Indirect effects of commercial fishing in the Marlborough Sounds on the foraging of king shag, *Leucocarbo carunculatus*.

Department of Conservation Project BCBC2019-05

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Feedback from previous TWG

- Because collection of fine-scale data was introduced part-way through the study period (about 2007–08), the low levels of activity and catch volumes reported in the analysis pre 2007 reflect that change in reporting requirement and not a change in fishing activity levels.
- Recreational fishing data were not included in the analyses.
- The 20 km foraging circles appear less than 100% effective, particularly with respect to Port Gore.
- Were known changes in the number of vessels and gear types related to hector dolphin closure/marine mammal sanctuary considered, given the effect on catches of certain species because of limitations on headline height?
- Details related the lack of blue cod potting information requires consideration, particularly given that the required reporting is still only by statistical area.
- Were factors like sedimentation effects considered?

The study

- This research investigated commercial finfish catch taken from a defined study-area in the Marlborough Sounds over the past 30 years.

- It provides essential information for use in future research, and is part of a wider body of work to determine the relationship between the availability of prey species and changes to king shag population data over the past 30 years.

3 indirect effect indicators

1. Any major changes in the volume of extractions occurring over a relatively short timeframe.
2. Whether there have been any obvious sustained changes in the rate that fish have been harvested for the amount of fishing effort expended.
3. Whether there has been any obvious evidence of these catch rates decreasing in certain areas followed by the transfer of that effort to other, previously unfished areas, thus acting as an indicator of possible local depletions.

Data constraints

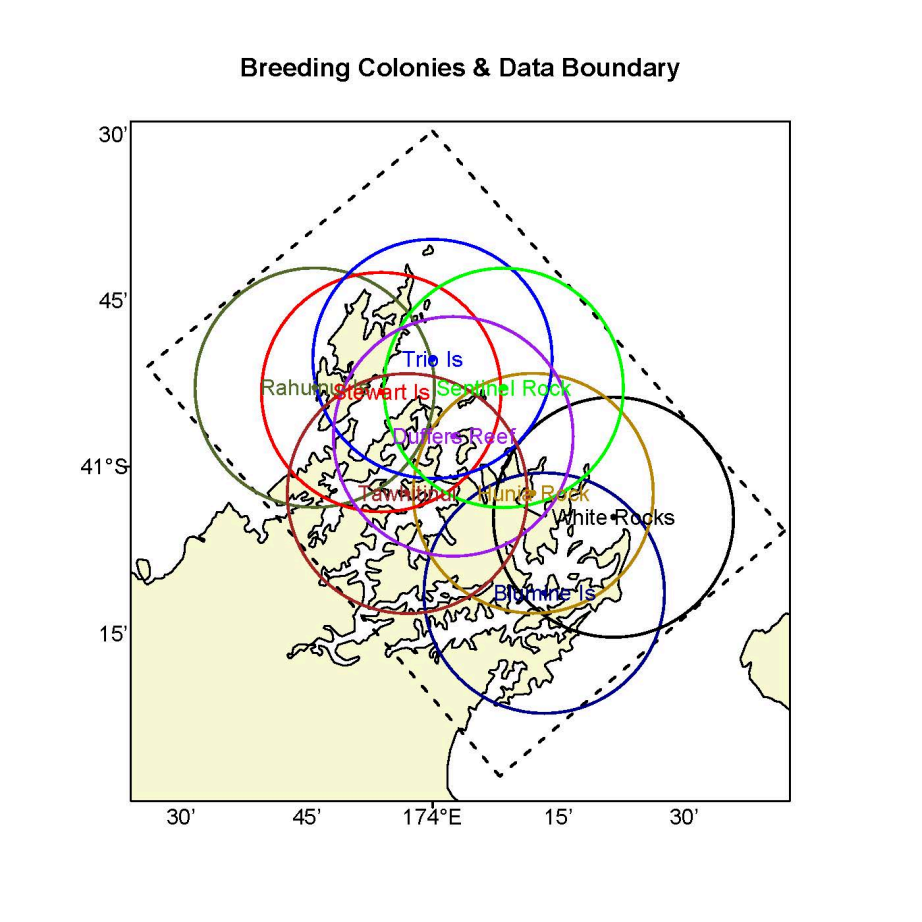
- Thanks to Fisheries NZ and the Fisheries Data Management team who provided the data used here.
- Use of the data requires that confidentiality of permit holders supplying commercial fishing data is maintained according to a two-step method requested by FNZ:

i. any cell of any plot or data summary must be suppressed if the number of permit holders contributing to that cell total is less than three, and

ii. the suppressed cells must be indistinguishable from any null values occurring in the plot or summary.

iii. all outputs shown here comply with this request.

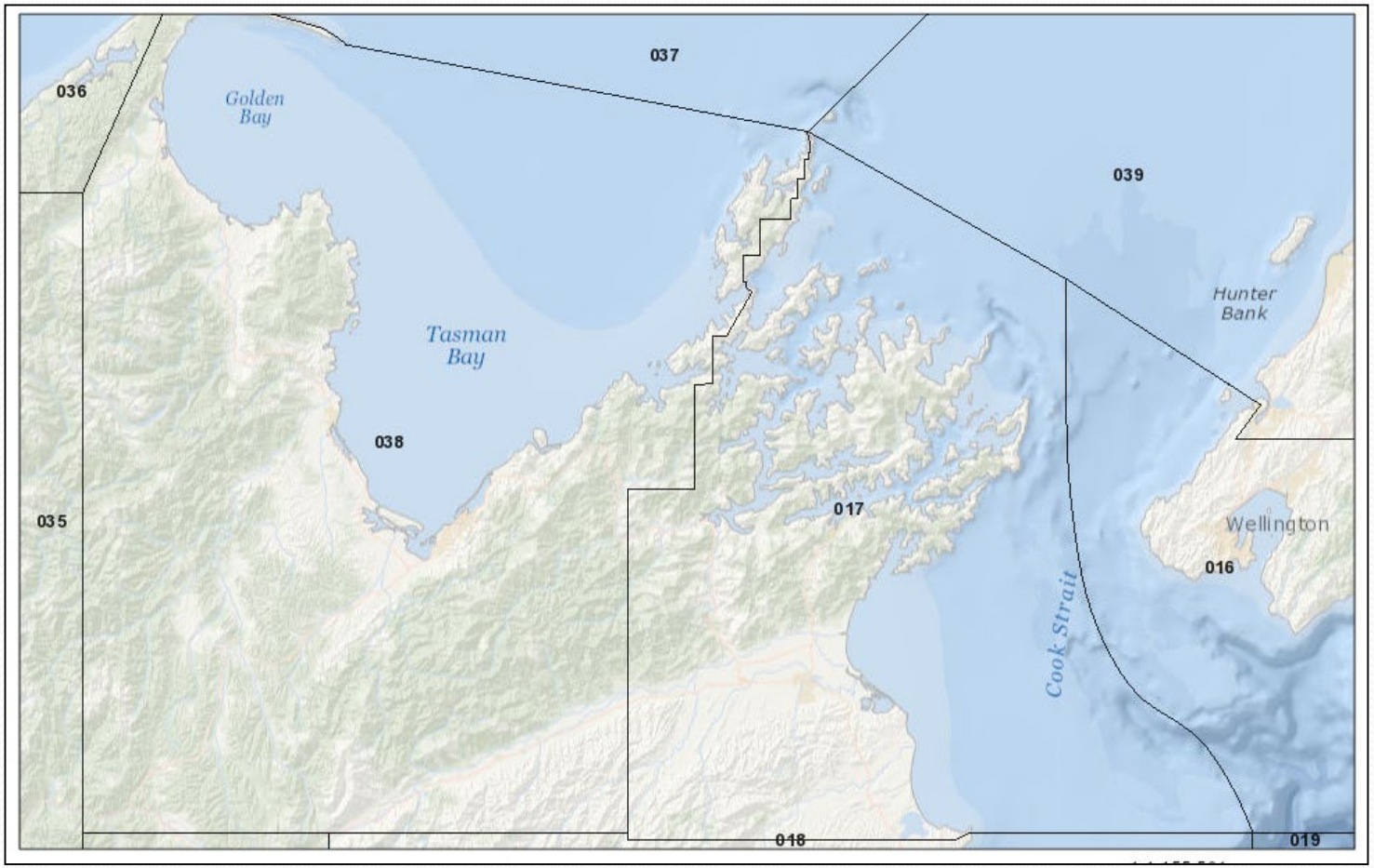
Foraging ranges (20 km) centred on king shag breeding colonies (labelled) and polygon defining the original data area or area of interest



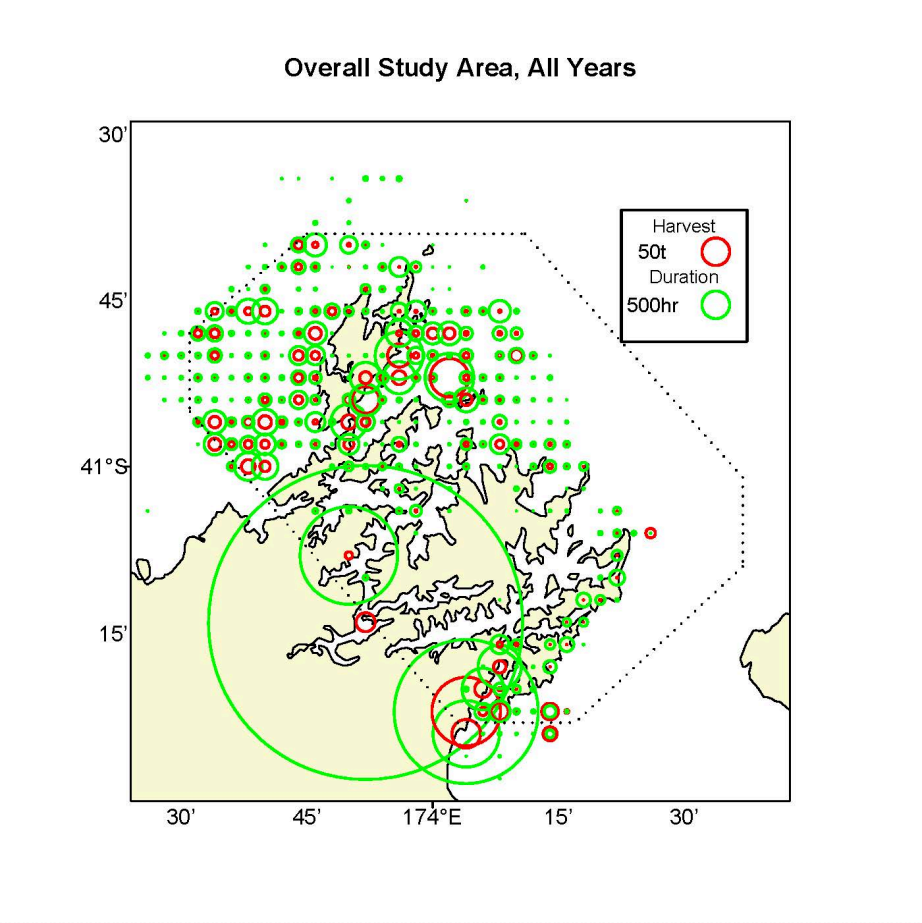
Datasets used in the analysis

- **Dataset 1, the fine-scale data:** records of all commercial fishing events catching all species of finfish over the last 30-years (01/10/1989–30/09/2019): occurring within the area of interest described above.
- **Dataset 2, the stat-area data:** catches over the same period from stat-areas, 016, 017, 036, 038, 039.

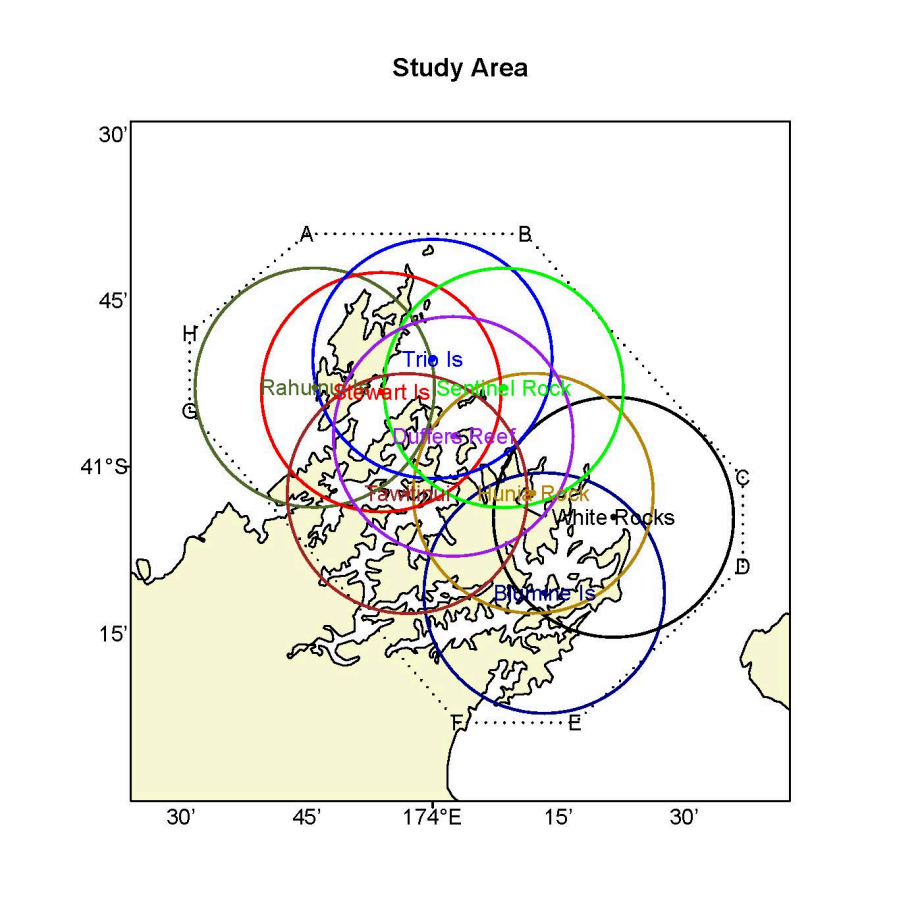
Stat-areas encompassing the study-area



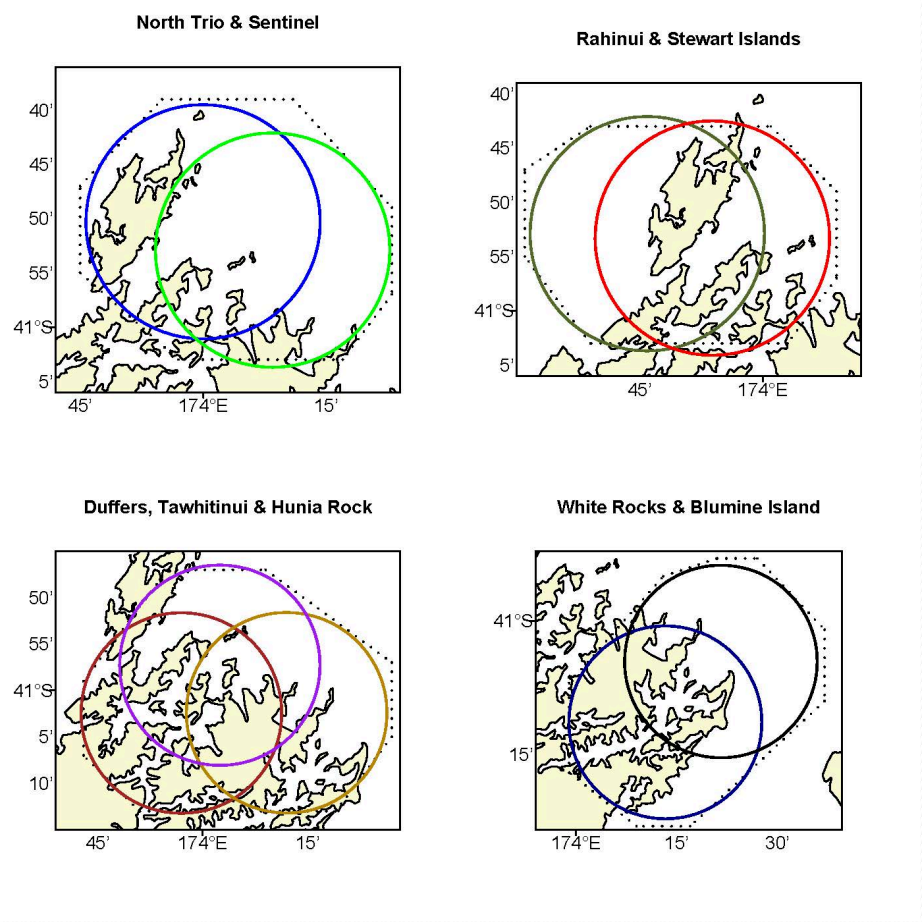
Spatial distribution of total greenweight catches (red) and fishing duration (green) for the entire study area in all years (1989–90 to 2018–19)



Study area = revised data boundary



Sub-areas, ranges and boundaries



Fishing years and year groups
(Fishing year: October 1 to September 30)

Year group	Fishing years		Year group	Fishing years
1	1989–90 to 1994–95		4	2005–06 to 2009–10
2	1995–96 to 1998–99		5	2010–11 to 2014–15
3	2000–01 to 2004–05		6	2015–16 to 2018–19

Catch levels - ranges

Level	Range		Level	Range
1	<= 100 kg		4	>10,000 & <= 100,000 kg
2	>100 & < =1,000 kg		5	>100,000 & <= 1,000,000 kg
3	>1000 & <= 10,000 kg		6	>1,000,000 kg

List of finfish species contributing 10 t or more to the commercial catch within the area of king shag breeding colonies in the Marlborough Sounds; *Chondrichthyan spp; green=final list

Common name	Taxon	SppCatch(kg)	Catch level	Habitat type
Barracouta	*Thyrsites atun*	1 272 946	6	Pelagic
Blue cod	*Parapercis colias*	65 872	4	Demersal
Butterfish	*Odax pullus*	114 107	5	Demersal
Carpet shark*	*Cephaloscyllium Isabella*	137 282	5	Demersal
Conger eel	*Conger verreauxi*	10 232	4	Demersal
Eagle ray*	*Myliobatis tenuicaudatus*	11 223	4	Bentho-pelagic
Elephant fish*	*Callorhincus milii*	26 763	4	Demersal
NZ sole	*Peltorhamphus novaezelandiae*	16 575	4	Flatfish
Flatfish	Various possible	190 387	5	Flatfish
Greenback flounder	*Rhombosolea taparini*	25 872	4	Flatfish
Ghost shark*	*Chimaera* spp., *Hydrolagus* spp.	105 896	5	Demersal
Marblefish	*Aplodactylus arctidens*	10 535	4	Bentho-pelagic
Gurnard	*Chelidonichthys kumu*	671 928	5	Demersal
Hapuku & Bass	*Polyprion oxygeneios, P.americanus*	25 951	4	Demersal
John dory	*Zeus faber*	132 437	5	Bentho-pelagic
Jack mackerel	*Trachurus* spp	937 472	5	Pelagic
Kahawai	*Arripis trutta*	340 928	5	Pelagic
Ling	*Genypterus blacodes*	19 710	4	Demersal
Lemon sole	*Pelotresis flavilatus*	31 901	4	Flatfish
Blue moki	*Latridopsis ciliaris*	44 697	4	Demersal
Porcupine fish	*Allomycterus pilatus*	24 368	4	Demersal
Rattails	Family Macrouridae	12 821	4	Demersal
Rough skate*	*Raja nasuta*	54 577	4	Demersal
School shark*	*Galeorhinus galeus*	374 189	5	Pelagic
Sand flounder	*Rhombosolea plebeian*	99 299	4	Flatfish
Snapper	*Pagrus auratus*	323 901	5	Demersal
Spiny dogfish*	*Squalus acanthias*	329 709	5	Demersal
Rig*	*Mustelus lenticulatus*	196 919	5	Demersal
Spotted stargazer	*Geniagnus monopterygius*	11 864	4	Demersal
Giant stargazer	*Kathetostoma giganteum*	12 156	4	Demersal
Tarakihi	*Nemadactylus macropterus*	126 042	5	Demersal
Trevally	*Pseudocaranx dentex*	169 406	5	Bentho-pelagic
Common warehou	*Seriolella brama*	486 471	5	Bentho-pelagic
Yellowbelly flounder	*Rhombosolea leporina*	96 799	4	Flatfish

Known prey species of king shag identified by Lalas & Brown (1998), Falla (1932, 1933), Oliver (1955), Nelson (1971), Schuckard & Melville (in prep)

Species	Common name		Species	Common name
Arnoglossus scapha	Witch		*Rhombosolea* spp.	Flounder spp.
Pelotretis flavilatus	Lemon sole		*Caesioperca lepidoptera*	Butterfly perch
Hemerocoetes monopterygius & *H. pauciradiatus*	Opalfish		Uranoscopidae	Stargazer
Helicolenus percoides	Sea perch		Leptoscopidae	Stargazer
Peltorhamphus novaezeelandiae	Common sole		*Chelidonichthys kumu*	Gurnard
Sardinops neopilchardus	Pilchard		*Gonorhynchus gonorhynchus*	Sandfish
Parapercis colias	Blue cod		*Pseudophycis bachus*	Red cod
Tripterygiidae	Triplefin spp.		*Lepidorhynchus denticulatus*	Javelinfish
Gnathophis habenatus	Silver conger		Palaemonidae	Shrimp
Genypterus blacodes	Ling		*Octopus* spp.	
Trachichthydae	Roughy		*Munida gregaria*	Lobster krill
Notolabrus celidotus	Spotty		*Jasus edwardsii*	Rock lobster
Parika scaber	Leatherjacket		*Nectocarcinus* spp and Hymenosomidae	Red swimming crab and penny crab spp
Scorpaena papillosus	Red scorpionfish			

Number of fishing events by method – entire study area; nulls not necessarily zero

Method	No of fishing events		Method	No of fishing events
Bottom longline	172		Handline	433
Bottom pair trawl			Lampara nets	
Bottom trawl	10 536		Rock lobster pot	
Cray pot	33		Setnet	2 628
Danish seine			Troll	

Number of fishing events by method and study sub-area; nulls not necessarily zero

Fishing method	Trio-Sentinel	Rahuinui-Stewart	Duffers-Tawhitinui-Hunia	White Rock-Blumine
Bottom longline	87	37	66	59
Bottom pair trawl				
Bottom trawl	4678	6022	4236	1512
Cray pot	25	22	17	7
Danish seine				
Handline	353	410	232	
Lampara net				
Rock lobster pot				
Setnet	696	516	1326	989
Troll				

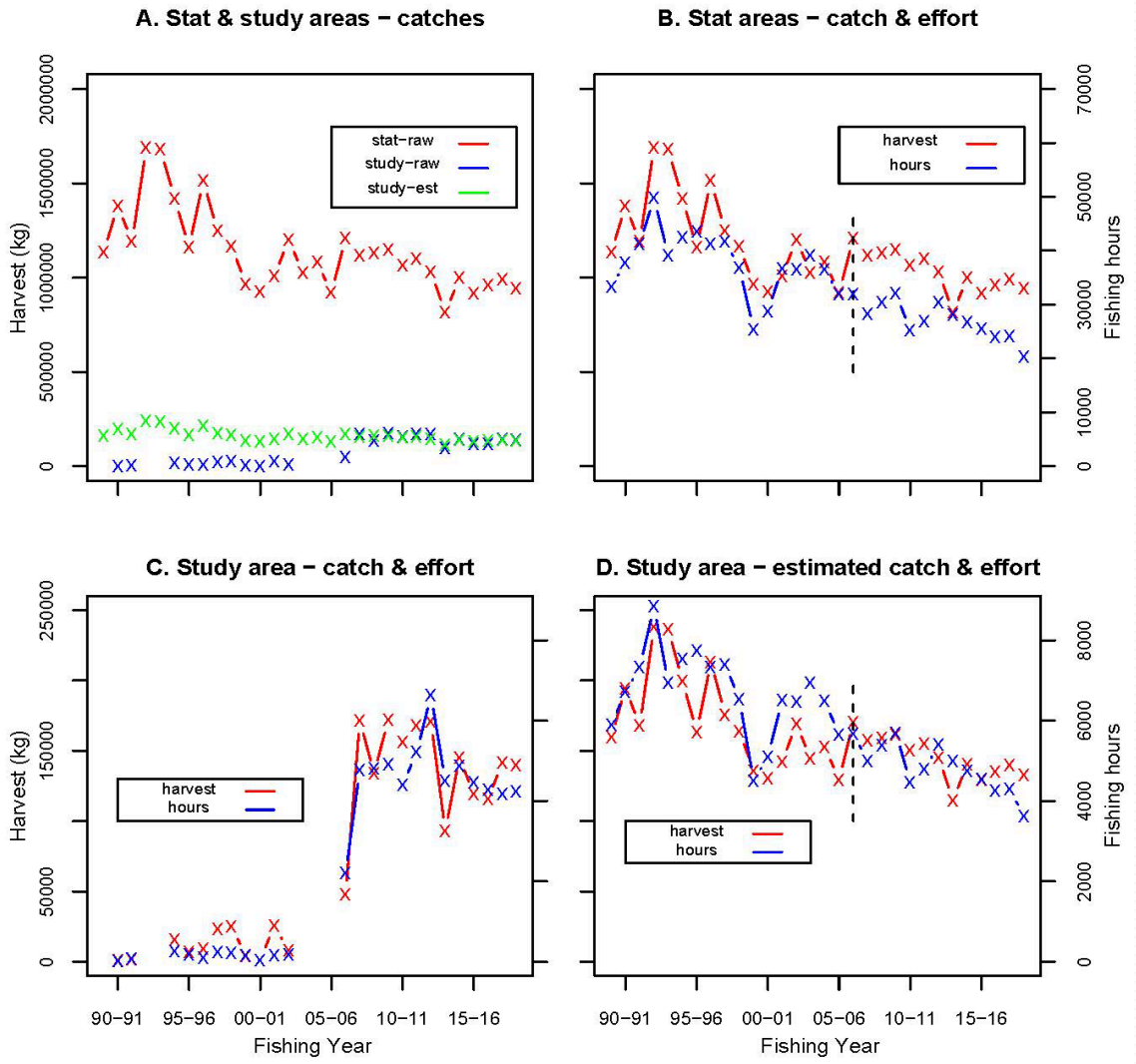
Number of events and catch (kg) in the study area, by 10 m depth ranges – trawl methods only (BT, PBT)

Depth (m)	No of events	Catch (kg)		Depth (m)	No of events	Catch (kg)
1–10	433	12 076		41–50	5369	245 130
11–20	8379	260 862		51–60	10 581	520 316
21–30	4237	128 905		61–70	5233	297 370
31–40	2256	105 468				

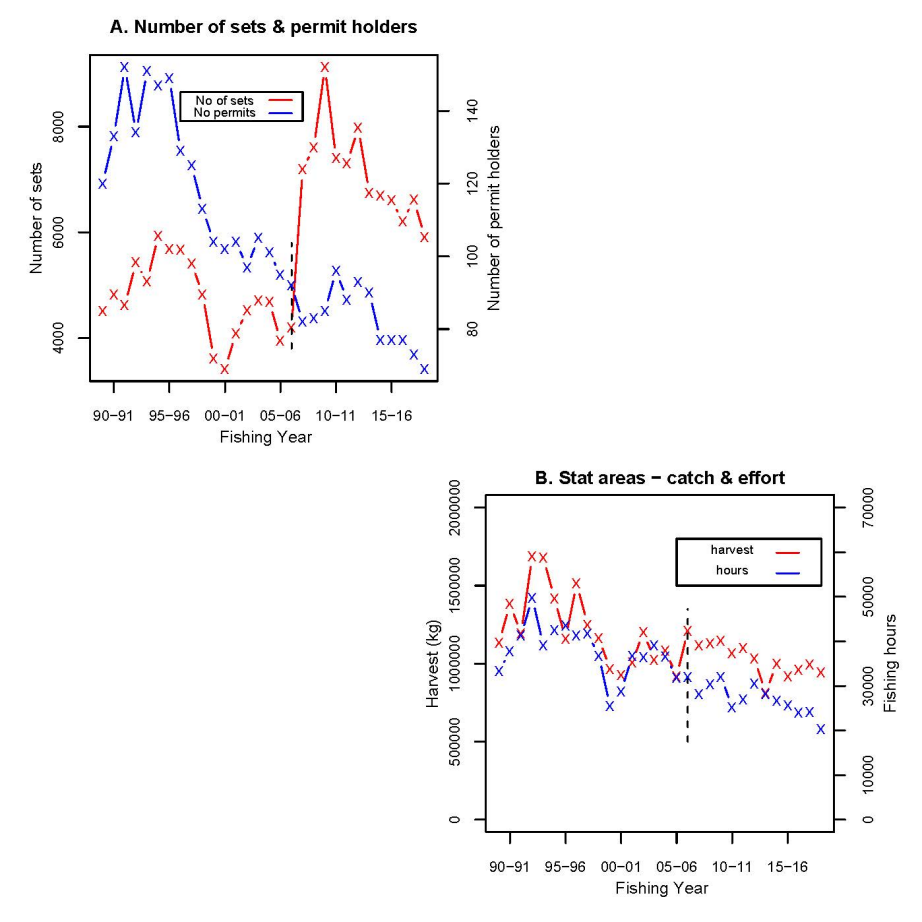
Number of fishing events by fishing year and year group; entire study area

Fishing year	No of events	Year group	No of events		Year	No of events	Year group	No of events
1989–90					2004–05			
1990–91	9				2005–06			
1991–92	17				2006–07	231		
1992–93					2007–08	1245		
1993–94		1	49		2008–09	1030	4	2514
1994–95	63				2009–10	1316		
1995–96	31				2010–11	1171		
1996–97	36				2011–12	1241		
1997–98	50				2012–13	1591		
1998–99	56	2	236		2013–14	922	5	6241
1999–00	34				2014–15	1053		
2000–01	9				2015–16	944		
2001–02	50				2016–17	838		
2002–03	33				2017–18	917		
2003–04		3	145		2018–19	903	6	4309

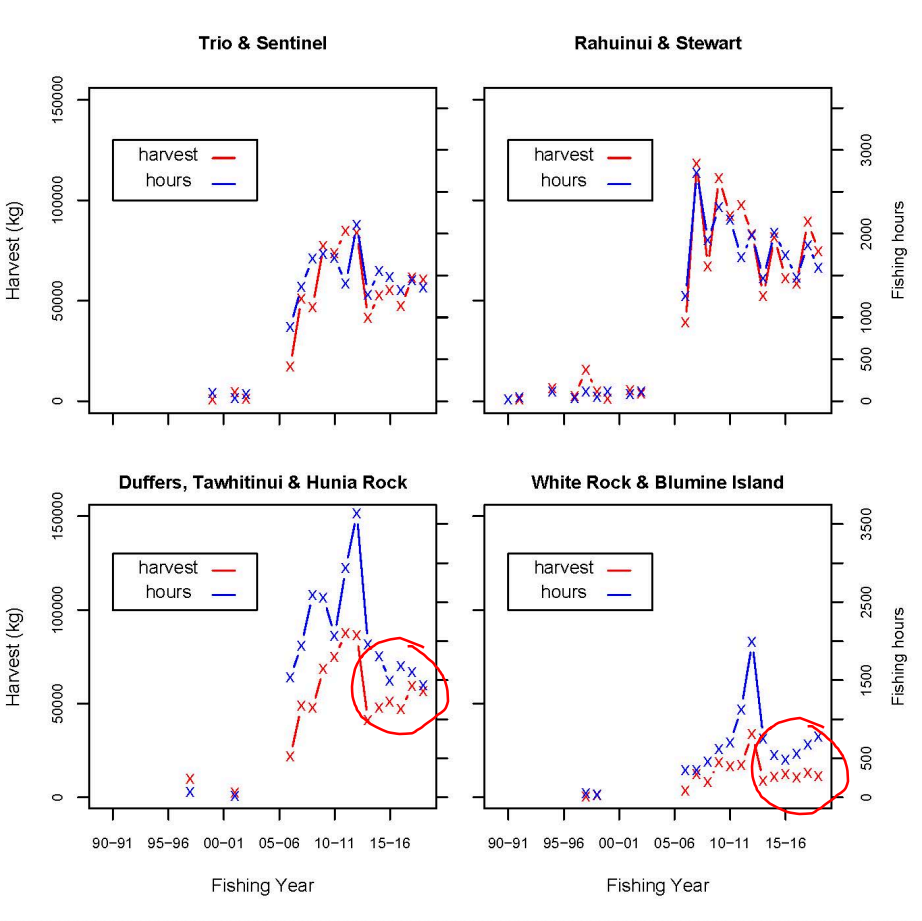
Annual catch greenweight (kg) and fishing duration (h) by fishing year for stat-areas 017 & 038 and the entire study area, and estimated catch (kg) and estimated fishing duration (h) for the study area



Number of sets, number of permit holders, annual catch greenweight (kg) and fishing duration (h) by fishing year for stat-areas 017 & 038



Annual catch greenweight (kg) and fishing duration (h) for each sub-area



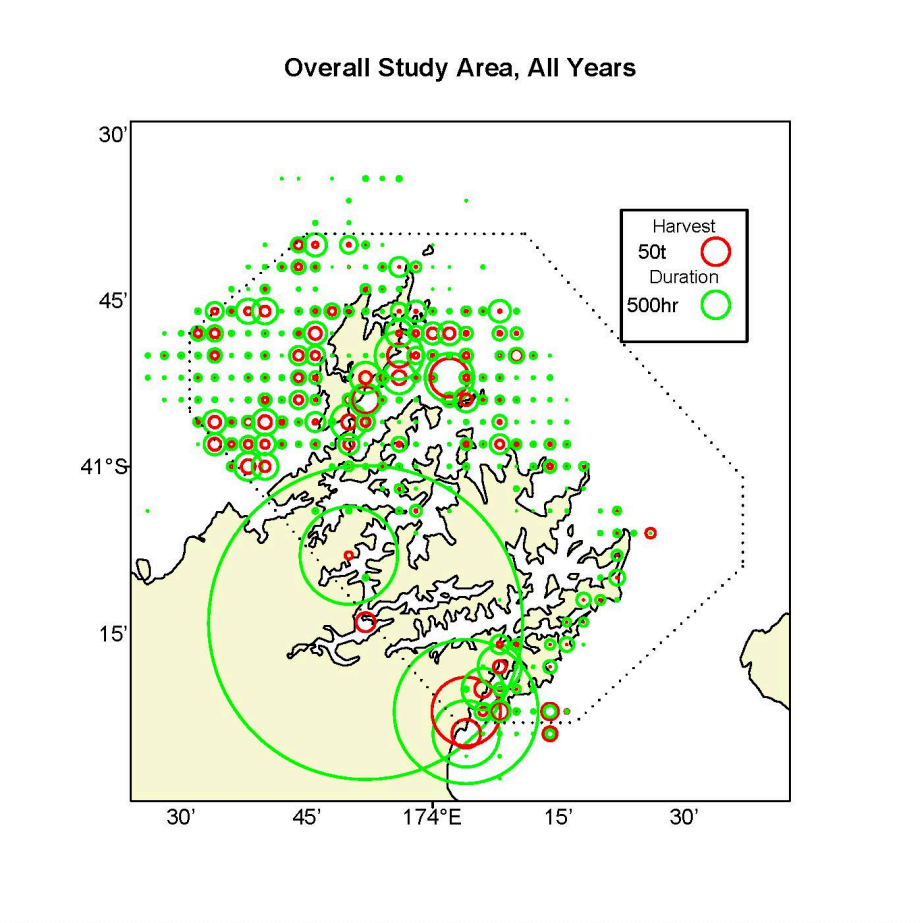
Greenweight tonnages from stat-areas 017 & 038, the entire study area and sub-areas, by year group; nulls not necessarily zero catch

Area	1	2	3	4	5	6
Stat-areas 017 & 038	7 072.2	6 503.4	5 123.7	5 458.9	5 155.4	4 808.3
Entire study area	26.1	80.4	43.8	355.1	760.1	661.5
North Trio & Sentinel		11.2	7.7	114.9	360.3	276.8
Rahuinui & Stewart	6.4	33.7	13.3	224.8	436.2	364.8
Duffers, Tawhitinui & Hunia		10.6	5.2	118.0	358.6	261.9
White Rocks & Blumine Is		2.6		24.1	94.7	58.1

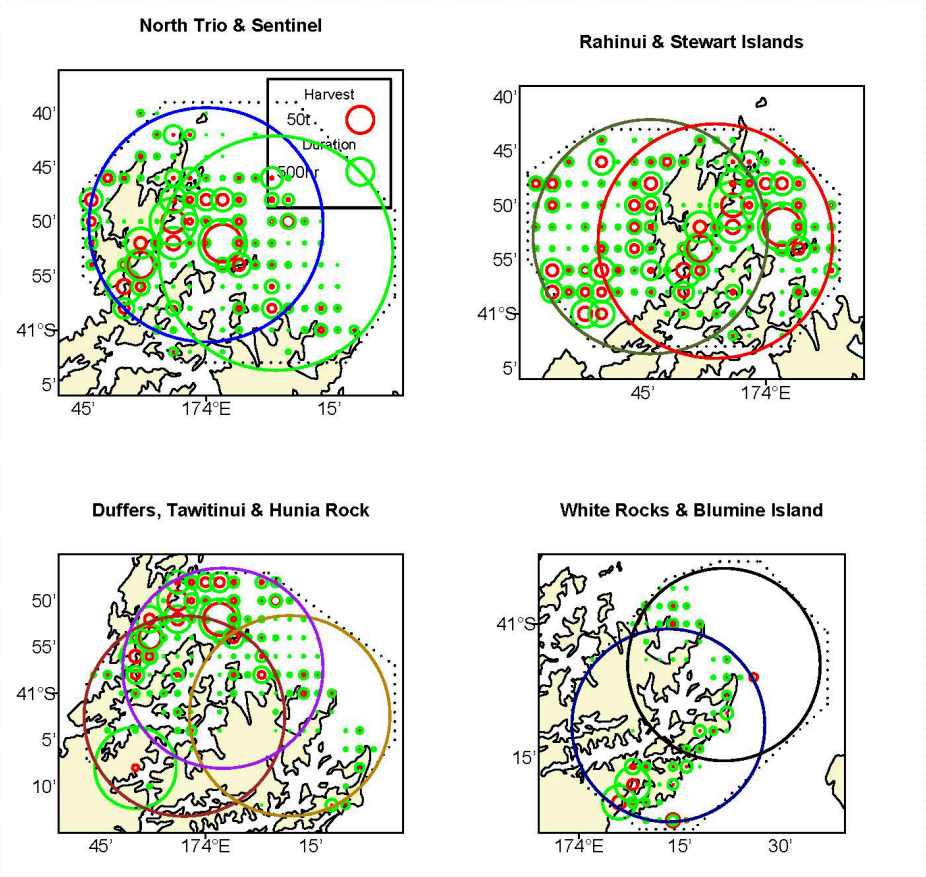
Catch (greenweight t) summary by area

	Gurnard	Spiny dogfish	All flats (All species combined)	All chondrichthyans	Other
Stat-areas 017 & 038					
Status	2	1			
Tonnage	5 860	8 947	9 990	13 186	
Percent	17	26	30	39	
Study-area					
Status	1	2			
Tonnage	672	324	460	613	
Percent	35	17	24	32	
Trio & Sentinel					
Status	1	2			
Tonnage	320	143	111	237	
Percent	42	19	15	31	
Rahuinui & Stewart					
Status	1	2			
Tonnage	463	158	180	326	
Percent	44	15	17	31	
Duffers etc					
Status	1	2			
Tonnage	275	131	157	223	
Percent	38	18	22	31	
White Rock & Blumine					Flats (catch category)
Status	2	3			1
Tonnage	36	34	64	50	39
Percent	21	20	37	29	23

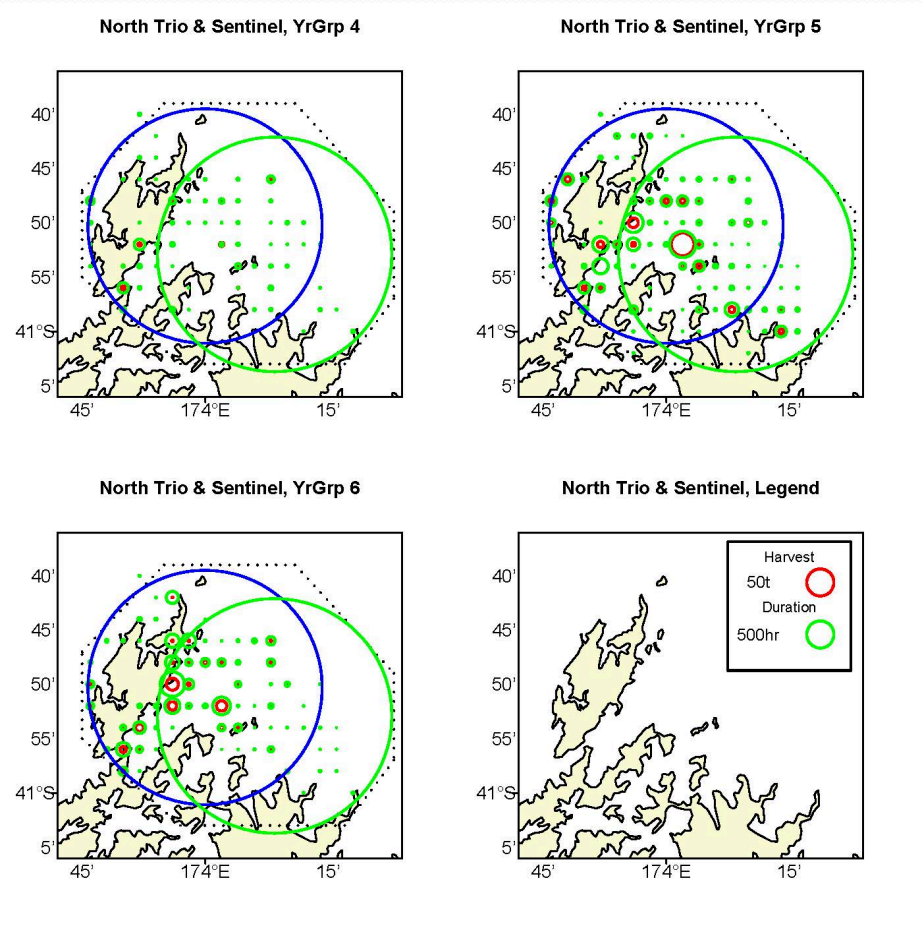
Spatial distribution of total greenweight catches (red) and fishing duration (green) for the entire study area in all years (1989–90 to 2018–19)



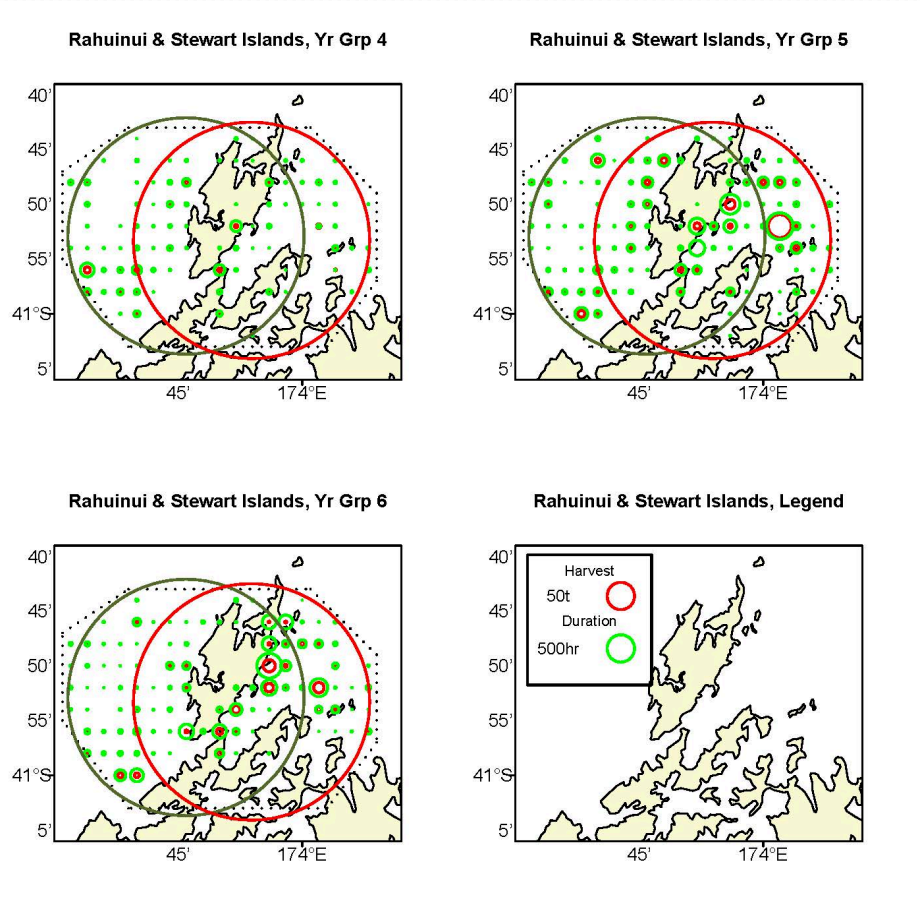
Spatial distributions of total greenweight catches (red) and fishing duration (green) of all years (1989–90 to 2018–19) for each of the sub-areas; circle diameters are proportional to catch greenweight tonnage and fishing duration; large circles show 20 km colony range boundaries



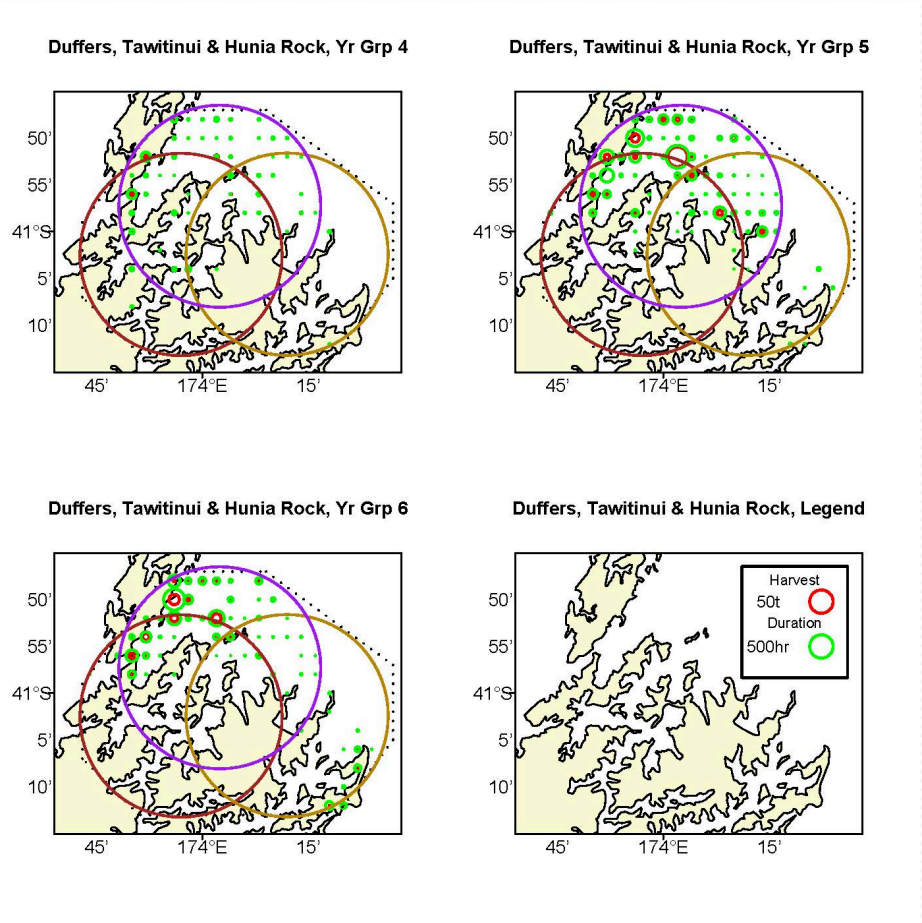
Spatial distributions of total greenweight catches (red) and fishing duration (green) for year-groups 4 (2005–09), 5 (2010–14) and 6 (2015–19) in the North Trio Island (blue circle) Sentinel Rock (green circle) sub-area; small circle diameters are proportional to catch greenweights and fishing duration; large circles (blue & green) show 20 km colony range boundaries



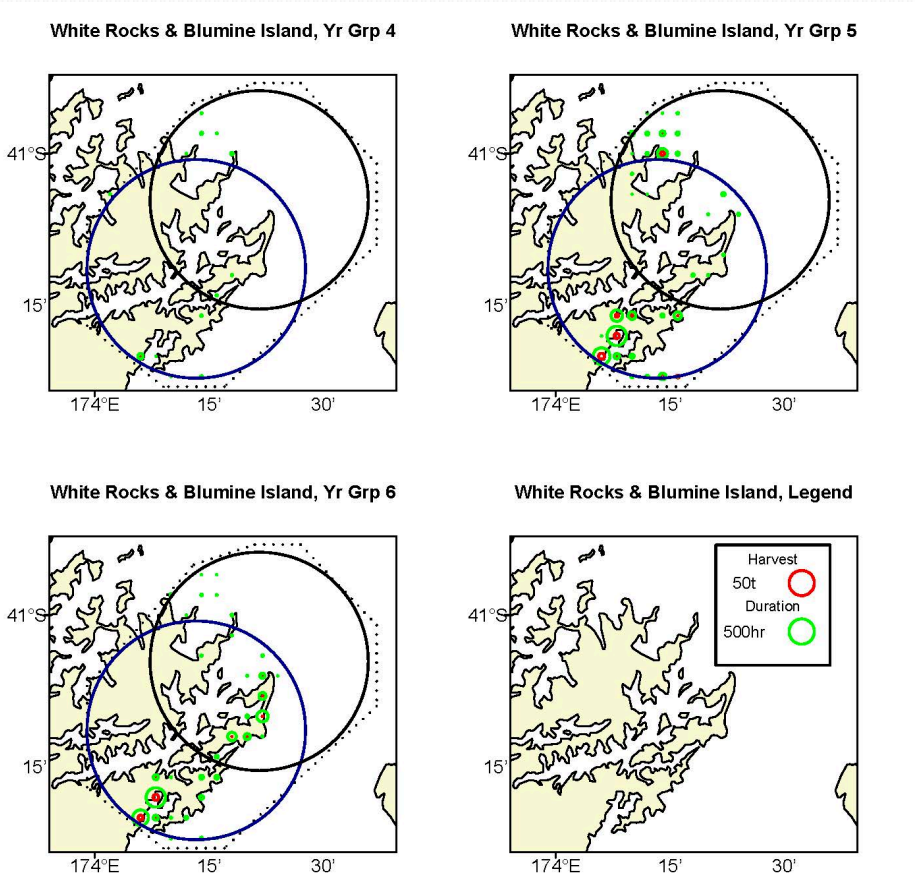
Spatial distributions of total greenweight catches (red) and fishing duration (green) for year-groups 4 (2005–09) , 5 (2010–14) and 6 (2015–19) in the Rahuinui-Stewart Islands sub-area; small circle diameters are proportional to catch greenweights and fishing duration; large circles show 20 km colony range boundaries



Spatial distributions of total greenweight catches (red) and fishing duration (green) for year-groups 4 (2005–09) , 5 (2010–14) and 6 (2015–19) in the Duffers Reef-Tawhitinui-Hunia Rock sub-area; small circle diameters are proportional to catch greenweights and fishing duration; large circles show 20 km colony range boundaries



Spatial distributions of total greenweight catches (red) and fishing duration (green) for year-groups 4 (2005–09) , 5 (2010–14) and 6 (2015–19) in the White Rocks-Blumine Island sub-area; small circle diameters are proportional to catch greenweights and fishing duration; large circles show 20 km colony range boundaries



Summary – indicators of an indirect effect on king shag

1. **Indicator 1:** there was no evidence of this indicator in either the processed study-area dataset or the estimated catch and effort.
2. **Indicator 2:** for Duffer-Tawhitinui-Hunia and White Rocks-Blumine Island there was evidence of large contrast between fishing effort and catch that was not evident in the overall study area or the other two sub-areas; examination of the distribution plots suggest that this could be related to the setnet fishery.
3. **Indicator 3:** There is no conclusive evidence for effort being redirected in a coordinated way.

Summary – impact on finfish taxa

- Catch of gurnard is consistently the highest in all areas except White Rock-Blumine (21-44%, 35% overall).
- Catch of all species of flatfish combined represents a relatively high proportion (15-37%) of the total in each case.
- Two flatfish species, greenback and yellowbelly flounder, were poorly represented in most areas, providing a plausible reason for their absence from the prey list. Chondrichthyan species, whose contribution to king shag feeding is unknown but possibly masked by the absence of otoliths, represented about 30% of the total catch for all sub-areas.
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- These figures are similar to summaries for stat-areas 017-038 although the gurnard ratio there is a little lower at 15%.

Summary – unexplained features of the stat-area 017 & 038 (combined) dataset

1. There appears to be a reduction in the annual effort (fishing hours) relative to the greenweight catch for stat-areas 017 & 038 (combined) that coincides with the introduction of the fine-scale data collection.
2. Similarly, there appears to be a change in the annual total number of sets coinciding with introduction of the fine-scale data collection, but in this case the change is an increase.
3. These changes have occurred with an overall reduction in the numbers of permit holders, although this reduction follows a “stepping” trend.
4. Note: features #1 and #2 are both measures of effort, but follow contradictory trends.

Conclusions

- In terms of the Indicators #1 and #3, the results of the work carried out here suggest little evidence of the commercial fishery having any definite effect on the availability of king shag prey and, therefore, an indirect impact on the king shag itself.

- There is evidence for Indicator #2 in the Duffers-Tawhitinui-Hunia and White Rock-Blumine sub-areas; it seems that the setnet fishery could be the major contributor to the high contrast between effort and catch, although this needs to be investigated further.

- The total annual catch for stat-areas 017 & 038 appears to follow a declining trend, but this is associated with a declining trend in the effort measure, suggesting the absence of a declining catch rate; however, the major feature of the apparent reduction in the effort is coincident with the introduction of the fine-scale data collection and confuses the interpretation of this relationship.

Future work

- The nominal measure of fishing effort used here was, by definition, un-standardised; work to standardise catch per unit effort (CPUE) may provide further insight into the various elements of the fishery, but this relies on data coverage and reliability.

- Further investigation on elements of the fishery could clarify whether the relatively high fishing effort for lower catch is related to a lower effective fishing success for the setnet fishery in this area compared with other methods.

Acknowledgements

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