded : lbs retained), associated discard rates (lbs or count per dredge hr), and estimated discard mortality.

Season	Retained (lbs)	Discarded (lbs)	Discarded (count)	Discard ratio	Discard rate (lbs)	Discard rate (count)	Discard mortality (lbs)	Discard mortality (count)
2009/10	2,514,004	698,303	1,203,448	0.28	159	274	139,661	240,690
2010/11	2,163,050	595,071	2,021,093	0.28	166	565	119,014	404,219
2011/12	2,380,618	567,361	1,713,437	0.24	122	368	113,472	342,687
2012/13	1,989,071	575,164	2,199,616	0.29	142	545	115,033	439,923
2013/14	1,853,114	252,104	773,345	0.14	83	256	50,421	154,669
2014/15	1,555,495	138,716	368,960	0.09	44	117	27,743	73,792
2015/16	1,708,707	182,817	420,416	0.11	71	164	36,563	84,083
2016/17	1,637,710	251,181	705,475	0.15	119	335	50,236	141,095
2017/18	1,841,714	407,477	1,047,967	0.22	141	361	81,495	209,593
2018/19	1,777,744	198,606	515,219	0.11	88	227	39,721	103,044
2019/20	1,989,202	564,085	1,704,553	0.28	171	518	112,817	340,911

Table 43: Area D clapper summary including total dredge hours, clapper rate, and total estimated clappers (count) by season.

Season	Dredge hours	Clappers	
		(rate)	(count)
2009/10	4,385	9.53	41,788
2010/11	3,578	15.16	54,251
2011/12	4,655	13.18	61,348
2012/13	4,038	11.06	44,662
2013/14	3,025	8.58	25,947
2014/15	3,159	4.61	14,564
2015/16	2,571	6.53	16,786
2016/17	2,106	5.98	12,596
2017/18	2,899	2.76	8,012
2018/19	2,267	2.71	6,144
2019/20	3,293	20.00	65,856



Figure 124: Total discarded scallops as round weight (top) and number of count (bottom) for each district by season.

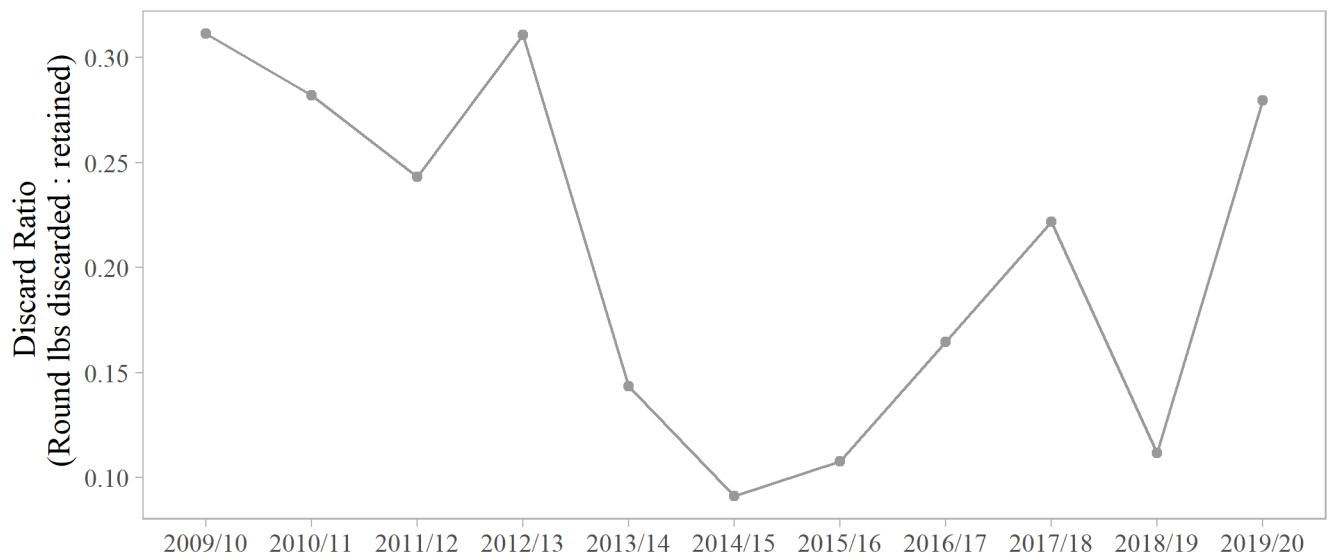


Figure 125: Scallop discard ratio (round weight discarded : retained) for each district by season.

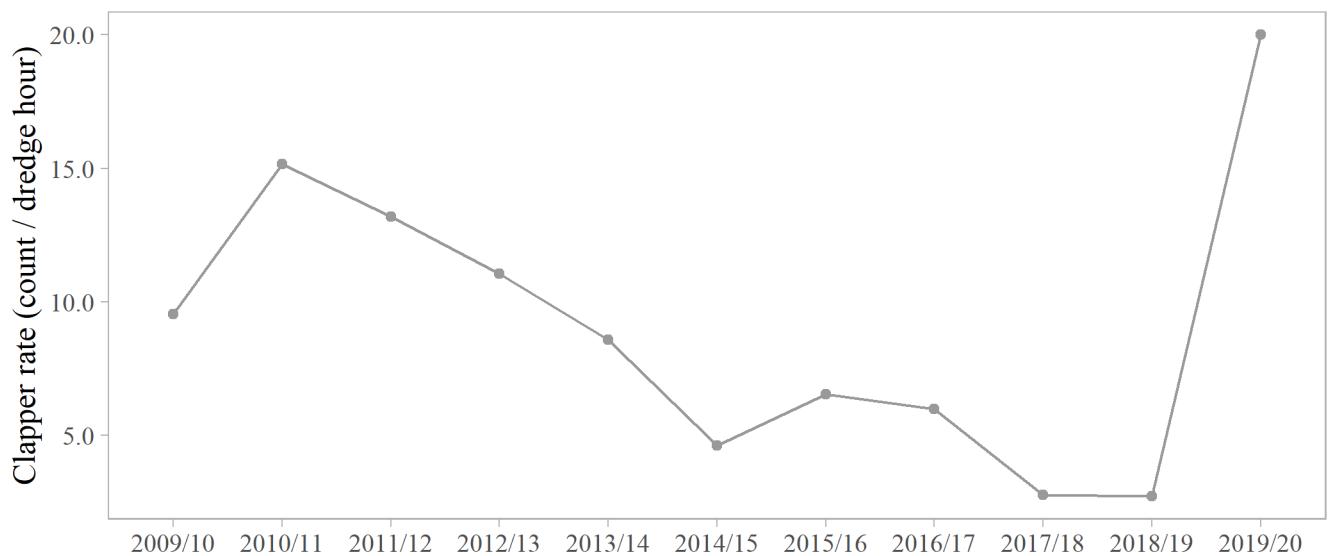


Figure 126: Rate of clapper catch by season in area D.

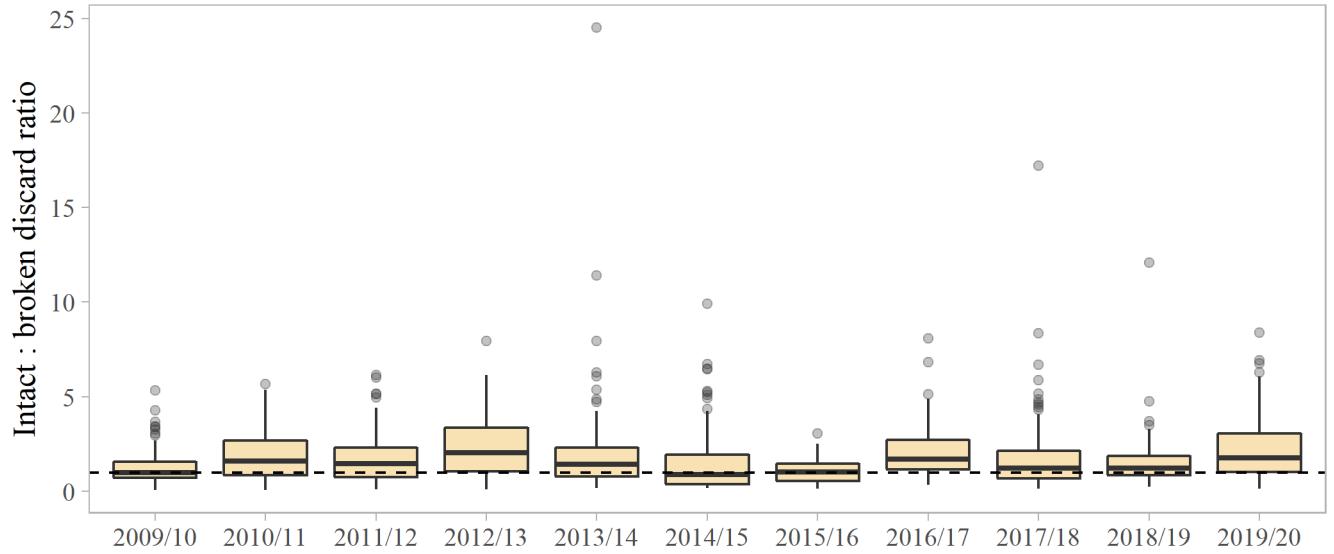


Figure 127: Boxplots of the ratio between intact and broken scallop discards in every haul within area D. The dotted line represents a 1:1 ratio.

10.3 Fishery bycatch

Area D does not utilize crab bycatch limits for any species. Halibut and Dungeness crab experienced the greatest total bycatch during the 2019/20 season, though historically, Tanner crab has dominated bycatch (Table 44, Figure 128 - 129). No red king crab were caught during the 2019/20 season. Overall, bycatch ratios (bycatch count:lbs retained meats) were low for all species (< 0.01) (Table 44, Figure 129). Only *Chionoecetes* crabs are measured for carapace width. Tanner crab bycatch was composed of all small, immature crab (Figure 130).

Table 44: Area D bycatch summary including total number caught for each species.

Season	Scallop GHL	Tanner crab (total)	Tanner crab (ratio)	Red King crab (total)	Red King crab (ratio)	Dungeness crab (total)	Dungeness crab (ratio)	Pacific halibut (total)	Pacific halibut (ratio)
2009/10	185,000	12,310	0.07	0	0.00	112	0.00	645	0.00
2010/11	185,000	15,492	0.10	0	0.00	19	0.00	148	0.00
2011/12	185,000	11,191	0.07	0	0.00	136	0.00	521	0.00
2012/13	145,000	13,263	0.09	0	0.00	45	0.00	335	0.00
2013/14	145,000	28,727	0.19	0	0.00	56	0.00	383	0.00
2014/15	145,000	1,319	0.01	1	0.00	35	0.00	245	0.00
2015/16	145,000	2,105	0.02	0	0.00	109	0.00	236	0.00
2016/17	125,000	918	0.01	0	0.00	262	0.00	202	0.00
2017/18	145,000	2,183	0.02	0	0.00	710	0.00	324	0.00
2018/19	145,000	709	0.00	0	0.00	275	0.00	206	0.00
2019/20	155,000	260	0.00	0	0.00	480	0.00	590	0.00

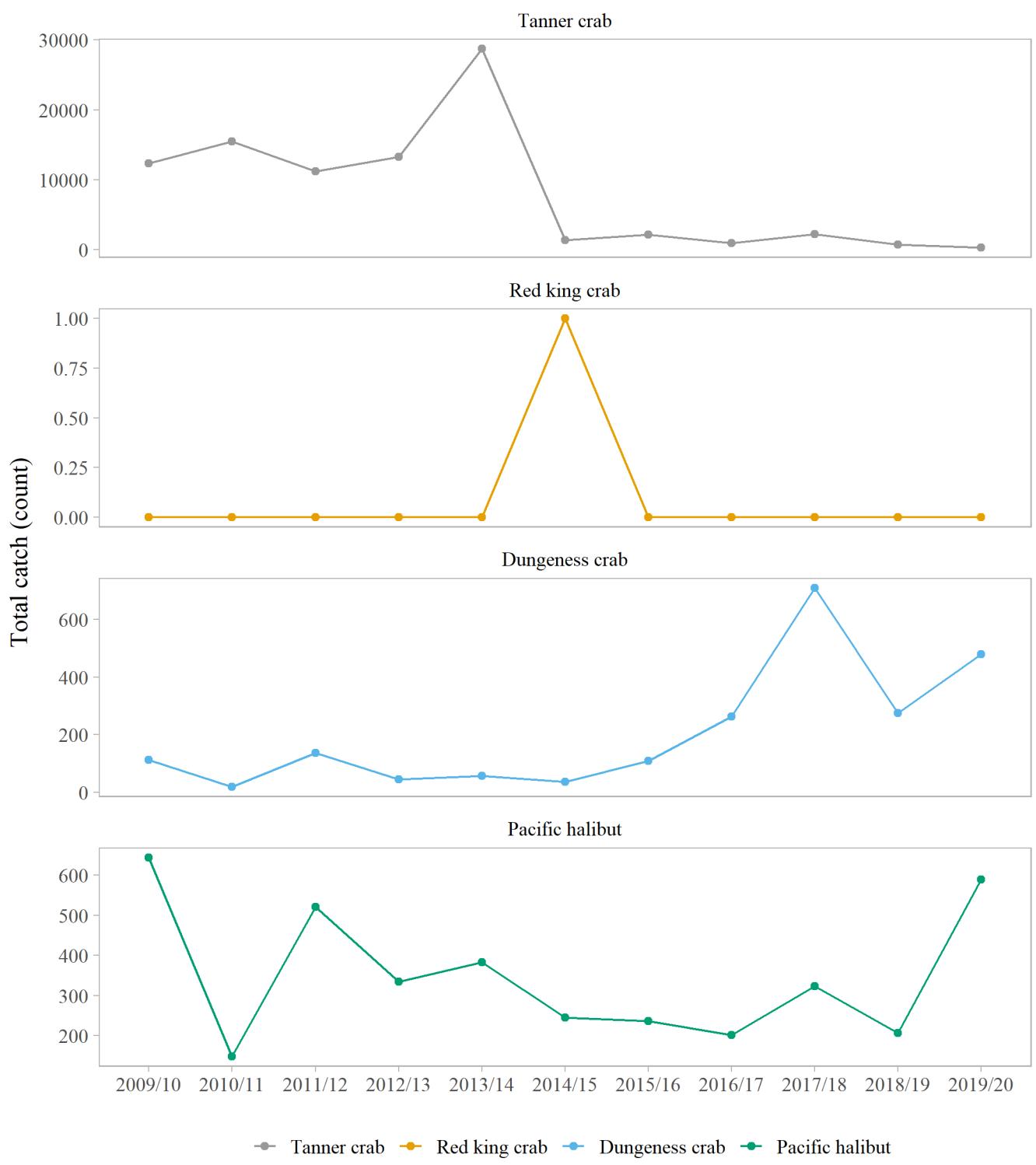


Figure 128: Total bycatch of Tanner crab, red king crab, Dungeness crab, and Pacific halibut by fishing season within area D.

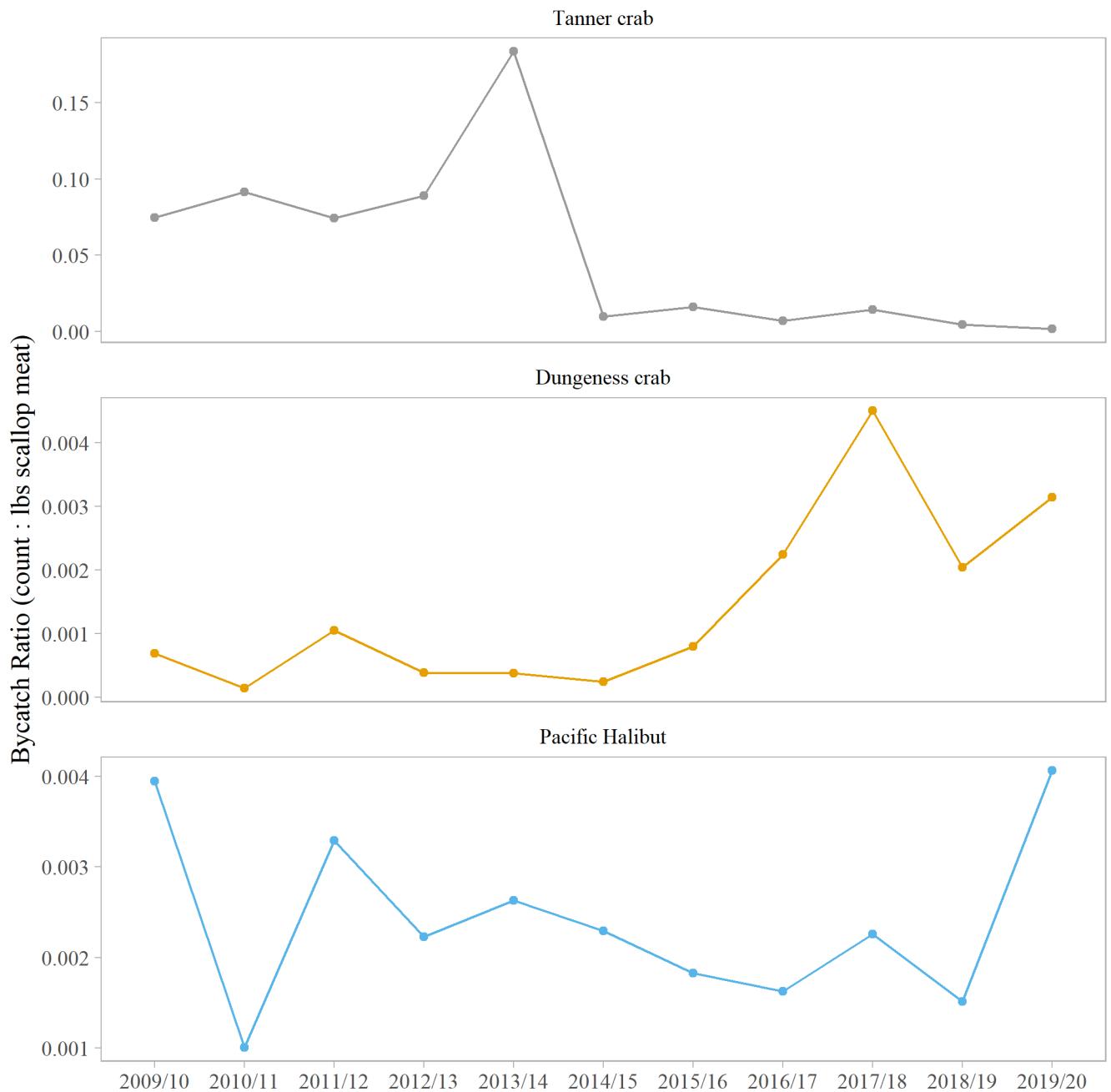


Figure 129: Bycatch ratio, expressed as number of Tanner crab, Dungeness crab, or Pacific halibut per pound of scallop meat weight, by year and district within area D

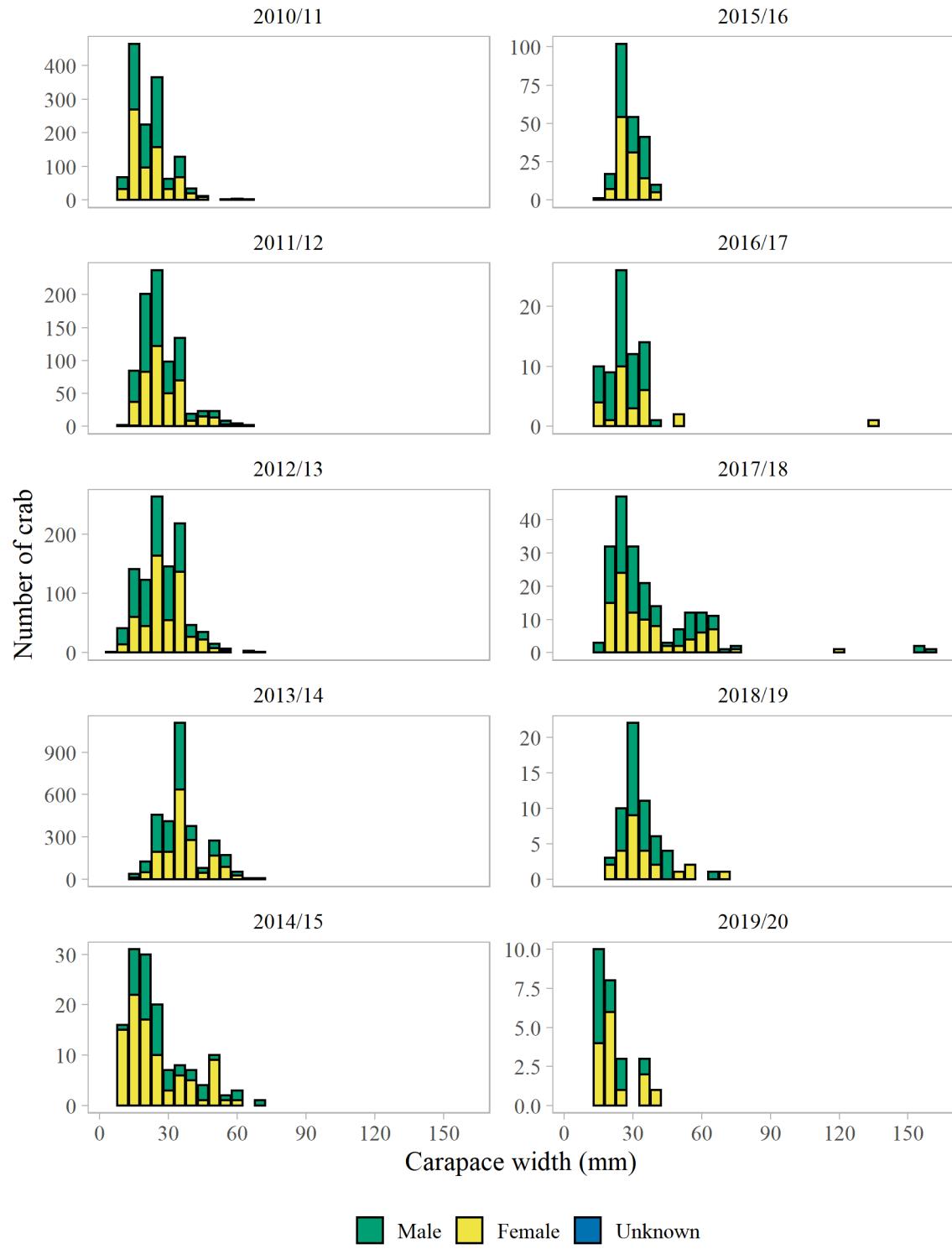


Figure 130: Size frequency histogram of the number of Tanner crab caught by sex during each season in area D.

10.4 Fishery biological information

Shell height composition of catch in area D remained similar to what was observed in 2018/19, one or possibly two strong cohorts overlapping in size between 100 - 150 mm (Figure 131).

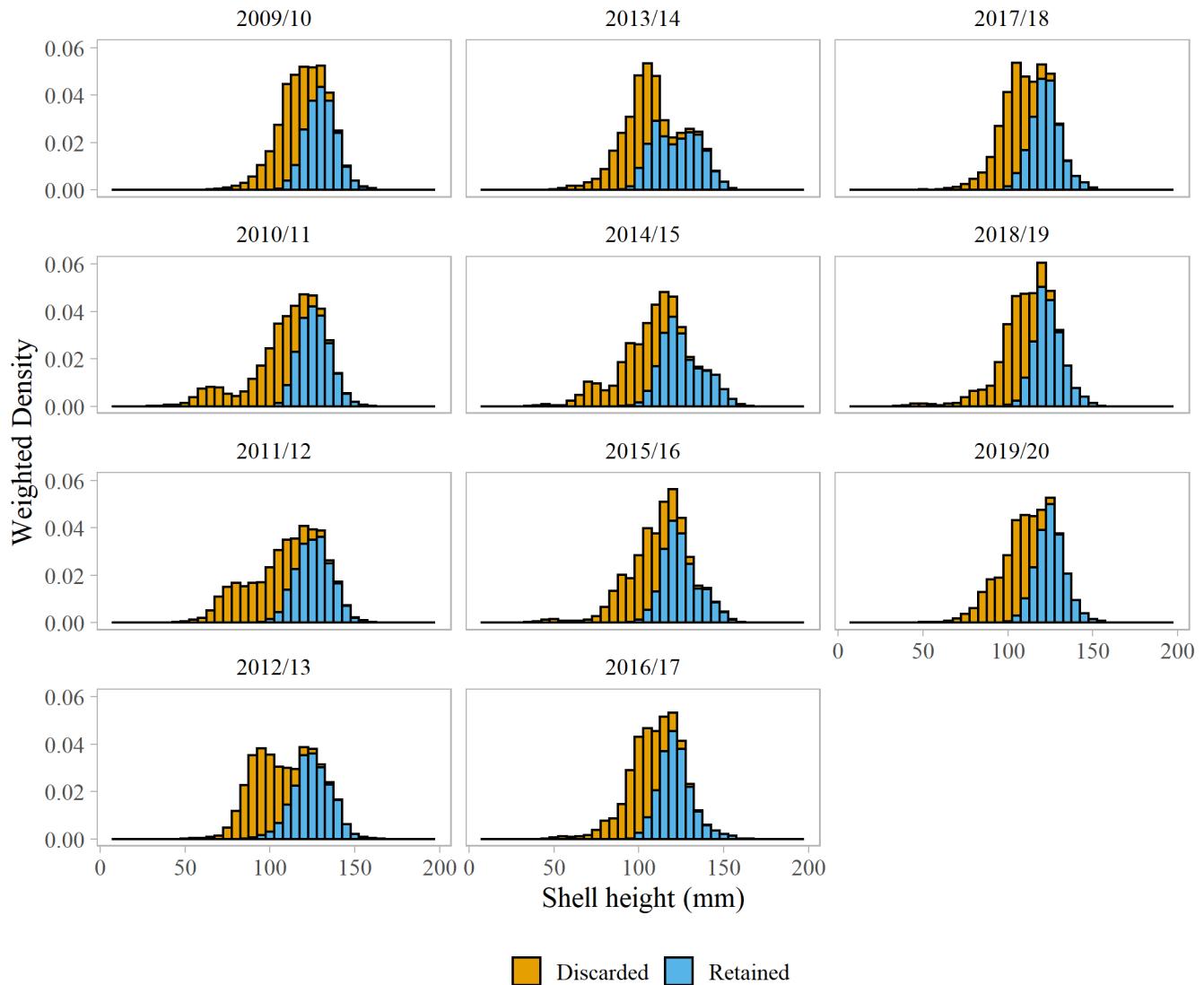


Figure 131: Shell height composition of scallops caught within area D in 5mm bins expressed as a weighted probability density function.

As with area K, the effect of season on allometric growth parameters of the meat weight \sim shell height relationship in area D was significant without random effects ($\alpha_2, p = 0.03$; $\beta_2, p = 0.02$), but not after incorporating random effects on α by bed ($\sigma = 0.08$) ($\alpha_2, p = 0.16$; $\beta_2, p = 0.12$). The shift in this relationship was less obvious than observed in area K, though it was noted by fisherman and was corroborated by data collected during the 2019 dredge survey (Table 45, Figure 132 - 133).

Table 45: Allometric growth parameters characterizing the meat weight, shell height relationship in area D by season.

Season	α	β
2018/19	2.58e-05	2.771
2019/20	1.29e-04	2.405

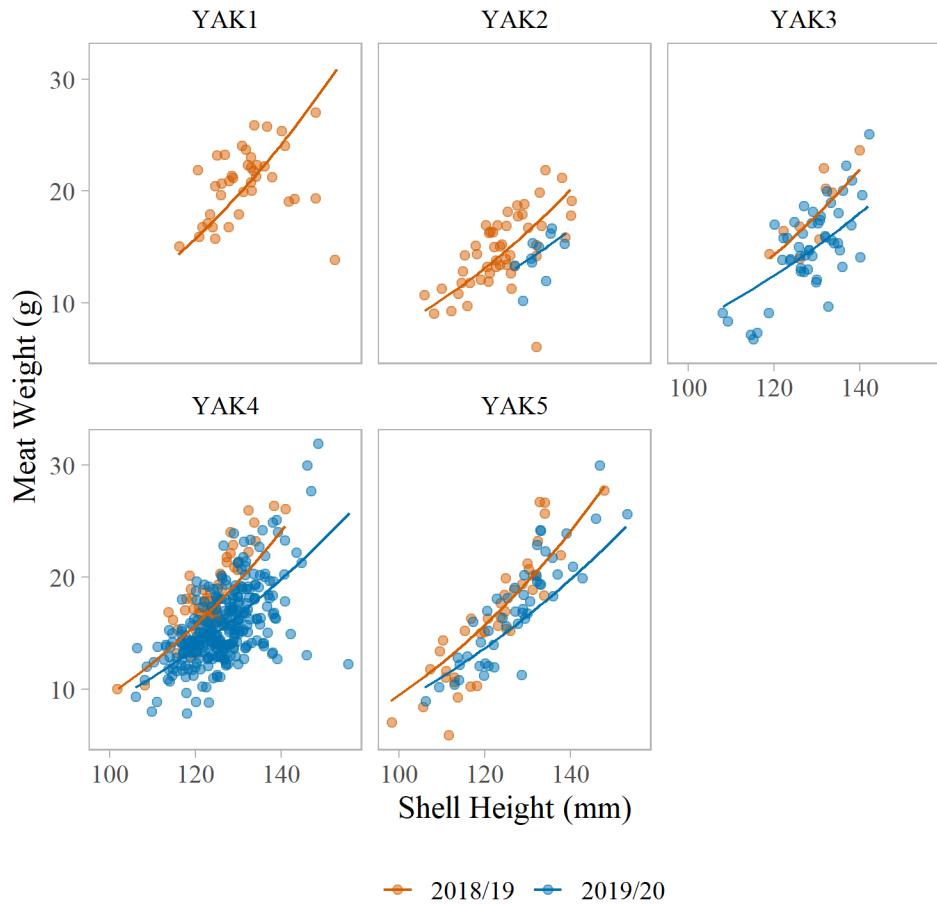


Figure 132: Individual meat weight (g) as a function of shell height (mm) for scallops caught in area D during the 2018/19 and 2019/20 seasons, by bed.

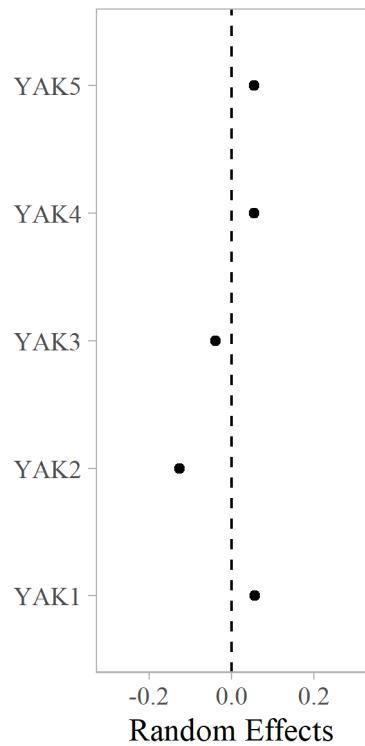


Figure 133: Random effects on the parameter α by bed.

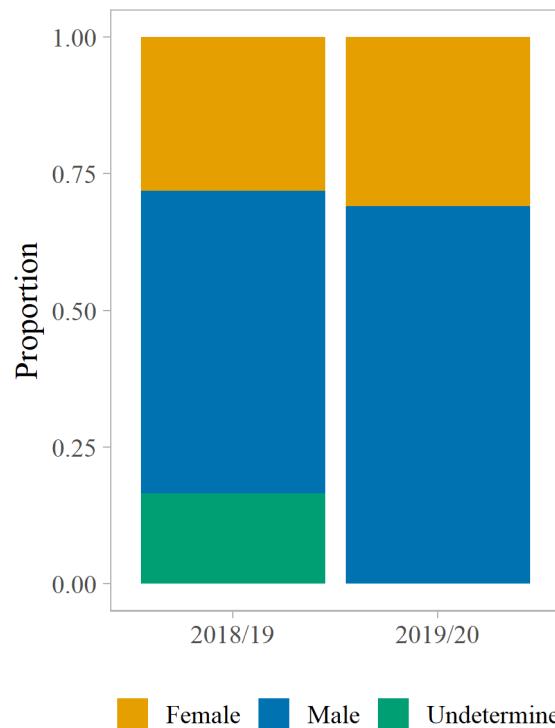


Figure 134: Proportion by sex in area D.

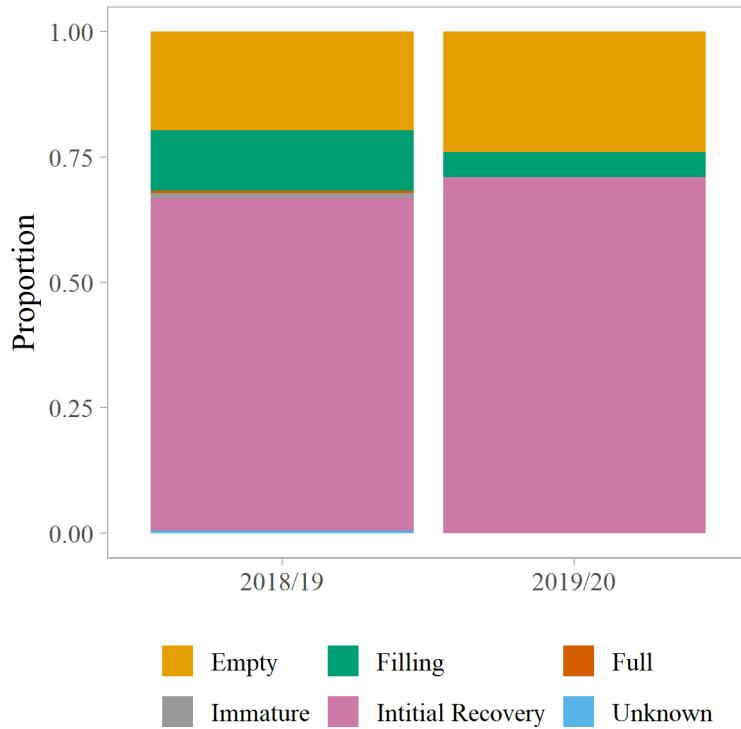


Figure 135: Proportion by gonad condition in area D.

11 Statewide

11.1 Catch and GHL units: meat weight vs round weight

The weathervane scallops fishery is currently managed in units of shucked meat weights, though there is interest in giving additional consideration to round weight and/or number of animals in management decision making, as those metrics more accurately represent total biomass (or number of animals) caught during the fishery. As a general conversion, individual meat weight is roughly assumed to be 10% of round weight (NPFMC 2014). Individual weights of whole animals and shucked meats from the ADF&G Statewide dredge survey (2016 - 2019), suggests 10% may be a slight over estimate of meat weight with the actual ratio (using all available data) is approximately 9.1% (Figure 136).

In fishery data collection, round weight of each haul is estimated by extrapolating the number of full bushels of retained scallops record by either the vessel captain or onboard observer, by the average weight of a full bushel as measured by the observer. Meat weight of each haul is estimated by dispersing the daily total retained meats to individual hauls proportional to retained round weight of each haul. Preliminary examination of this data suggest that on average retained meats account for less than 10% of retained round weight (Figure 137), suggesting that not all shucked meats are retained, or, that weight is lost during onboard processing that is not lost during sample preservation on the dredge survey. The exact ratio is variable by haul, season, and district (Figure 138). Moving towards a stock assessment based on round weight biomass and translating biological reference points to management decisions will require refined analysis of the meat weight ~ round weight relationship.

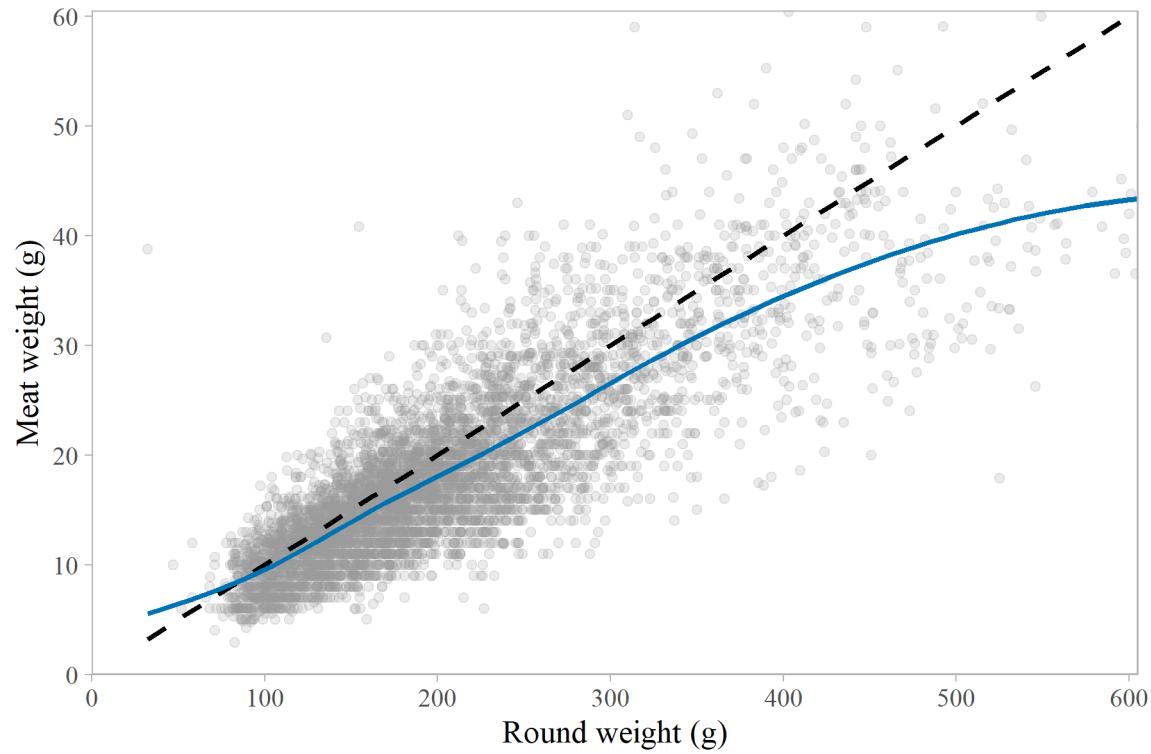


Figure 136: Individual meat weight (g) as a function of round weight (g) for all scallops weighted during the dredge survey from 2016 - 2019. The dashed line represents a ratio of 0.1 and the solid blue line is a LOESS curve fitting the data.

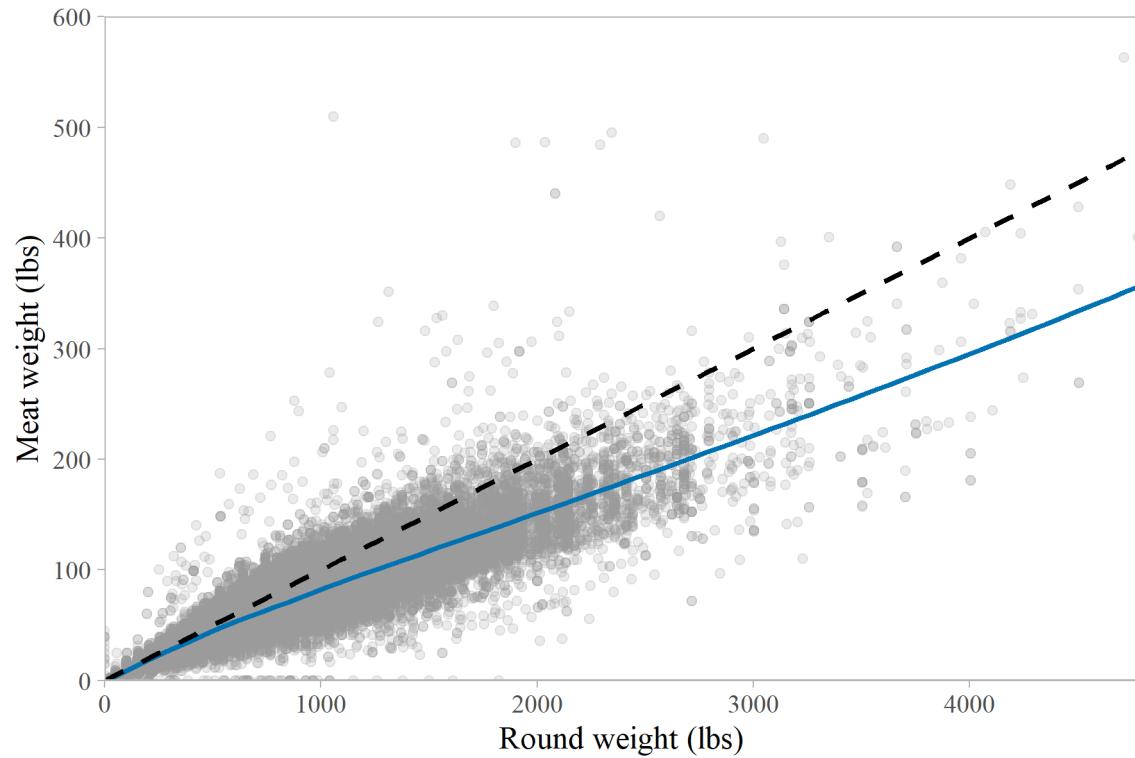


Figure 137: Retained meat weight (lbs) as a function of round weight (lbs) for all hauls in the statewide scallop fishery from 2009/10 - 2019/20. The dashed line represents a ratio of 0.1 and the solid blue line is a LOESS curve fitting the data.

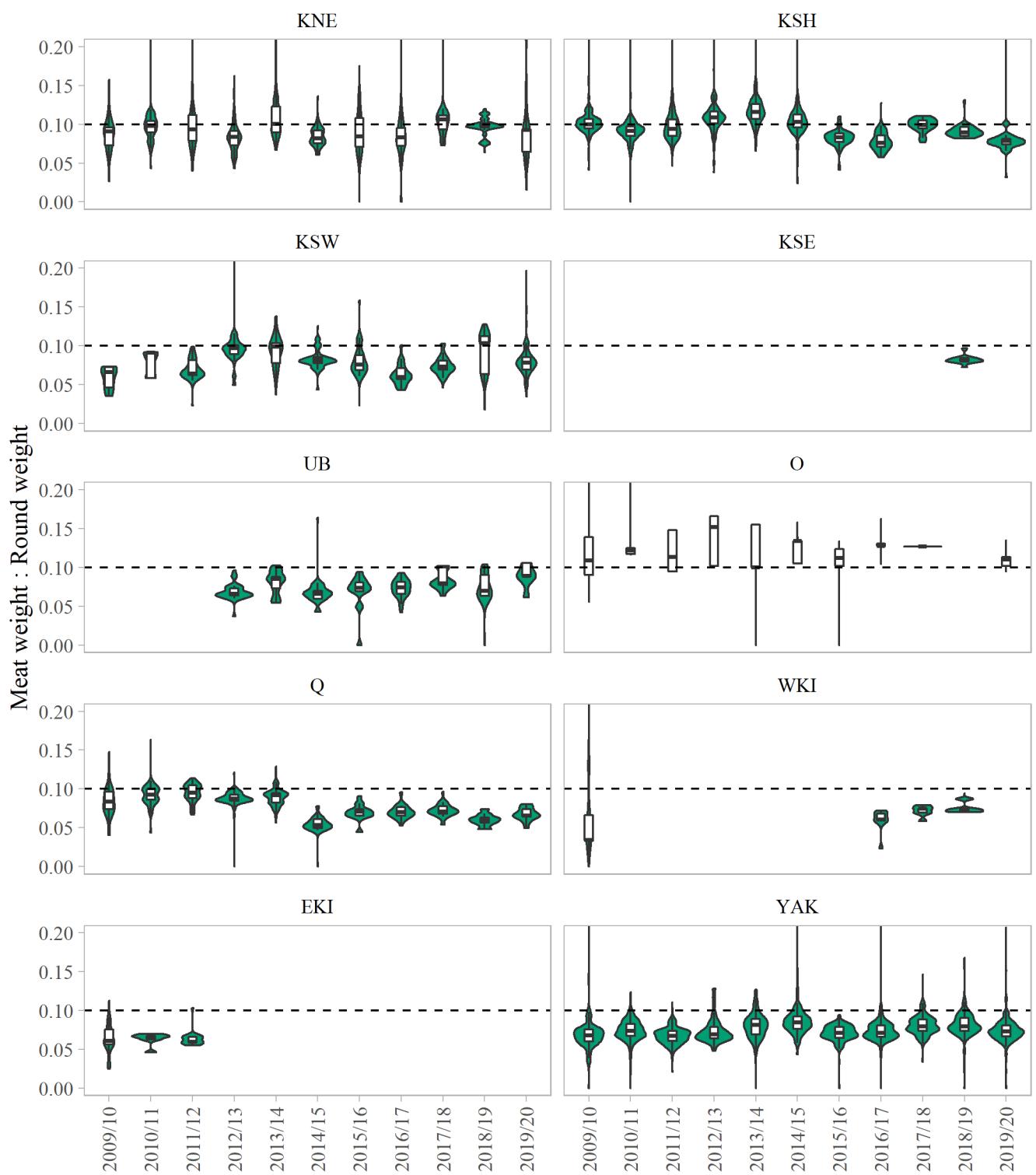


Figure 138: Violin plots of retained meat weight (lbs):round weight (lbs) for all hauls in the statewide scallop fishery from 2009/10 - 2019/20, by district and season. District C and KSEM are excluded from this figure. The dashed line represents a ratio of 0.1.

11.2 Fishery Performance

Fishery performance among all districts is below the statewide 11 year timeseries (2009/10 - 2019/20) average, but the trend appears stationary (Figure 139). The statewide average discard ratio (rounds lbs discarded:retained) has increased since the 2014/15 season (Figure 140 - 141).

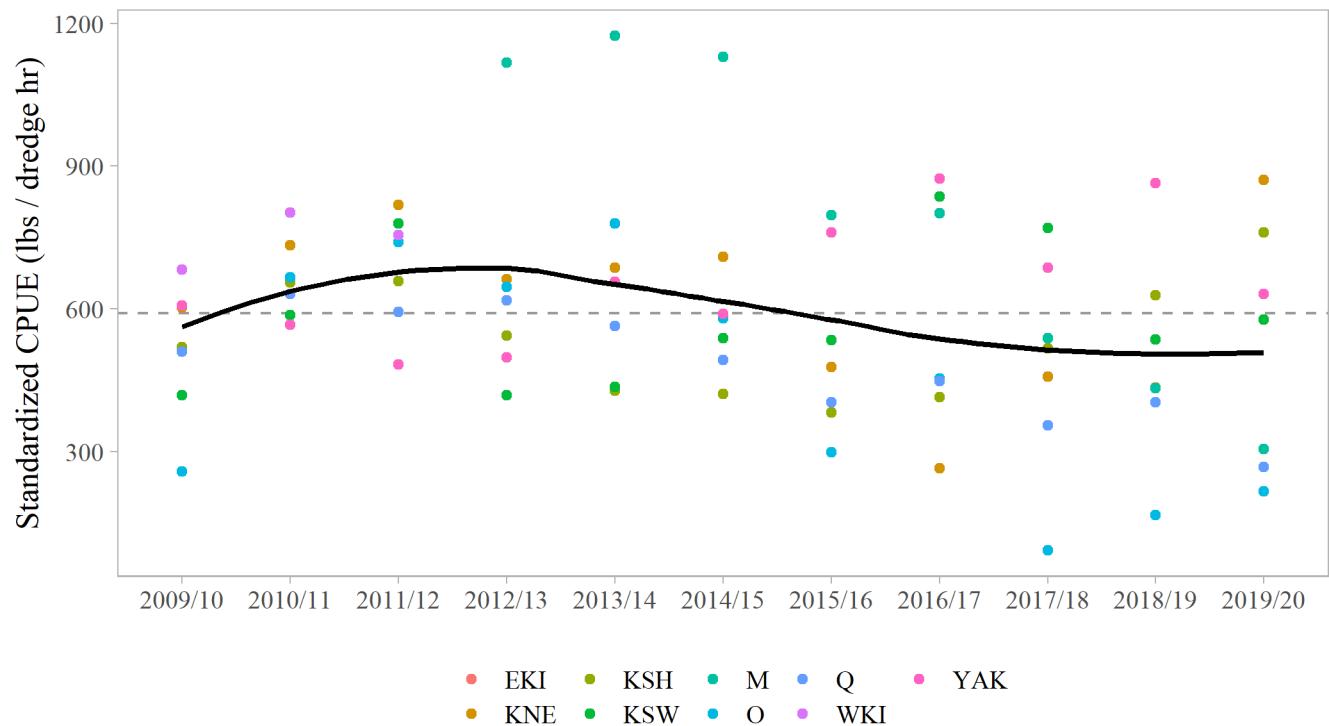


Figure 139: Standardized CPUE (round lbs / dredge hour) estimates for each district fished from 2009/10 - 2019/20. The dashed line represents the timeseries mean, and the solid line represents a LOESS curve fit to the data.

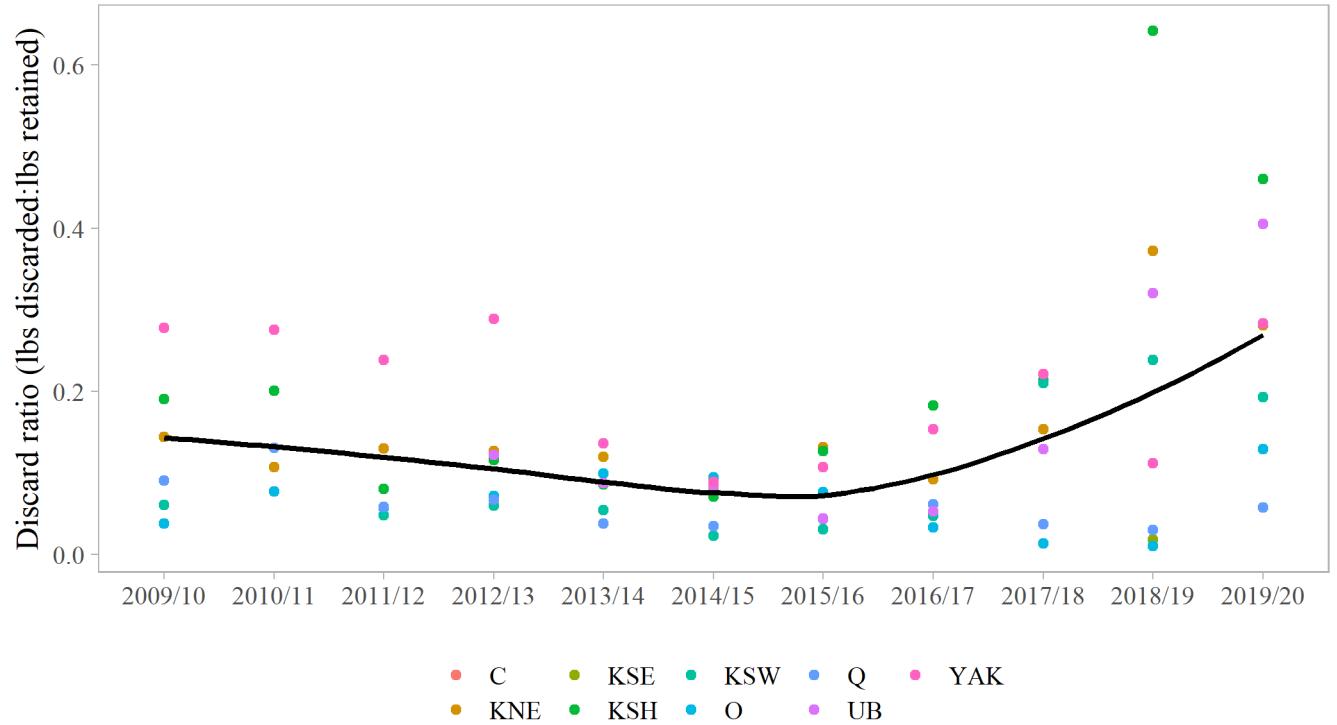


Figure 140: Discard ratio (round lbs discarded:retained) estimates for each district fished from 2009/10 - 2019/20. The dashed line represents the timeseries mean, and the solid line represents a LOESS curve fit to the data.

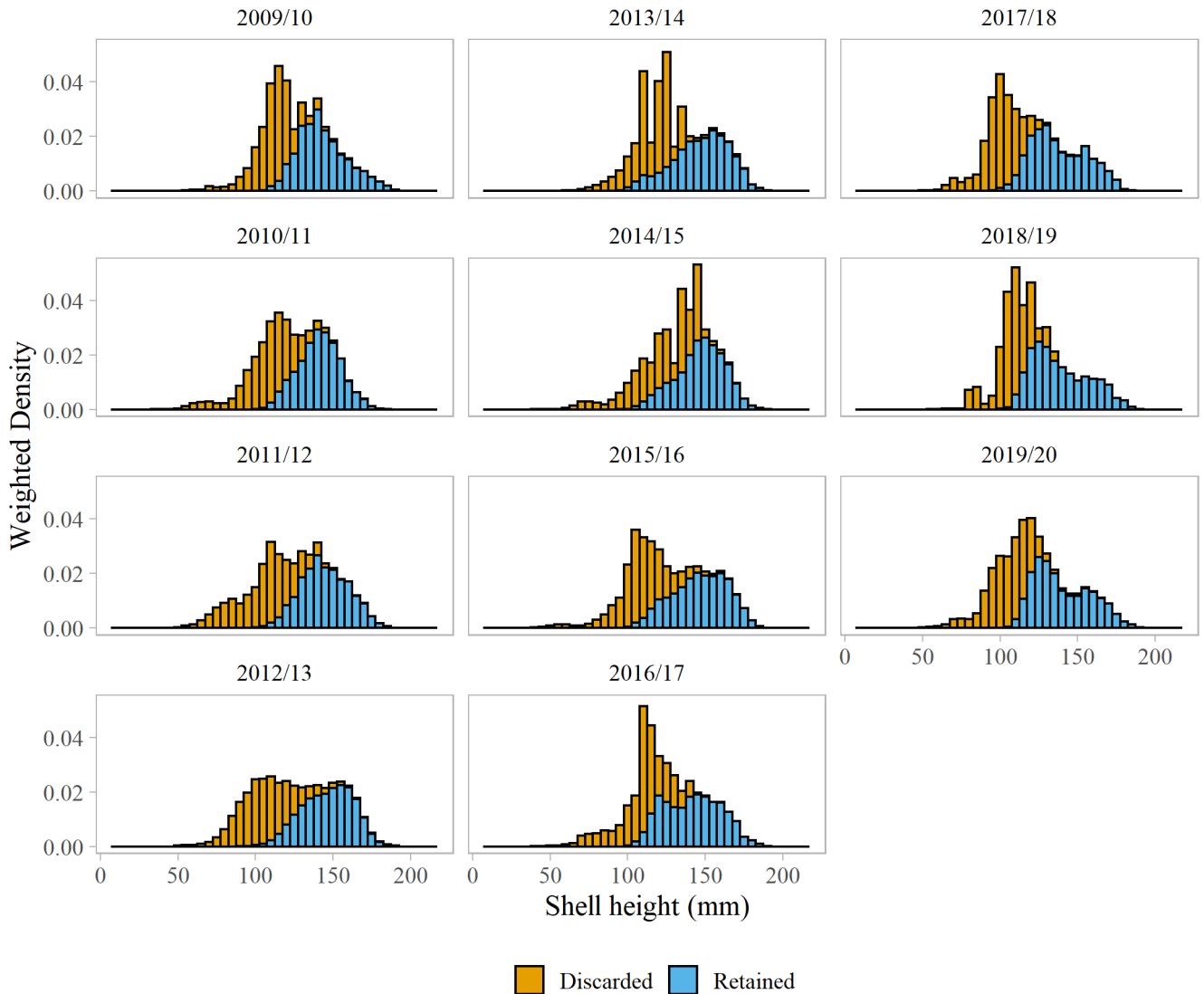


Figure 141: Statewide shell height (mm) composition from 2009/10 - 2019/20.

11.3 Ecosystem

The most recent Ecosystem Status Report for the Gulf of Alaska was published in 2019 (Zador and Yasumiishi 2019). The full document and executive summary can be found at <https://access.afsc.noaa.gov/REFM/REEM/ecoweb/>. Below are several bullets from this document relevant to the status of weathervane scallops and the associated community:

- Echinoderms have declined in the Shumagin and Chirikof areas during 2019 but appear relatively stable in the other regions.
- Motile epifauna biomass including eelpouts, octopi, crab, sea stars, brittle stars, sea urchins, sand dollars, sea cucumbers, snails, and hermit crabs has increased from 2017.
- Summer sea surface temperature has increased.
- GOA groundfish fisheries bycatch of assorted invertebrates (including bivalves) is trending down.

Data collected specific to scallop and bivalve communities is sparse. Average summer bottom temperature recorded during the NMFS RACE Gulf of Alaska survey in 2019 was higher than average for all scallop districts (Figures 142 - 143).

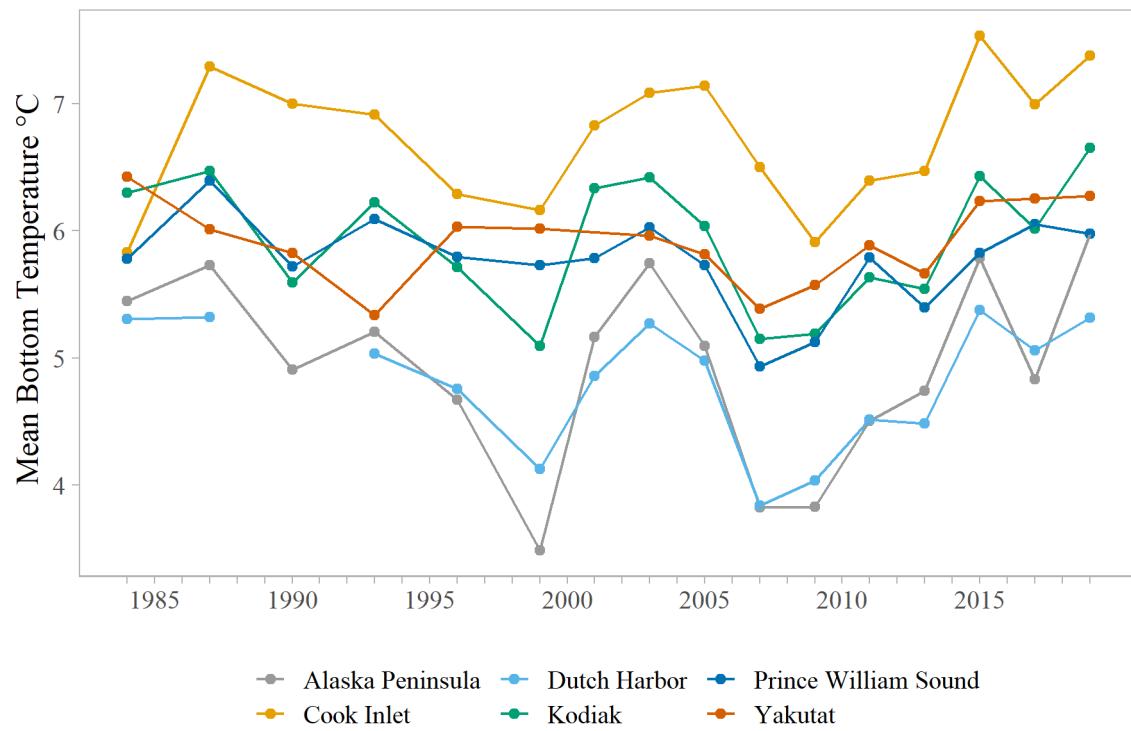


Figure 142: Bottom temperature as measured during the NMFS RACE Gulf of Alaska survey.

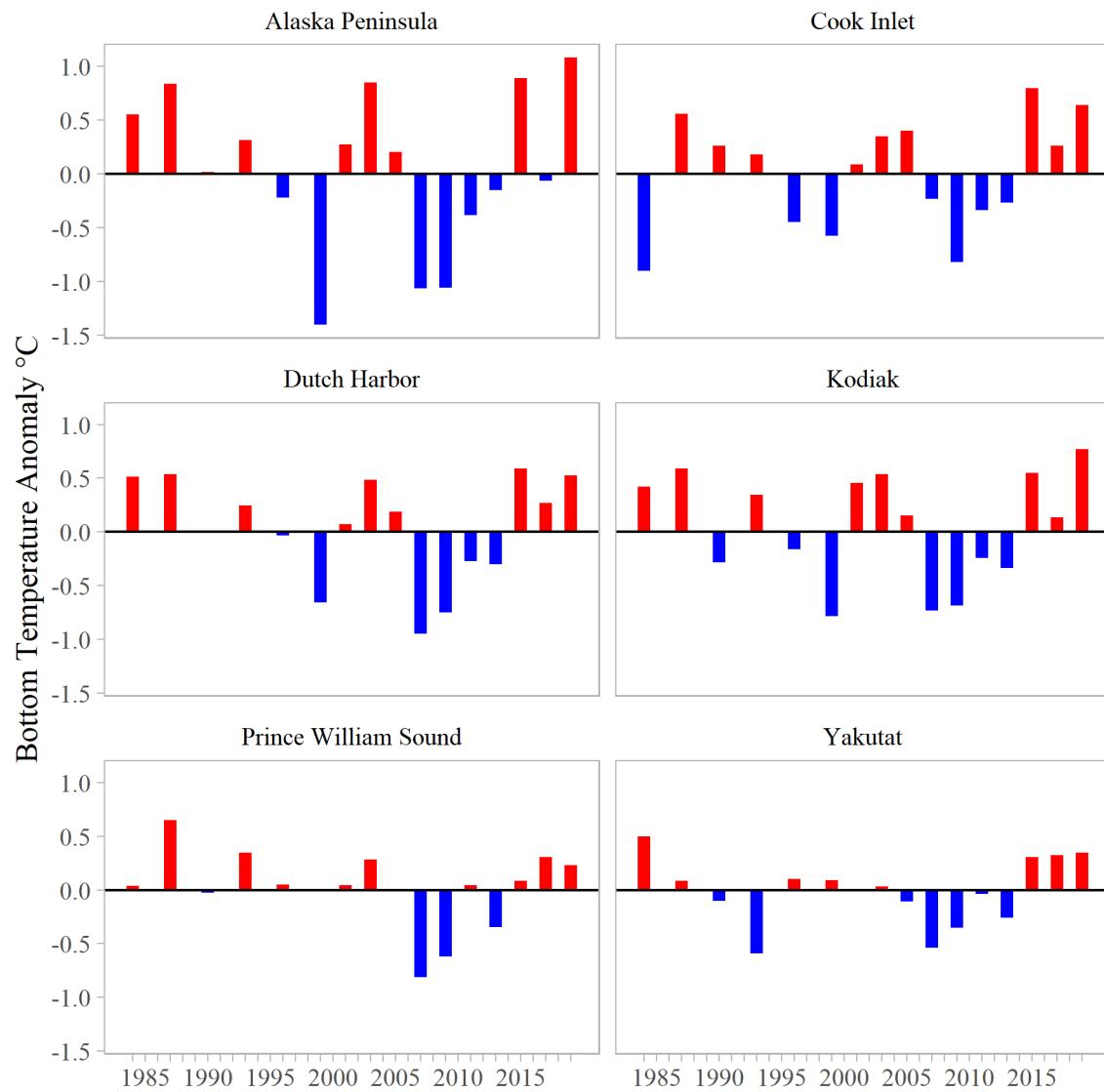


Figure 143: Bottom temperature anomaly based on the full timeseries average (1984 - 2019).

12 Acknowledgements

Thank you to the ADF&G Shellfish Observer program staff (Ryan Burt, Alyssa Hopkins, Bo Whiteside, Mark Stichert), Joe Chaszar, 2019/20 observers (Alex Hoover and Sean Rogers), Ric Shepard, Ben Williams, Katie Palof, as well as ADF&G research biologists (Mike Byrely, Chris Russ) and fishery managers (Nat Nichols, Miranda Westphal, Andrew Olson, Natura Richardson, Ethan Nichols, Asia Beder) for without whom this document would not be possible. Finally, thank you to the F/V Provider and F/V Ocean Hunter for releasing fishery data.

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