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Supplementary material

Geostatistical tools to assess shifts in recreational fishing

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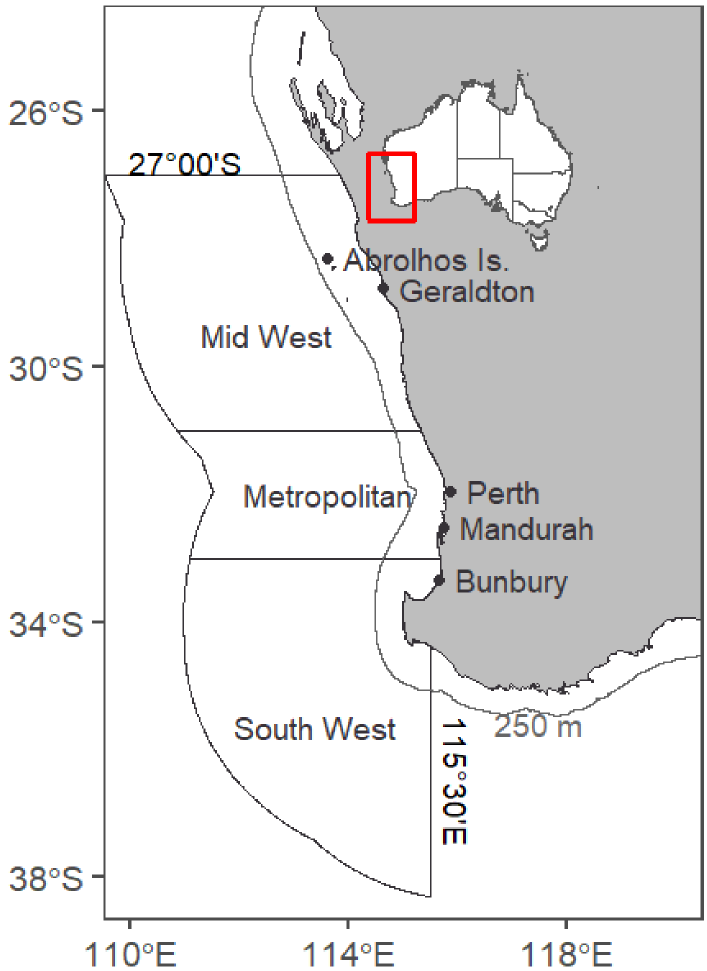


Fig. S1. Study area within the West Coast Bioregion of Western Australia with management zones for the West Coast Demersal Scalefish Resource

Table S1. Spatial indices application with reference to relevant studies.

Reference application	Spatial indices
Capture and detect spatial changes in European Hake in the Bay of Biscay through time using trawl survey data to inform stock assessments and quota allocation (Woillez *et al*. 2005).	CG, I, An, GIC, LIC, PA, SA, EA, NP
Demonstrating the ability of various indices to describe various fisheries using demersal trawl, dredge and acoustic survey data (Petitgas *et al*. 2017).	CG, I, An, GIC, LIC, PA, SA, EA, NP
Identify fish distribution trends in South Africa using three decades of demersal trawl survey data (Currie *et al*. 2019).	CG
Summarise the spatial distribution of saucer scallop recruits and residuals in Shark Bay, Western Australia using trawl survey data (Mueller *et al*. 2012).	CG, I, An
Quantify the spatial overlap of the yellow tail flounder and the American plaice in the Southern Grand Banks area using trawl survey data (Kulka *et al*. 2003).	CG, I, An, GIC, NP
Detect changes in the diversity distribution of demersal species across survey years in Western Australia using recreational fishing data (Aidoo 2016).	CG, GIC, LIC
Assess associations between eight demersal species distributions (juvenile and adult) with habitat characteristics in the Bay of Biscay from trawl survey data (Persohn *et al*. 2009).	SA
Develop map of spatially varying fish stocks with high-density values in the Bay of Biscay from fish stock acoustic survey data (Pierre Petitgas *et al*. 2018).	NP

Centre of gravity (CG), inertia (I), anisotropy (An), global index of collocation (GIC), local index of collocation (LIC), positive area (PA), spreading area (SA), equivalent area (EA) and number of spatial patches (NP).

Table S2. Summary statistics for retained and released CPUE across species and years. Minimum (Min.), maximum (Max.), standard deviation (s.d.), coefficient of variation (CV), the lower quartile (Q1) and the upper quartile (Q3).

Survey year	Min.	Max.	Mean	s.d.	CV	Q1	Median	Q3
All retained demersal species								
2011/12	0	1.2	0.2	0.2	0.8	0.1	0.2	0.3
2013/14	0	1.3	0.3	0.2	0.8	0.1	0.2	0.3
2015/16	0	1.1	0.3	0.2	0.7	0.1	0.2	0.3
2017/18	0	1.3	0.3	0.2	0.8	0.1	0.2	0.3
All released demersal species								
2011/12	0	1.9	0.4	0.3	0.9	0.2	0.3	0.5
2013/14	0	4.2	0.4	0.5	1.3	0.2	0.3	0.4
2015/16	0	7.3	0.4	0.8	1.9	0.2	0.3	0.4
2017/18	0	1.6	0.3	0.3	0.9	0.2	0.3	0.4
Retained West Australian dhufish								
2011/12	0	0.7	0.1	0.1	1.4	0	0	0.1
2013/14	0	1.3	0.1	0.2	1.8	0	0	0.1
2015/16	0	0.6	0.1	0.1	1.1	0	0.1	0.1
2017/18	0	0.4	0.1	0.1	0.9	0	0.1	0.1
Released West Australian dhufish								
2011/12	0	0.8	0.1	0.1	1.3	0	0.1	0.2
2013/14	0	2	0.2	0.3	1.9	0	0.1	0.2
2015/16	0	3.6	0.2	0.4	2.2	0	0.1	0.2
2017/18	0	0.6	0.1	0.1	1.2	0	0.1	0.2
Retained Baldchin groper								
2011/12	0	0.4	0.1	0.1	1.7	0	0	0.1
2013/14	0	0.3	0	0.1	1.6	0	0	0.1
2015/16	0	0.3	0	0.1	1.4	0	0	0.1
2017/18	0	1	0.1	0.1	2.2	0	0	0.1
Released Baldchin groper								
2011/12	0	1	0	0.1	3.4	0	0	0
2013/14	0	0.3	0	0.1	2.4	0	0	0
2015/16	0	0.2	0	0.1	1.7	0	0	0
2017/18	0	0.9	0	0.1	3	0	0	0

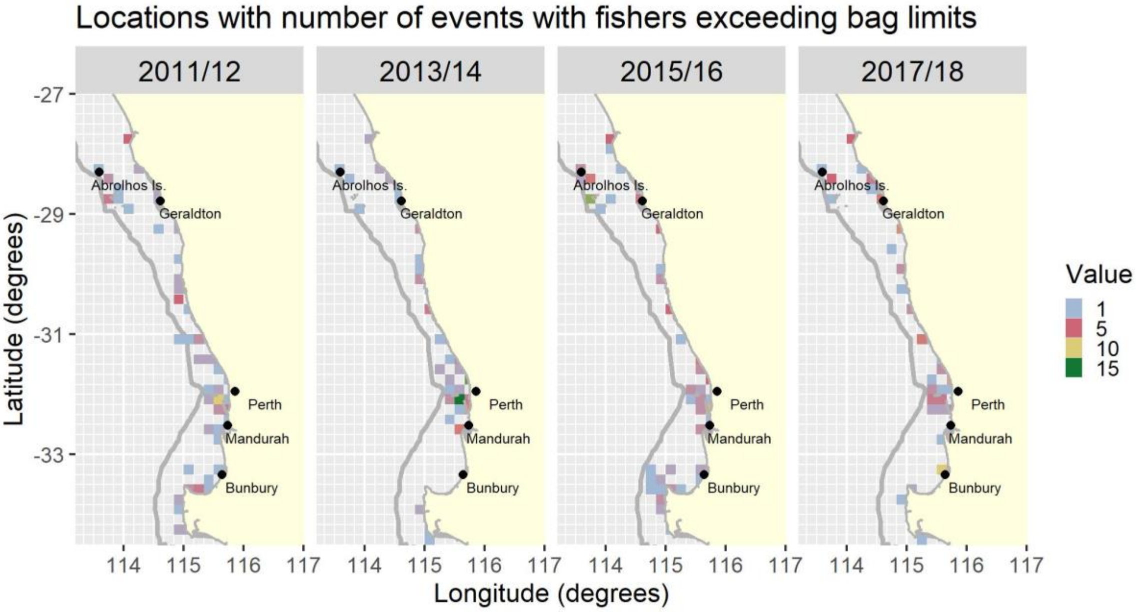
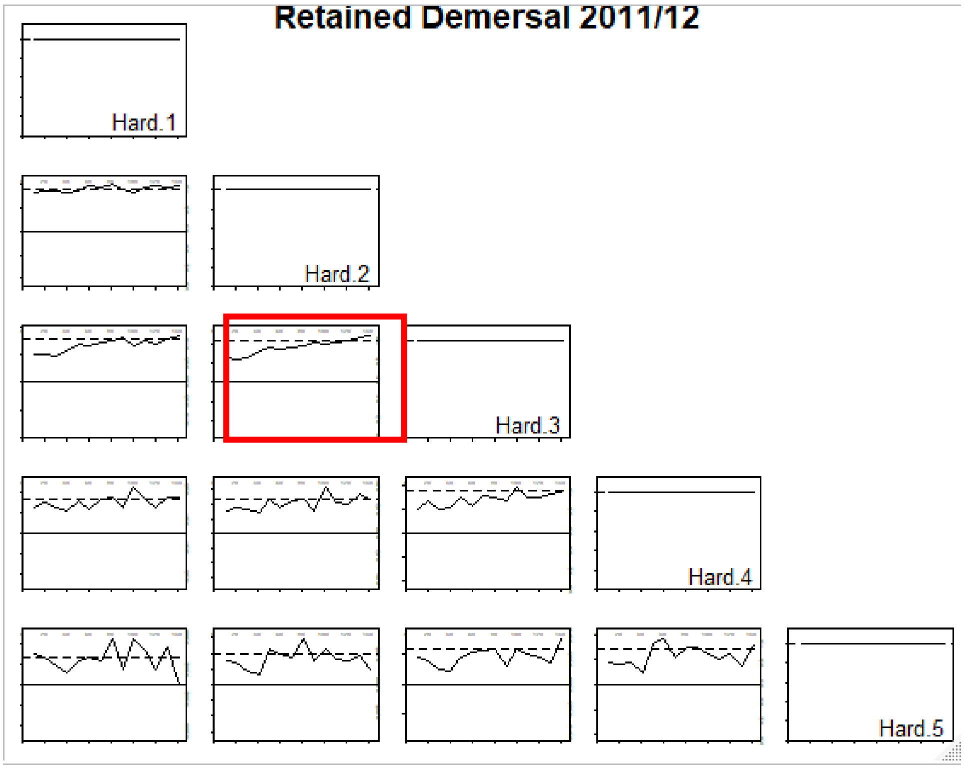
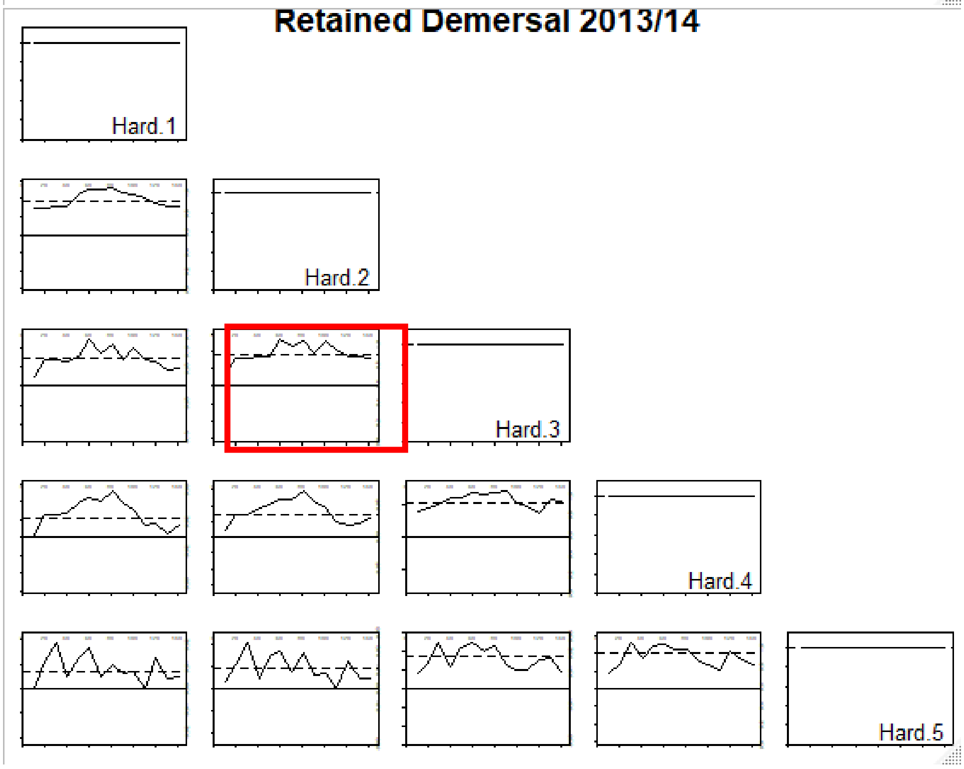


Fig. S2. Maps showing the number of events with fishers exceeding their mixed demersal species bag limit per block across survey years 2011/12, 2013/14, 2015/16 and 2017/18 (left to right) in the West Coast Bioregion.

Table S3. Indicators cut-offs with associated percentiles for retained and released (in brackets) demersal, WA dhufish and Baldchin groper CPUEs for survey years 2011/12, 2013/14, 2015/16 and 2017/18.

Year	CPUE	Demersal	WA dhufish	Baldchin groper
2011/12	0.001	36 (31)	25 (18)	45 (68)
	0.02	50 (43)	39 (25)	60 (82)
	0.08	79 (74)	73 (51)	81 (92)
	0.2	95 (89)	93 (85)	92 (94)
	0.4	99 (96)	98 (96)	99 (99)
	0.8	100 (100)	99 (98)	100 (100)
2013/14	0.001	33 (33)	17 (16)	43 (61)
	0.02	42 (35)	24 (21)	64 (76)
	0.08	79 (62)	67 (50)	84 (92)
	0.2	93 (87)	95 (82)	96 (97)
	0.4	98 (97)	99 (95)	99 (99)
	0.8	99 (98)	100 (98)	100 (100)
2015/16	0.001	18 (24)	11 (9)	38 (56)
	0.02	35 (31)	19 (15)	54 (72)
	0.08	67 (71)	72 (39)	82 (85)
	0.2	90 (89)	97 (79)	94 (98)
	0.4	97 (94)	99 (93)	99 (99)
	0.8	100 (98)	100 (98)	100 (100)
2017/18	0.001	19 (19)	10 (17)	33 (47)
	0.02	40 (24)	19 (23)	53 (67)
	0.08	79 (68)	64 (56)	81 (91)
	0.2	96 (94)	97 (85)	96 (98)
	0.4	98 (96)	99 (95)	98 (99)
	0.8	99 (100)	100 (100)	100 (100)


Retained Demersal 2011/12
Hard.1
Hard.2
Hard.3
Hard.4
Hard.5


Retained Demersal 2013/14
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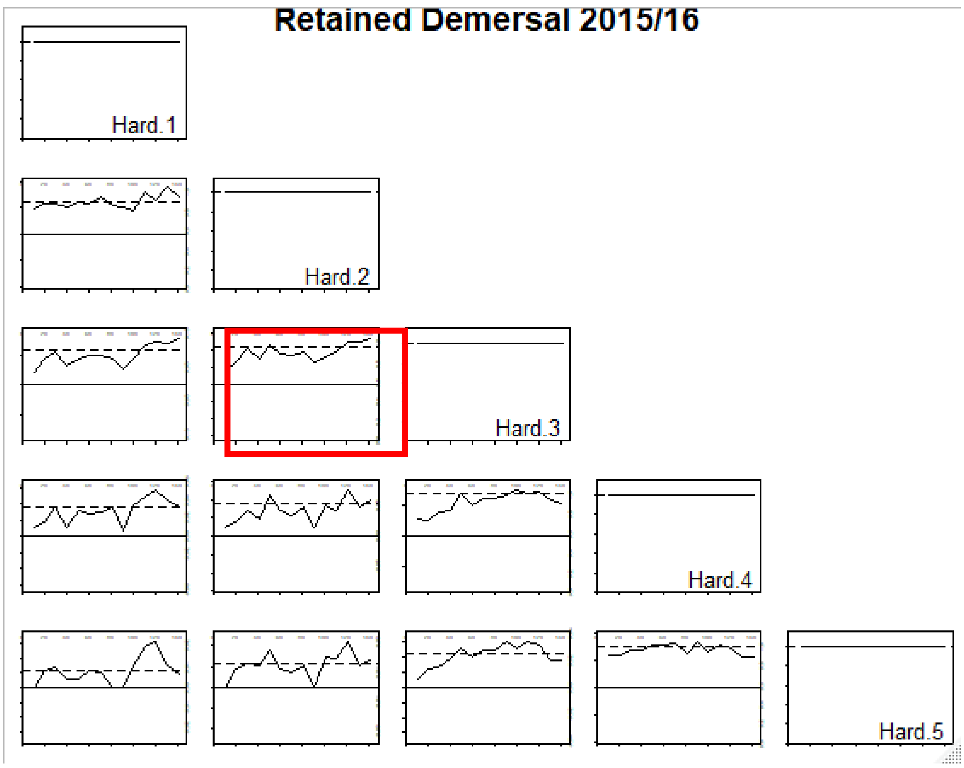


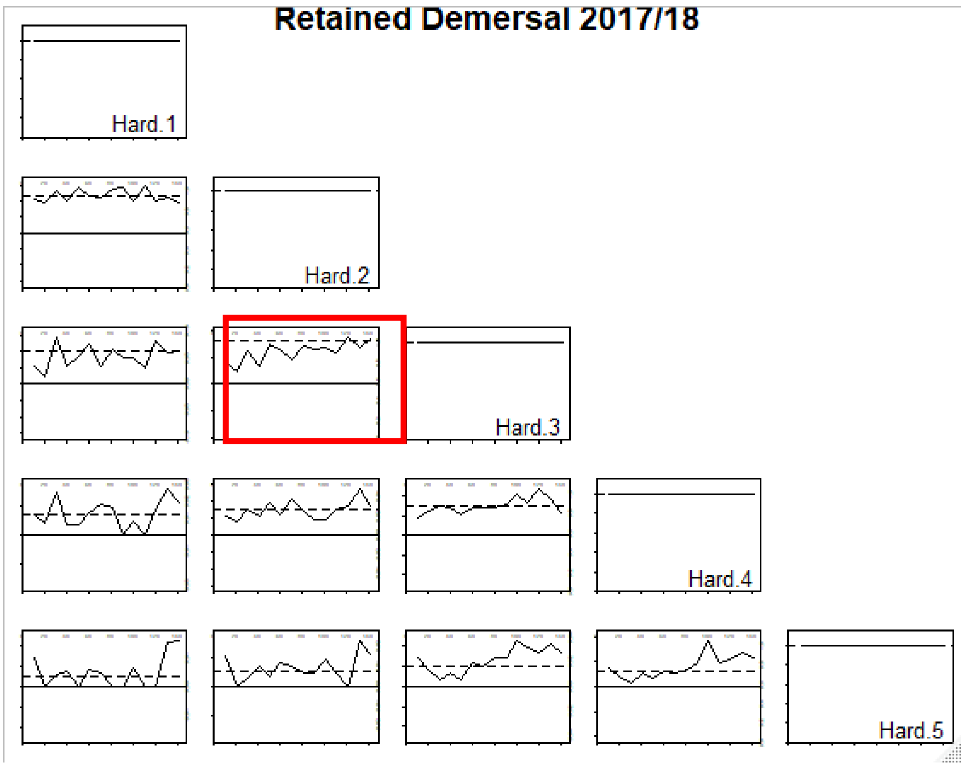
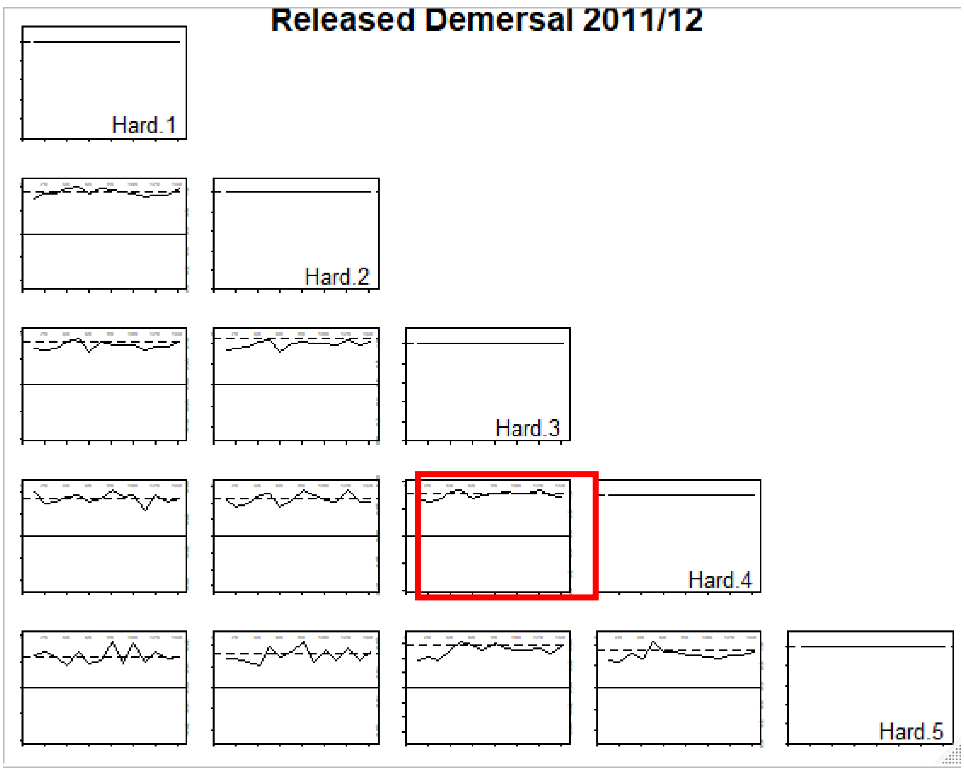


Fig. S3. Plots represent variogram ratios, $P[Z(u)\in A_j \mid Z(u)\in A_i, Z(u+h)\notin A_i]$, for all retained demersal CPUE in survey years 2011/12, 2013/14, 2015/16 and 2017/18 used to define the hotspot cut-off.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Hard.3
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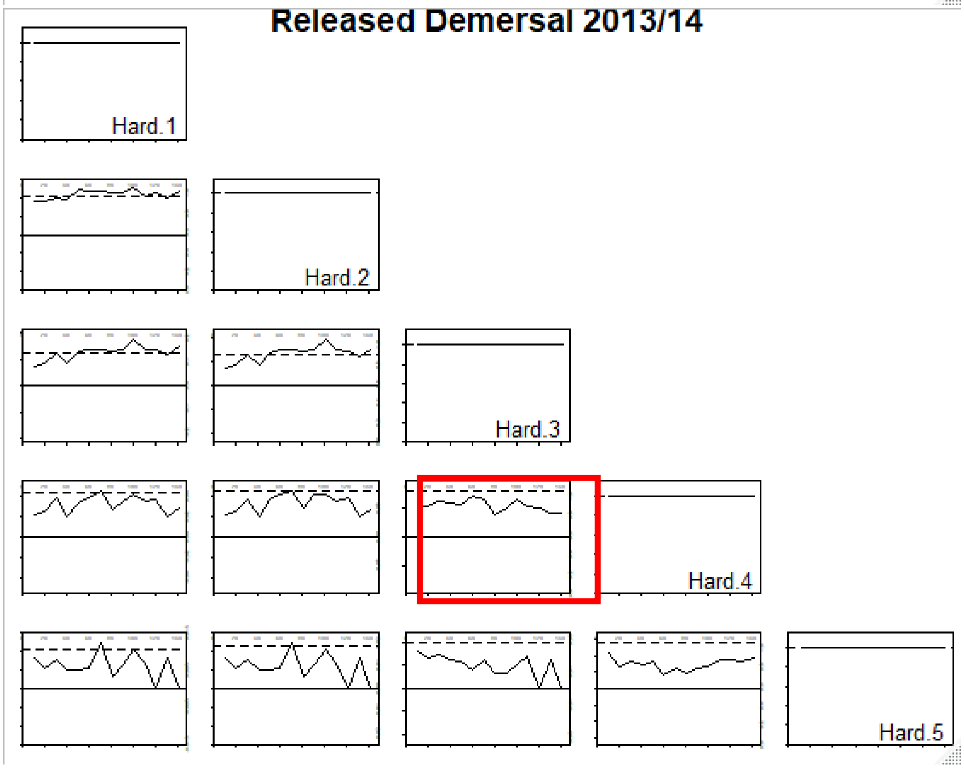
Released Demersal 2013/14
Hard.1
Hard.2
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Hard.4
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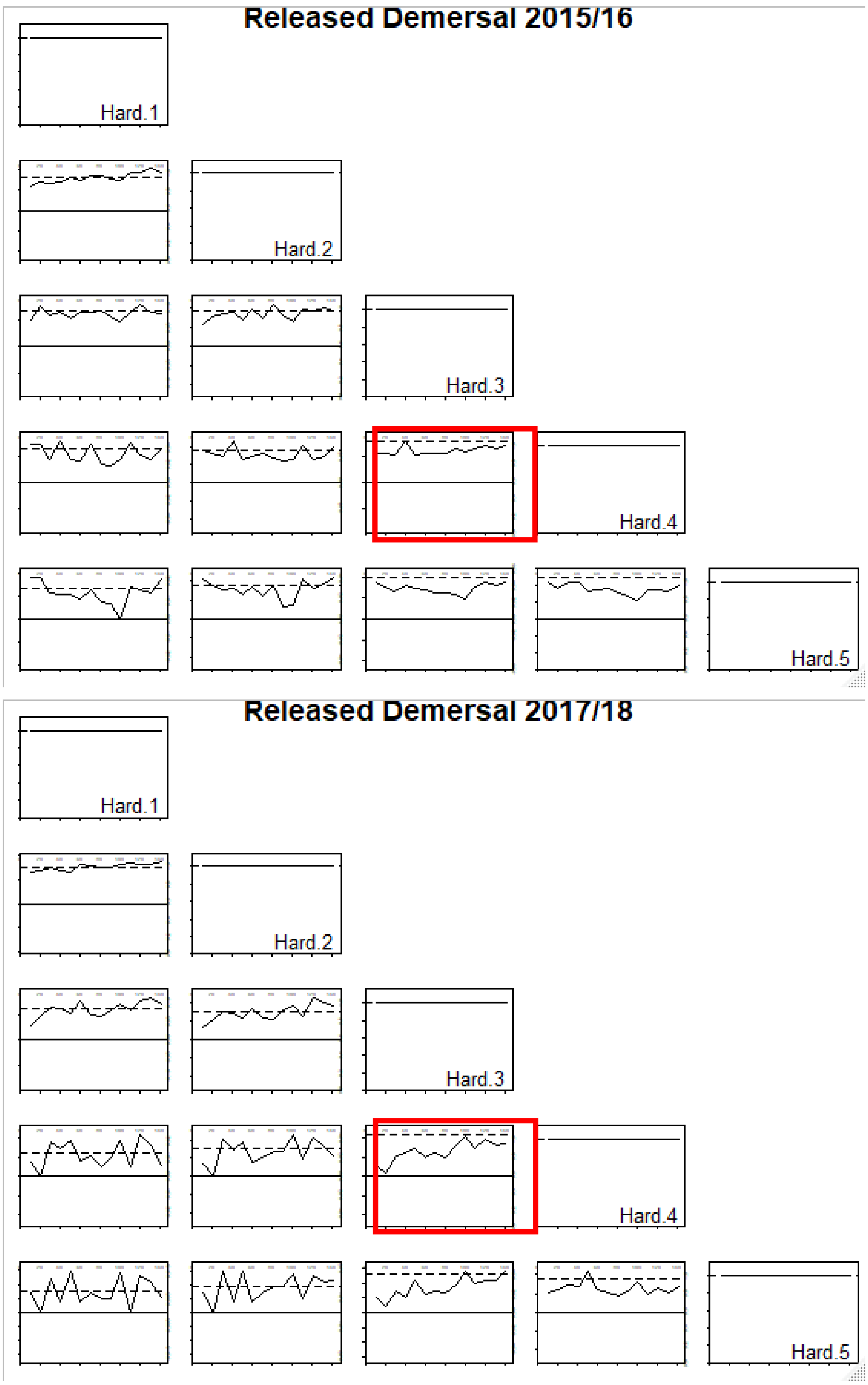
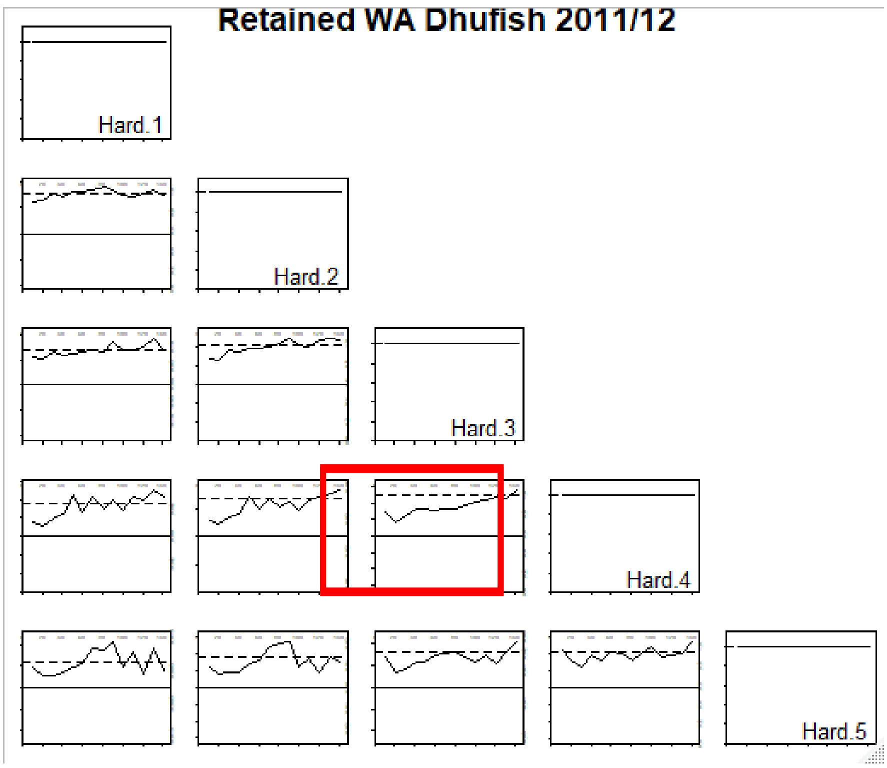


Fig. S4. Plots represent variogram ratios, $P[Z(u) \in A_j \mid Z(u) \in A_i, Z(u+h) \notin A_i]$, for all released demersal CPUE in survey years 2011/12, 2013/14, 2015/16 and 2017/18 used to define the hotspot cut-off.


Retained WA Dhufish 2011/12
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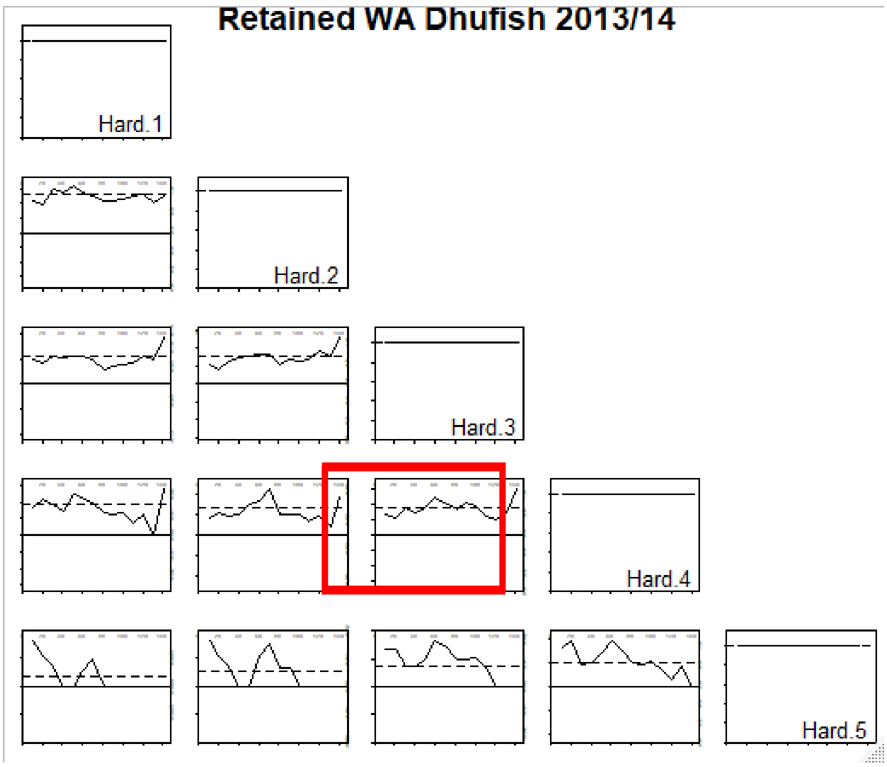
Hard.4
Hard.5


Retained WA Dhufish 2013/14
Hard.1
Hard.2
Hard.3
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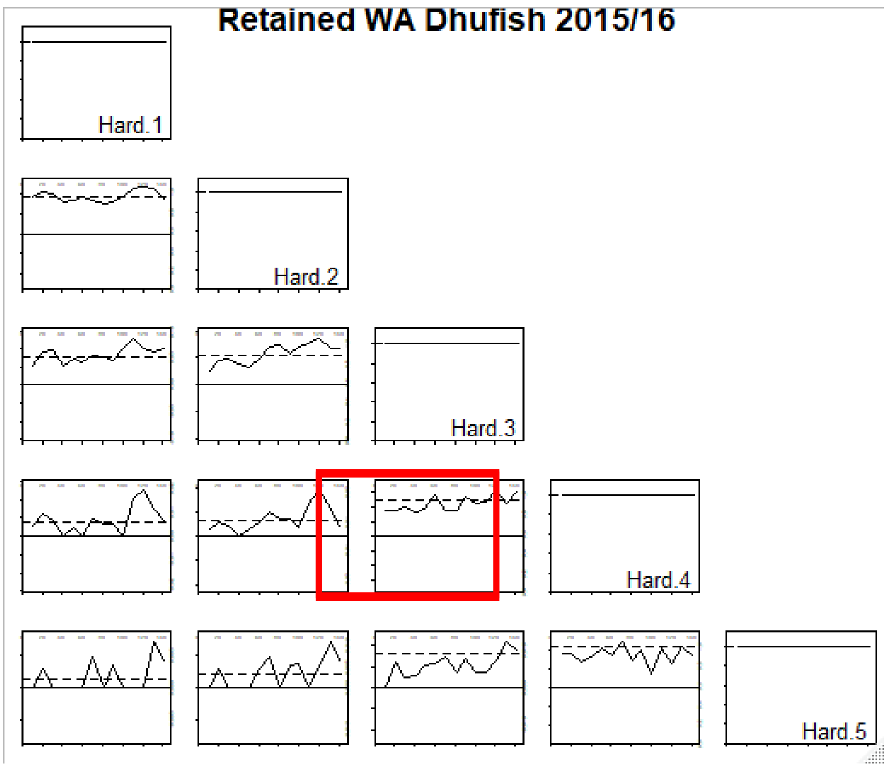
Hard.5



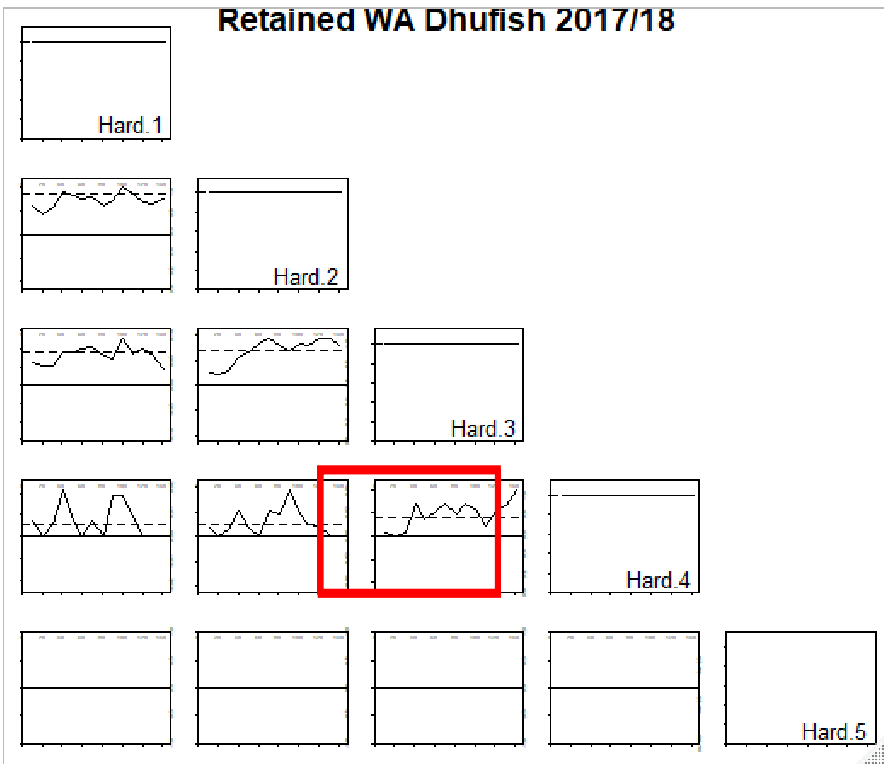
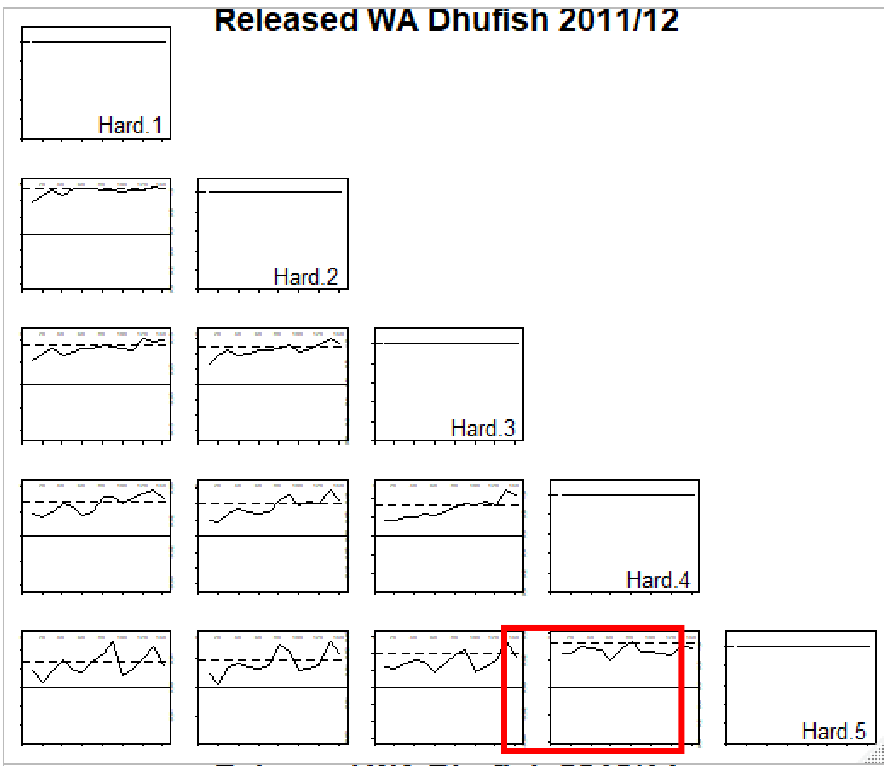


Fig. S5. Plots represent variogram ratios, $P[Z(u) \in A_j \mid Z(u) \in A_i, Z(u+h) \notin A_i]$, for retained WA dhufish CPUE in survey years 2011/12, 2013/14, 2015/16 and 2017/18 used to define the hotspot cut-off.


Released WA Dhufish 2011/12
Hard.1
Hard.2
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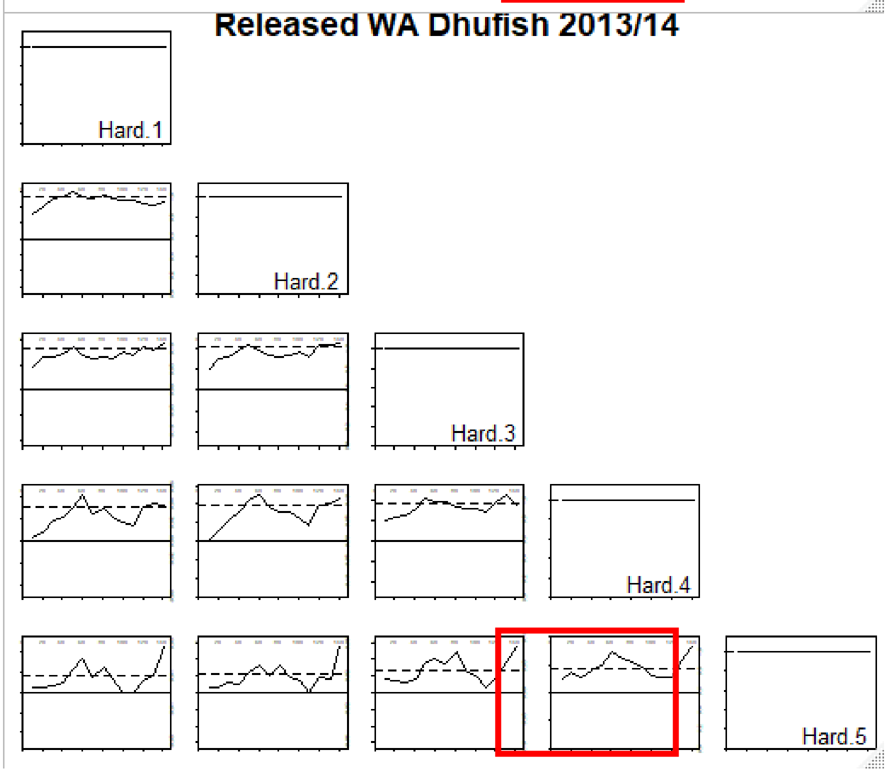
Released WA Dhufish 2013/14
Hard.1
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Hard.4
Hard.5

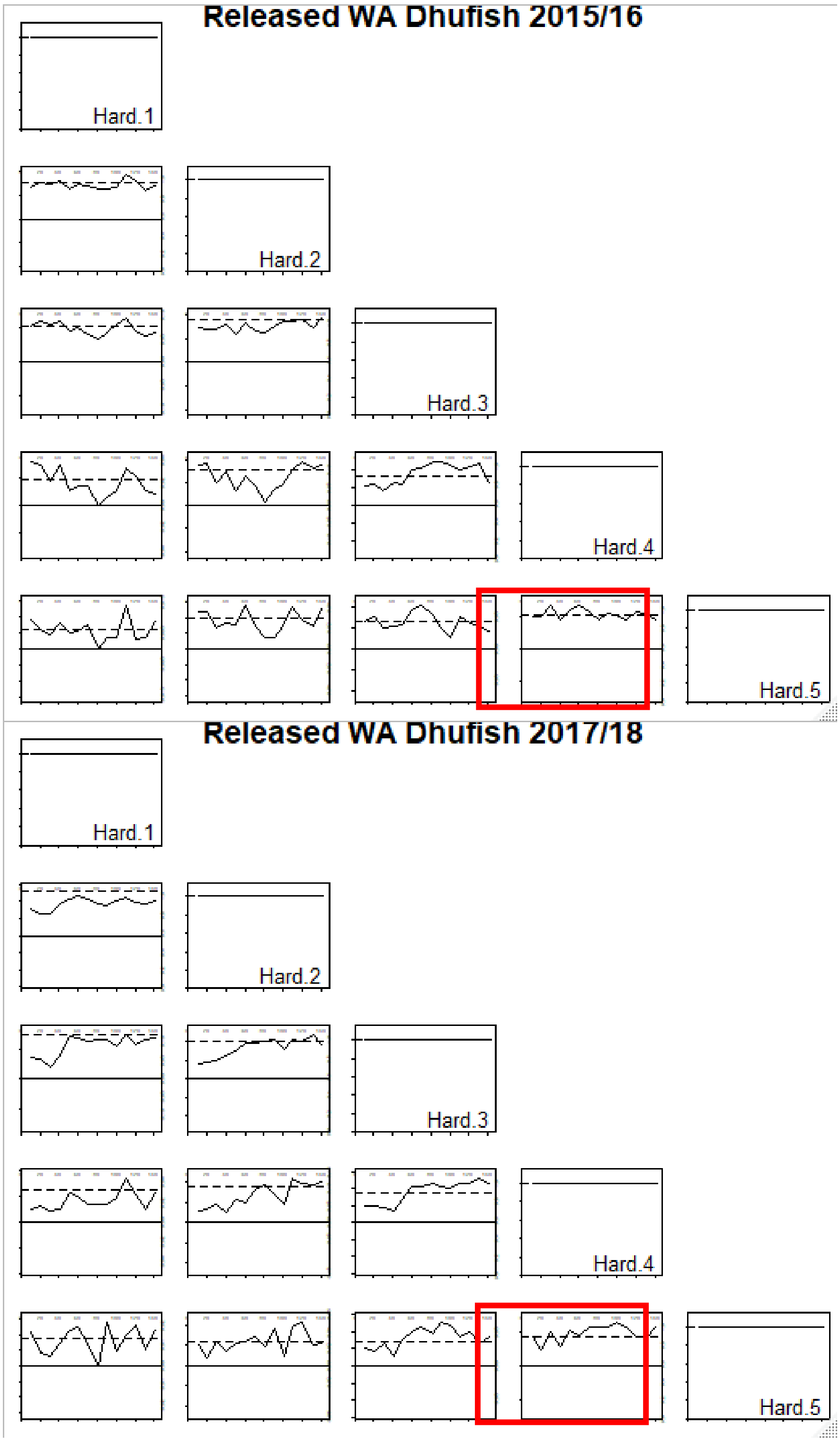
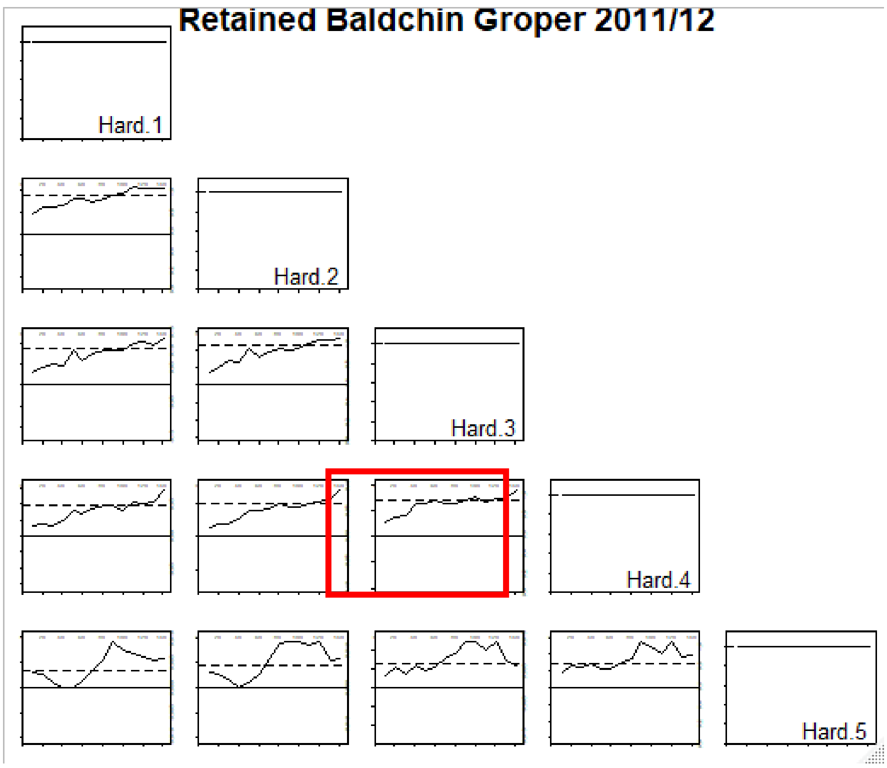


Fig. S6. Plots represent variogram ratios, $P[Z(u) \in A_j | Z(u) \in A_i, Z(u+h) \notin A_i]$, for released WA dhufish CPUE in survey years 2011/12, 2013/14, 2015/16 and 2017/18 used to define the hotspot cut-off.


Retained Baldchin Groper 2011/12
Hard.1
Hard.2
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Hard.4
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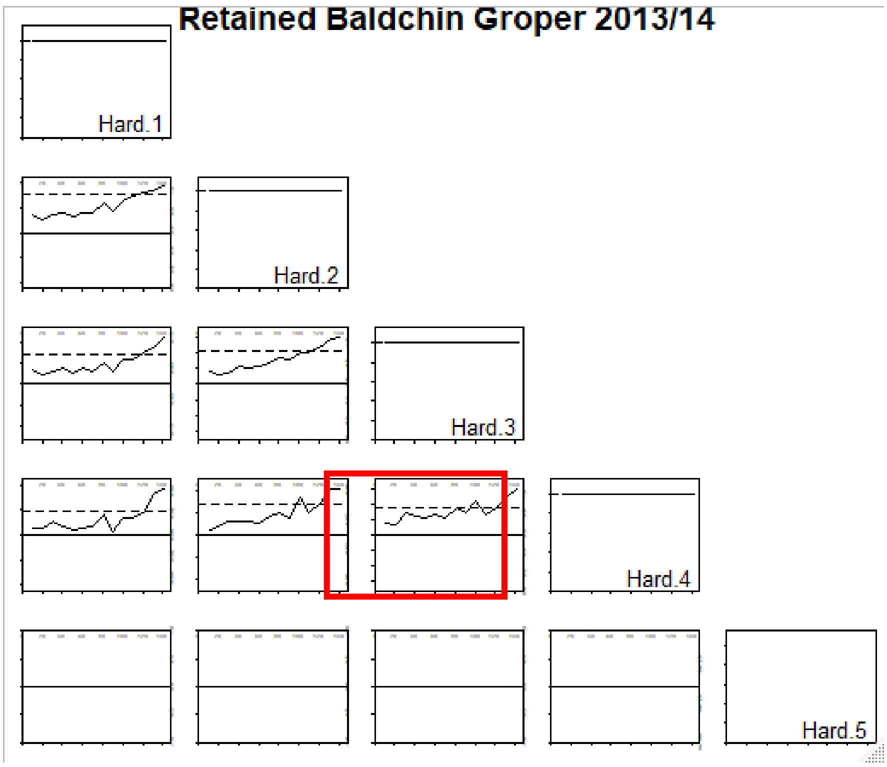
Retained Baldchin Groper 2013/14
Hard.1
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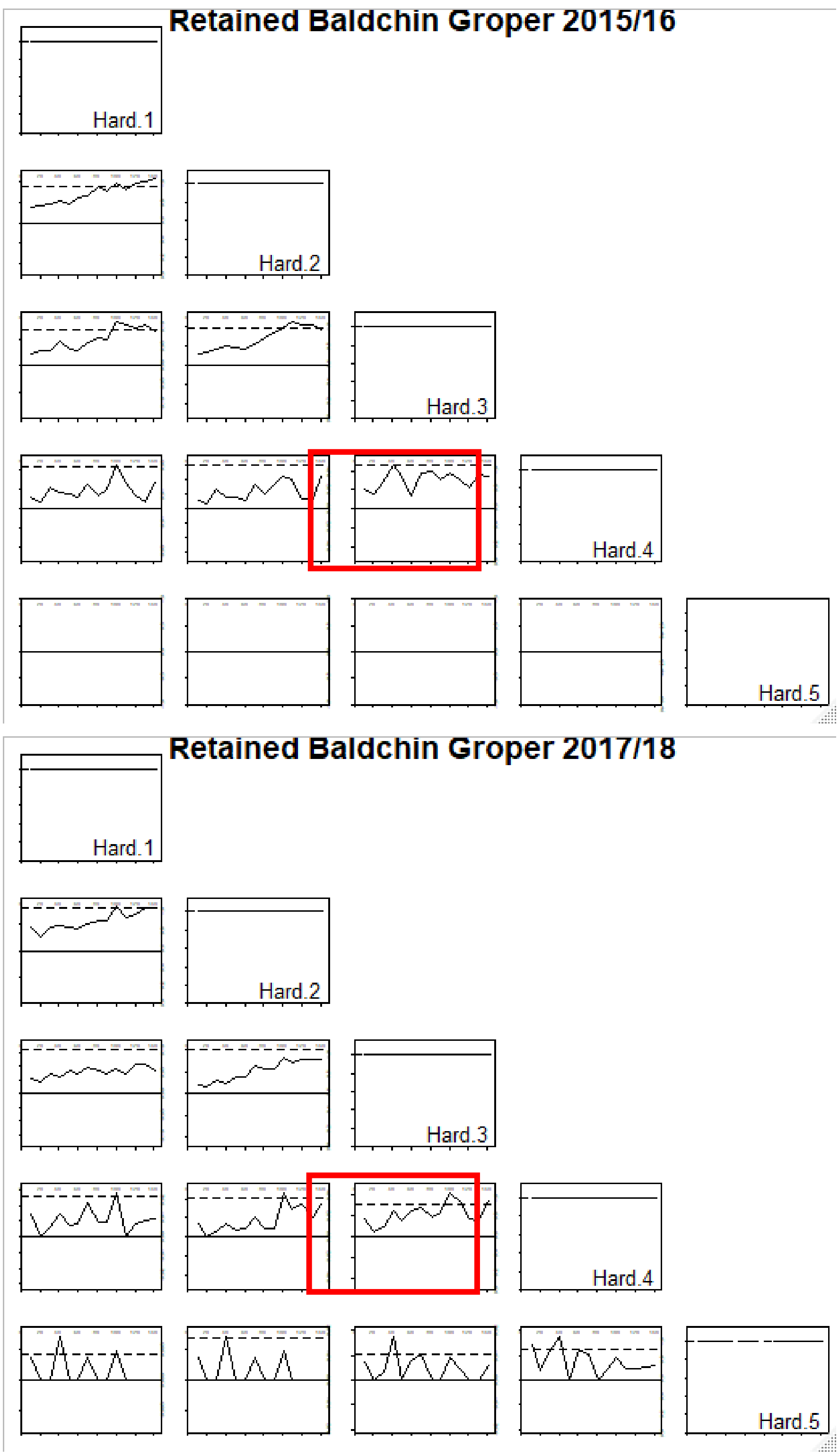
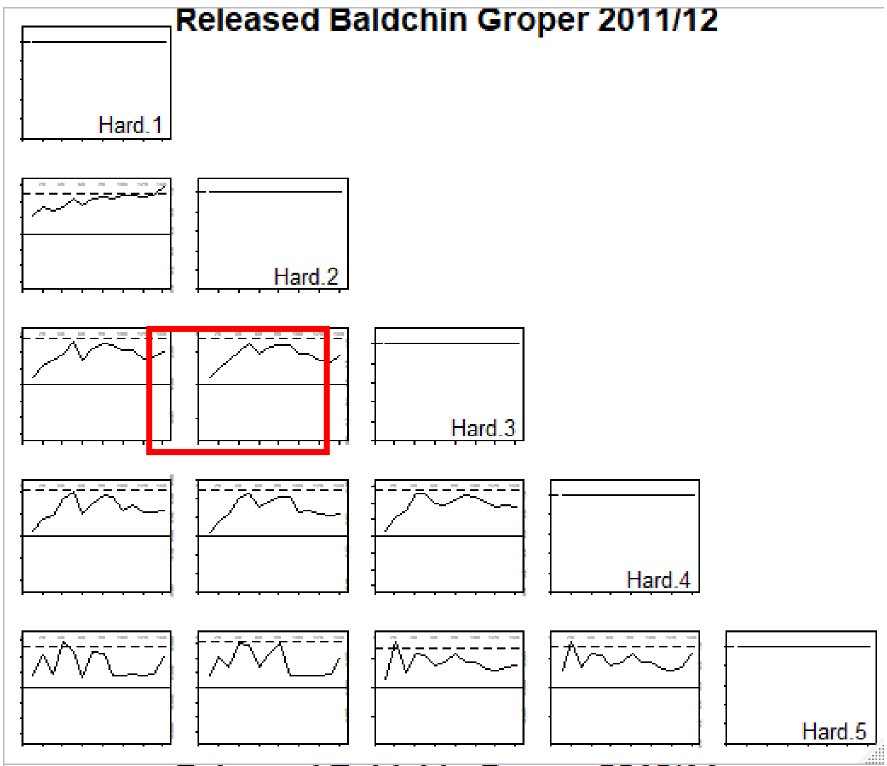
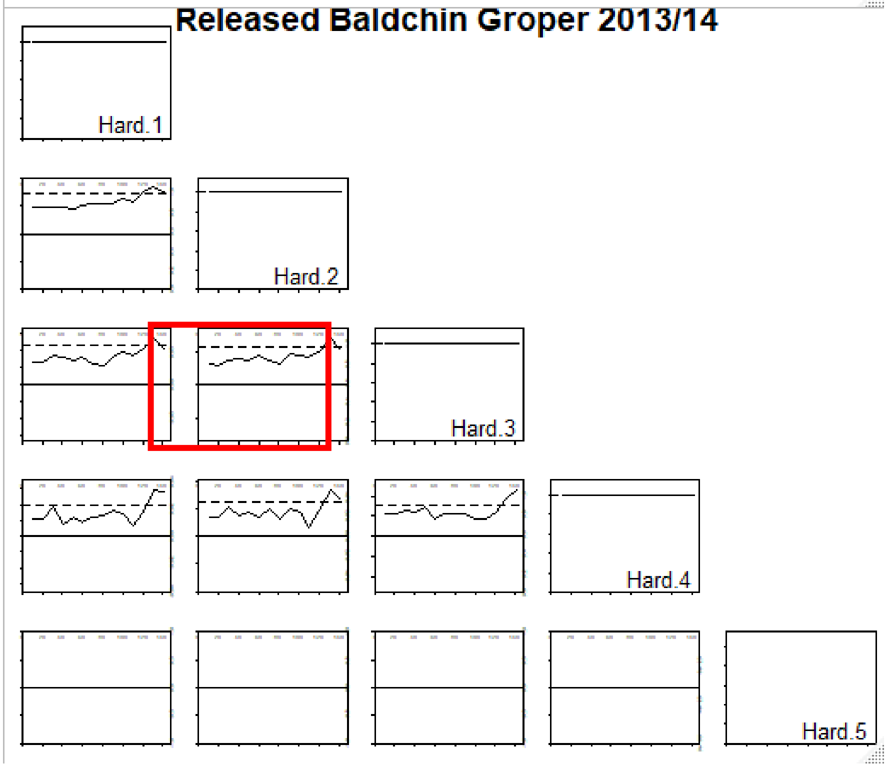


Fig. S7. Plots represent variogram ratios, $P[Z(u) \in A_j \mid Z(u) \in A_i, Z(u+h) \notin A_i]$, for retained Baldchin groper CPUE in survey years 2011/12, 2013/14, 2015/16 and 2017/18 used to define the hotspot cut-off.


Released Baldchin Groper 2011/12
Hard.1
Hard.2
Hard.3
Hard.4
Hard.5


Released Baldchin Groper 2013/14
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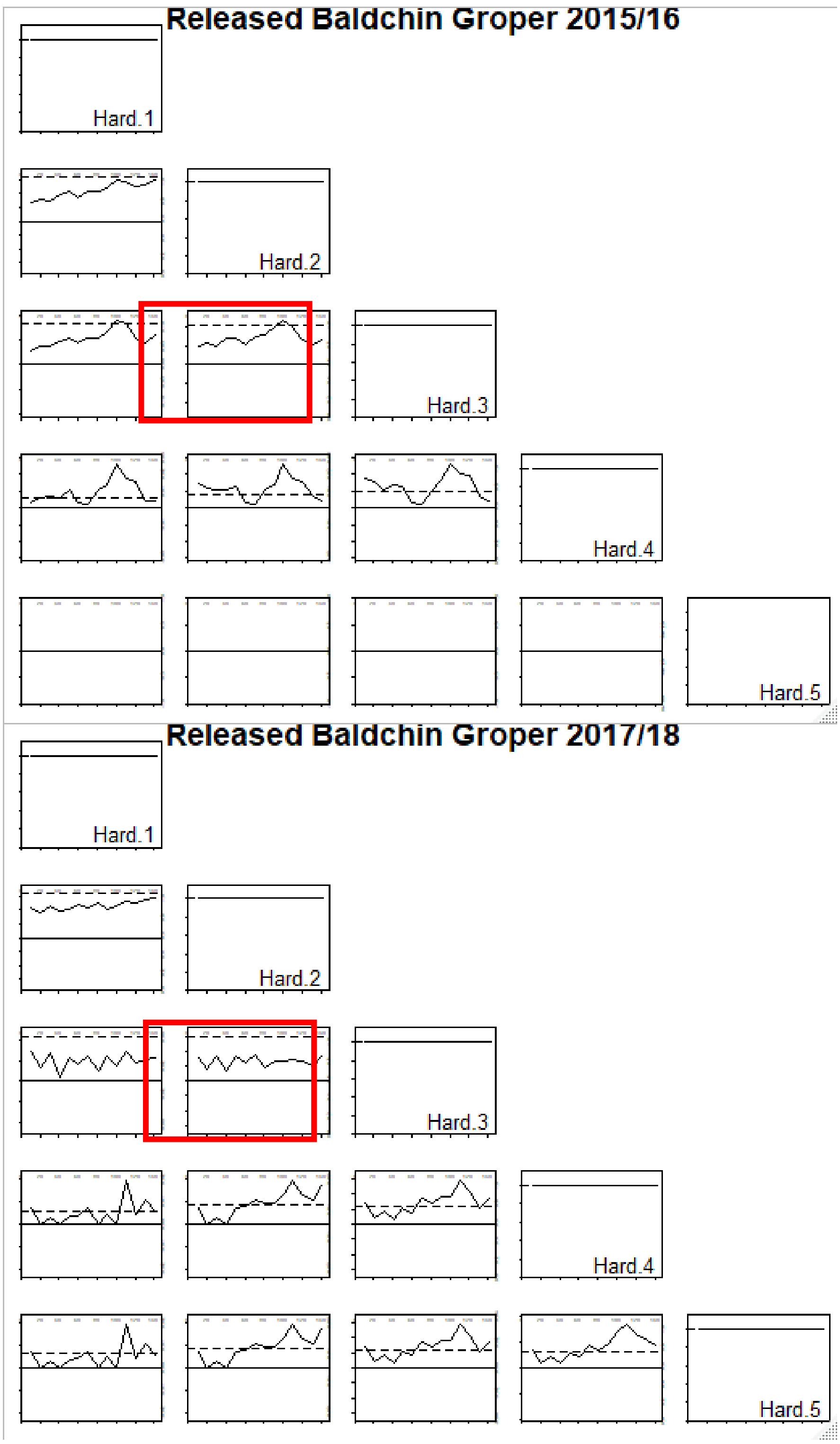

Fig. S8. Plots represent variogram ratios, $P[Z(u) \in A_j | Z(u) \in A_i, Z(u+h) \notin A_i]$, for released Baldchin groper CPUE in survey years 2011/12, 2013/14, 2015/16 and 2017/18 used to define the hotspot cut-off.

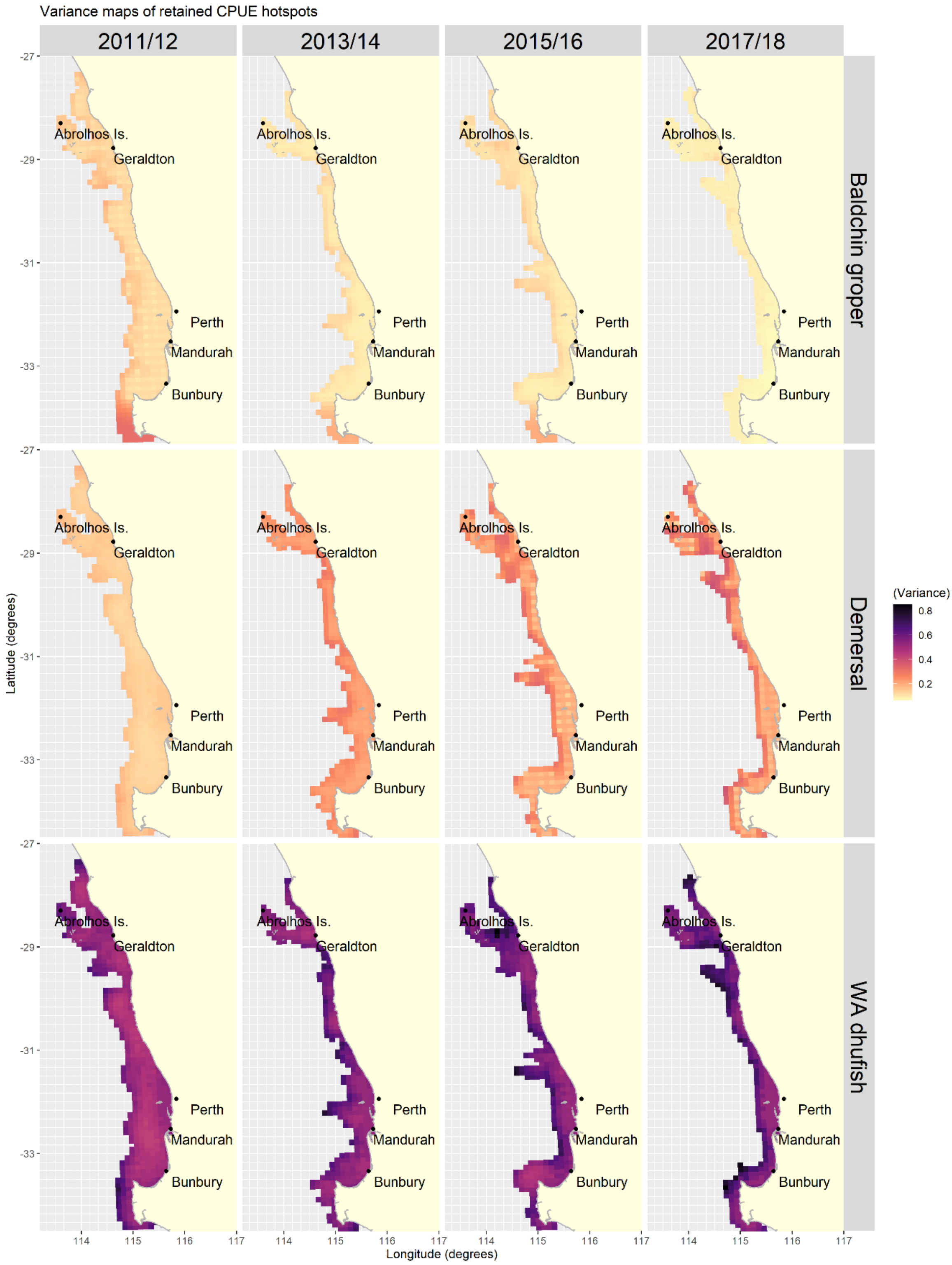

Fig. S9. Maps of variance associated with probability maps of retained demersal species, WA dhufish and Baldchin groper CPUE hotspots estimated on a 5 × 5-nautical mile grid in the West Coast Bioregion of Western Australia from 2011/12 to 2017/18 (left to right).

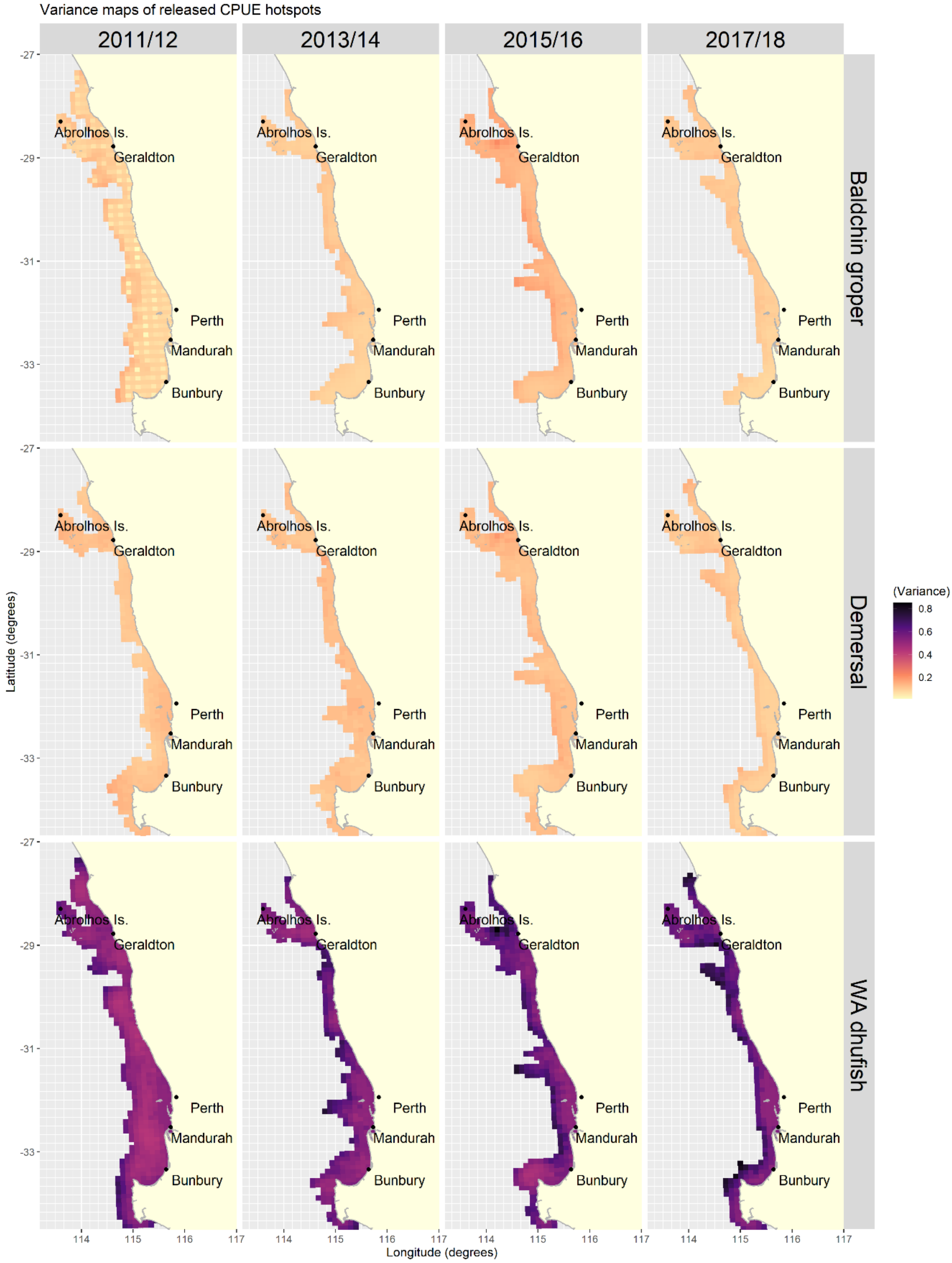

Fig. S10. Maps of variance associated with probability maps of released demersal species, WA dhufish and Baldchin groper CPUE hotspots estimated on a 5 ×5-nautical mile grid in the West Coast Bioregion of Western Australia from 2011/12 to 2017/18 (left to right).

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