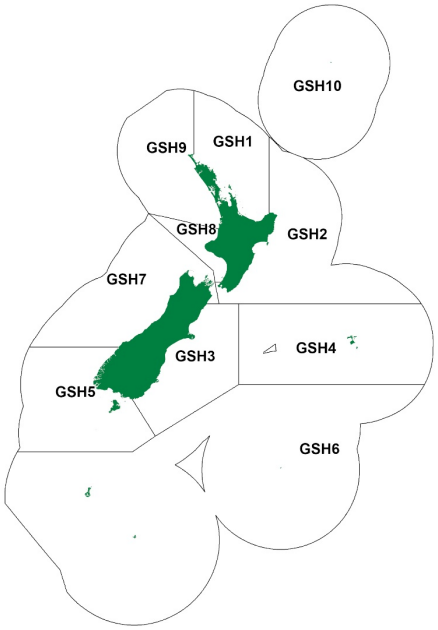
DARK GHOST SHARK (GSH)

(*Hydrolagus novaezealandiae*)



1. FISHERY SUMMARY

1.1 Commercial fisheries

Two species (dark and pale ghost sharks) make up effectively all commercial ghost shark landings. Dark ghost shark (*Hydrolagus novaezealandiae*) was introduced into the QMS from the beginning of the 1998–99 fishing year for the 10 FMAs shown above.

Both ghost shark species are taken almost exclusively as a bycatch of other target trawl fisheries. In the 1990s, about 43% of ghost sharks were landed as a bycatch of the hoki fishery, with fisheries for silver warehou, arrow squid and barracouta combining to land a further 36%. The two ghost shark species were seldom differentiated on catch landing returns prior to the start of the 1998–99 fishing year. Estimated landings of both species by foreign licensed and joint venture vessels over the period 1 April 1978 to 30 September 1983 are presented in Table 1. Landings by domestic (inshore) vessels would have been negligible during this time period. The unknown quantities of ghost sharks that were discarded and not recorded will have resulted in an under-reported total, particularly before both species were included in the QMS.

In the early to mid-1980s about half of the reported ghost shark landings were from FMA 3. Virtually all the additional catch was spread over FMAs 4–7. In 1988–89, landings from west coast South Island (FMA 7) began to increase, almost certainly associated with the development of the hoki fishery. In 1990–91, significant landing increases were apparent on the Chatham Rise, off southeast South Island and on the Campbell Plateau. The development of fisheries for non-spawning hoki were probably responsible for these increases.

Estimated landings of dark ghost shark by QMA are shown in Tables 2 and 3, while the historical landings and TACC for the main GSH stocks are depicted in Figure 1. Landings from 1983–84 to 1994–95 were derived by splitting all reported ghost shark landings into depth and area bins, and allocating to species based on distribution data derived from trawl surveys (*see* section 2). Landings from 1995–96 to 1998–99 were estimated assuming dark ghost shark made up 70% of the total ghost shark catch in FMAs 5 and 6, and 75% in all other FMAs. However this approach assumes that the proportion that each species contributes to the whole is consistent from year to year and does not change in response to various sources of mortality, fishing-induced or otherwise. As such, the data covered by this period of time should be treated with caution. Catches from the 1999–00 fishing year are more reliable, when pale ghost shark had also been included in the QMS, bringing both under the system.

Table 1: Reported landings (t) of both ghost shark species by fishing year and EEZ area, taken by foreign licensed and joint venture vessels. An approximation of these areas with respect to current QMA boundaries is used to assign catches to QMAs. No data are available for the 1980–81 fishing year.

Year	EEZ Area												
	B	C(M)	C(1)	D	E(B)	E(P)	E(C)	E(A)	F(E)	F(W)	G	H	Total
QMA	1&2	3	4	6	5	7	8						
1978–79*	1	37	99	26	3	16	11	88	90	8	68	17	465
1979–80*	1	55	54	426	10	4	28	138	183	7	1	5	912
1980–81*													-
1981–82*	0	84	28	117	0	2	6	29	71	9	4	0	350
1982–83*	0	108	35	84	0	2	17	98	99	29	1	1	474
1983–83#	0	84	41	73	0	0	17	5	16	17	0	0	253

* 1 April to 31 March # 1 April to 30 Sept.

Table 2: Reported landings (t) for the main QMAs from 1931 to 1982.

Year	GSH 1	GSH 2	GSH 3	GSH 4	GSH 5	GSH 6	GSH 7	GSH 8
1931–32	0	0	0	0	0	0	0	0
1932–33	0	0	0	0	0	0	0	0
1933–34	0	0	0	0	0	0	0	0
1934–35	0	0	0	0	0	0	0	0
1935–36	0	0	0	0	0	0	0	0
1936–37	0	0	0	0	0	0	0	0
1937–38	0	0	0	0	0	0	0	0
1938–39	0	0	0	0	0	0	0	0
1939–40	0	0	0	0	0	0	0	0
1940–41	0	0	0	0	0	0	0	0
1941–42	0	0	0	0	0	0	0	0
1942–43	0	0	0	0	0	0	0	0
1943–44	0	0	0	0	0	0	0	0
1944	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0
1947	0	0	0	0	0	0	0	0
1948	0	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0
1950	0	0	0	0	0	0	0	0
1951	0	0	0	0	0	0	0	0
1952	0	0	0	0	0	0	0	0
1953	0	0	0	0	0	0	0	0
1954	0	0	0	0	0	0	0	0
1955	0	0	0	0	0	0	0	0
1956	0	0	0	0	0	0	0	0
1957	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0
1961	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0
1972	0	0	103	0	11	0	0	0
1973	0	0	0	0	0	0	0	0
1974	0	0	7	0	1	0	0	0
1975	0	0	8	0	1	0	0	0
1976	0	0	19	0	2	0	0	1
1977	0	0	2	0	0	0	0	0
1978	0	0	54	0	100	30	15	2
1979	0	2	486	383	178	131	268	2
1980	0	0	150	230	92	144	144	28
1981	0	0	233	243	111	35	17	17
1982	0	0	320	97	223	29	11	7

Notes:
The 1931–1943 years are April–March but from 1944 onwards are calendar years. Data up to 1985 are from fishing returns: Data from 1986 to 1990 are from Quota Management Reports. Data for the period 1931 to 1982 are based on reported landings by harbour and are likely to be underestimated as a result of under-reporting and discarding practices. Data includes both foreign and domestic landings. Data were aggregated to FMA using methods and assumptions described by Francis & Paul (2013).

Table 3: Estimated landings (t) of dark ghost shark by Fishstock from 1982–83 to present, based on reported landings of both ghost shark species combined, and actual TACCs set from 1998–99. * - FSU data

Fishstock	GSH 1		GSH 2		GSH 3		GSH 4		GSH 5	
FMA (s)	1		2		3		4		5	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1982–83*	1	-	< 1	-	151	-	65	-	35	-
1983–84*	0	-	< 1	-	185	-	65	-	42	-
1984–85*	< 1	-	4	-	136	-	95	-	50	-
1985–86*	< 1	-	1	-	276	-	60	-	30	-
1986–87	3	-	13	-	472	-	97	-	34	-
1987–88	4	-	< 1	-	539	-	53	-	49	-
1988–89	9	-	27	-	460	-	21	-	67	-
1989–90	1	-	14	-	383	-	29	-	78	-
1990–91	1	-	40	-	665	-	271	-	70	-
1991–92	4	-	7	-	444	-	179	-	81	-
1992–93	8	-	5	-	399	-	151	-	76	-
1993–94	7	-	7	-	569	-	144	-	51	-
1994–95	3	-	2	-	737	-	187	-	63	-
1995–96	13	-	37	-	678	-	253	-	71	-
1996–97	17	-	66	-	817	-	402	-	94	-
1997–98	17	-	17	-	767	-	262	-	70	-
1998–99	18	15	60	37	950	1 187	318	373	64	109
1999–00	15	15	51	37	938	1 187	173	373	71	109
2000–01	15	10	50	33	1 111	1 185	179	370	85	109
2001–02	22	10	52	33	1 068	1 185	241	370	76	109
2002–03	17	10	58	33	1 371	1 185	265	370	93	109
2003–04	21	10	84	33	894	1 185	157	370	45	109
2004–05	14	10	74	33	880	1 185	282	370	80	109
2005–06	20	10	57	33	583	1 185	318	370	61	109
2006–07	20	22	60	66	654	1 185	396	370	115	109
2007–08	19	22	100	66	484	1 185	562	370	67	109
2008–09	14	22	71	66	490	1 185	251	370	61	109
2009–10	13	22	64	66	520	1 185	233	370	108	109
2010–11	17	22	95	66	640	1 185	311	370	73	109
2011–12	11	22	57	66	497	1 185	482	370	72	109
2012–13	12	22	51	66	420	1 185	210	370	111	109
2013–14	15	22	83	89	667	1 185	201	370	53	109
2014–15	16	22	44	89	406	1 185	217	370	42	109
2015–16	21	22	38	89	547	1 185	217	370	56	109
2016–17	21	22	47	89	493	1 185	223	370	83	109
2017–18	21	22	53	89	584	1 185	198	370	63	109
2018–19	28	22	40	89	528	1 185	166	370	51	109
2019–20	26	22	44	89	349	1 185	147	370	55	109

Fishstock	GSH 6		GSH 7		GSH 8		GSH 9			
FMA (s)	6		7		8		9		Total	
	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC	Landings	TAC
1982–83*	19	-	10	-	< 1	-	0	-	282	-
1983–84*	56	-	38	-	< 1	-	0	-	387	-
1984–85*	61	-	63	-	< 1	-	0	-	409	-
1985–86*	41	-	31	-	3	-	0	-	442	-
1986–87	36	-	71	-	4	-	0	-	729	-
1987–88	6	-	68	-	1	-	0	-	720	-
1988–89	6	-	133	-	2	-	0	-	725	-
1989–90	9	-	180	-	27	-	0	-	722	-
1990–91	94	-	217	-	3	-	0	-	1 361	-
1991–92	80	-	124	-	3	-	1	-	923	-
1992–93	68	-	221	-	11	-	0	-	938	-
1993–94	53	-	513	-	14	-	0	-	1 357	-
1994–95	61	-	703	-	3	-	0	-	1 778	-
1995–96	68	-	548	-	8	-	3	-	1 679	-
1996–97	135	-	926	-	9	-	11	-	2 477	-
1997–98	136	-	170	-	3	-	12	-	1 454	-
1998–99	110	95	409	1 121	7	12	22	14	1 958	2 963
1999–00	117	95	466	1 121	19	12	25	14	1 875	2 963
2000–01	76	95	475	1 121	22	12	31	8	2 043	2 943
2001–02	94	95	463	1 121	22	12	25	8	2 063	2 943
2002–03	99	95	593	1 121	15	12	20	8	2 531	2 943
2003–04	72	95	652	1 121	27	12	12	8	1 964	2 943
2004–05	53	95	694	1 121	31	12	10	8	2 118	2 943
2005–06	31	95	625	1 121	22	12	8	8	1 725	2 943
2006–07	43	95	696	1 121	16	22	6	22	2 006	3 012
2007–08	36	95	601	1 121	29	22	13	22	1 911	3 012
2008–09	49	95	991	1 121	24	22	16	22	1 967	3 012
2009–10	19	95	1 037	1 121	29	22	6	22	2 028	3 012
2010–11	38	95	1 129	1 121	33	22	6	22	2 341	3 012
2011–12	37	95	1 041	1 121	37	22	6	22	2 240	3 012
2012–13	70	95	767	1 121	32	22	10	22	1 683	3 012
2013–14	72	95	691	1 121	27	34	9	22	1 817	3 047
2014–15	72	95	458	1 121	20	34	7	22	1 283	3 047
2015–16	64	95	400	1 121	19	34	6	22	1 368	3 047
2016–17	59	95	423	1 121	19	34	14	22	1 382	3 047
2017–18	71	95	329	1 121	18	34	25	22	1 363	3 047
2018–19	68	95	485	1 121	20	34	19	22	1 406	3 047
2019–20	35	95	333	1 121	28	34	24	22	1 039	3 047

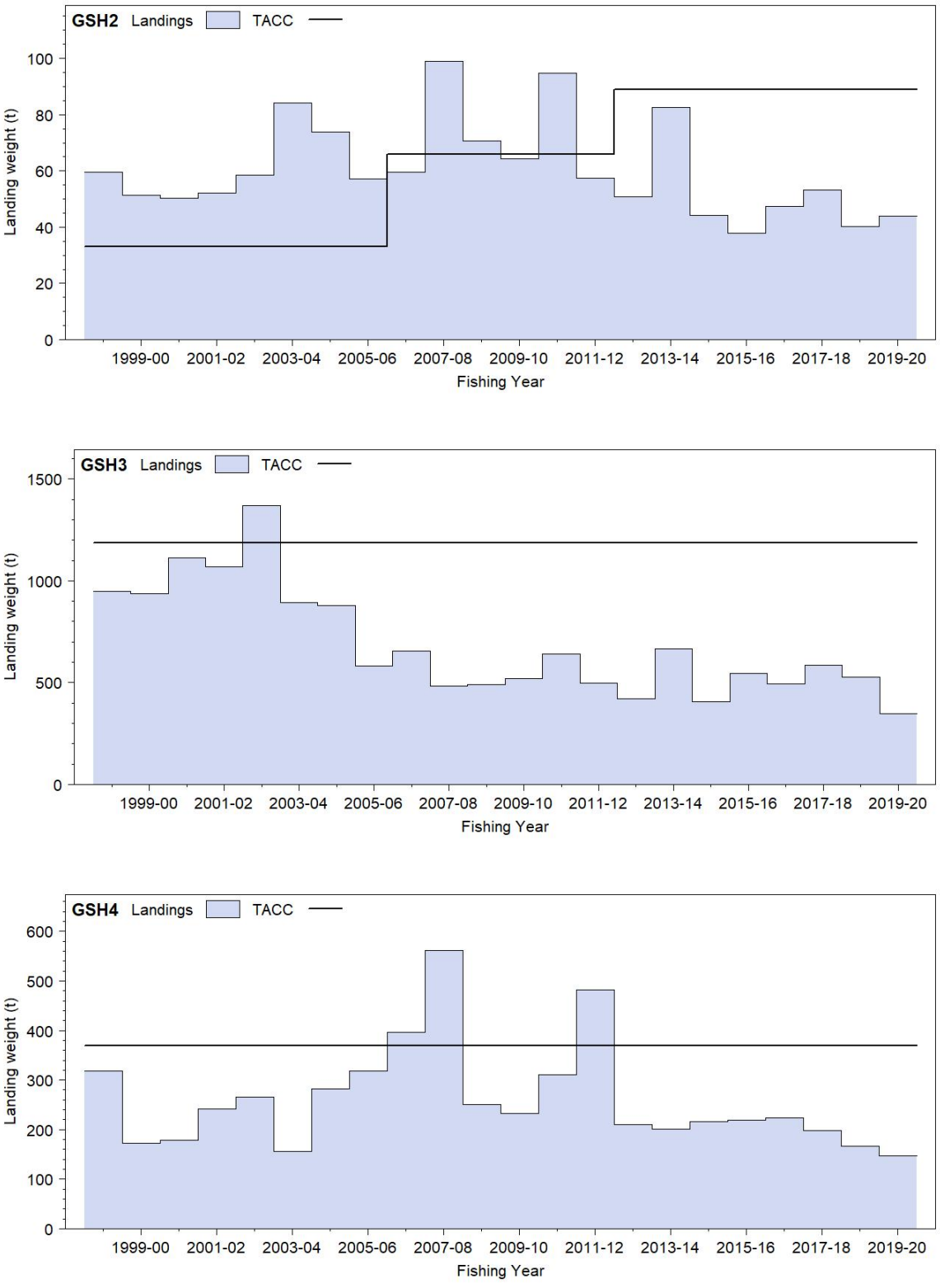


Figure 1: Reported commercial landings and TACC for GSH stocks. From top GSH 2 (Central East), GSH 3 (South East Coast), GSH 4 (South East Chatham Rise). [Continued on next page]

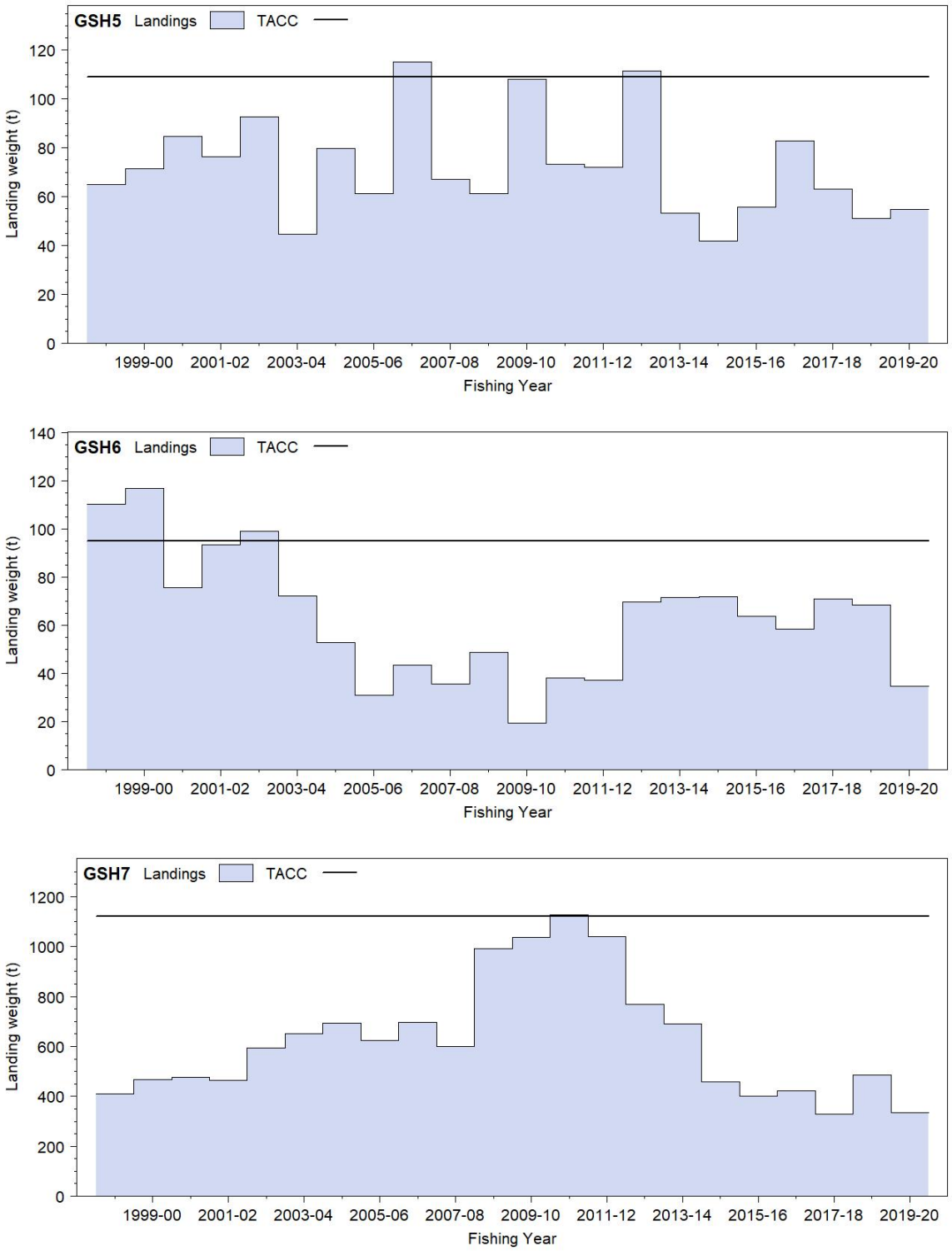


Figure 1 [Continued]: Reported commercial landings and TACC for GSH stocks. From top GSH 5 (Southland), GSH 6 (Sub-Antarctic), and GSH 7 (West Coast South Island).

The TACs currently applied to dark ghost shark were initially intended to apply to a combined fishery for both species, and were based on the average catch of both species over various periods (see the "Review of Sustainability Measures and Other Management Controls for the 1998–99 Fishing Year - Final Advice Paper" dated 6 August 1998). No allowance for non-commercial interests was included in the final allocation because recreational and customary non-commercial catches are likely to be very small due to the depth distribution of this species.

TACCs were increased from 1 October 2006 in GSH 1 to 22 t, in GSH 2 to 66 t, in GSH 8 to 22 t and in GSH 9 to 22 t. In these stocks landings had been above the TACC for a number of years and the

TACCs were increased to the average of the previous 7 years plus an additional 10%. In GSH 2 and 8 landings continued to consistently exceed the TACCs after 2006. Consequently the TACCs were further increased to 89 t in GSH 2 and 34 t in GSH 8 in 2013. Landings have remained below the TACCs for all GSH stocks since 2013.

1.2 Recreational fisheries

Current catches of dark ghost sharks by recreational fishers are believed to be negligible in all areas.

1.3 Customary non-commercial fisheries

Quantitative information on the current level of customary non-commercial catch is not available but is likely to be negligible

1.4 Illegal catch

Quantitative information on the level of illegal catch is not available. In 1998–99 (when dark ghost shark were in the QMS, but pale ghost shark were not), a quantity of dark ghost shark were reported as pale ghost shark.

1.5 Other sources of mortality

Ghost sharks have been dumped and not reported in the past by commercial fishers in QMAs 1 and 2. Similar behaviour is believed to occur in all other QMAs. The extent of the unreported dumping is unknown in all areas.

2. BIOLOGY

Dark ghost shark (*Hydrolagus novaezelandiae*) occur through much of the New Zealand EEZ in depths from 30 to 850 m, but they are sparse north of 40° S and have not been recorded from the Bounty Platform. They are most abundant in waters 150–500 m deep on the west coast of the South Island and the Chatham Rise, and in depths of 150–700 m on the Stewart-Snares shelf and Southland/sub-Antarctic. Smaller sharks (under 40 cm chimaera length) are more abundant in waters shallower than 200 m, particularly in the Canterbury Bight.

Trawl surveys show that dark and pale ghost shark exhibit niche differentiation, with water depth being the most influential factor, although there is some overlap of habitat. On the Chatham Rise, the main overlap range appears quite compact (from about 340 to 540 m). In the Southland/sub-Antarctic region, the overlap range is wider (about 350 to 770 m). Stomach contents indicate that both species are predominantly benthic feeders.

No published information is available on the age or growth rate of any *Hydrolagus* species, or even any species in the family Chimaeridae. A research report by Francis & Ó Maolagáin (2001) found that eye lens diameter showed potential as an ageing technique but further work was needed. They calculated Von Bertalanffy parameters (Table 4) from trawl survey caught fish and found that growth rates were similar and moderately rapid for males and females with both sexes reaching 50 cm in 5–9 years. They caution the use of these parameters, however, as ageing of dark ghost sharks has not been validated. Length-frequency histograms indicate that females grow to a larger size than males. Without population age structures or confident estimates of longevity, it is not possible to estimate natural or total mortalities.

On the Chatham Rise, the estimated size at 50% sexual maturity for dark ghost sharks is 52–53 cm for males and 62–63 cm for females. As for most other elasmobranchs, ghost shark fecundity is likely to be low.

Length-weight parameters are shown in Table 5.

Table 4: Von Bertalanffy growth parameters for dark ghost shark. Source: Francis & Ó Maolagáin (2001).

		Von Bertalanffy growth parameters		
Region	**Sex**	L_∞	**K**	t_0
East coast South Island	Female	135.3	0.052	–0.94
	Male	89.0	0.091	–0.61
West coast South Island	Female	123.0	0.065	–1.15
	Male	123.4	0.044	–1.43
Stewart–Snares Shelf	Female	122.1	0.087	–1.01
	Male	108.0	0.073	–1.34
Chatham Rise	Female	97.0	0.090	–1.17
	Male	-	-	-

Table 5: Length-weight parameters for dark ghost shark.

1. Weight = a (length)^b (Weight in g, length in cm chimaera length)

FMA	**Estimate**		
	a	**b**	**Source**
Chatham Rise	0.002986	3.170546	O'Driscoll et al (2011)
Sub-Antarctic	0.001653	3.3256	Bagley et al (2013)

3. STOCKS AND AREAS

The only information which may indicate a stock boundary is an apparent difference in maximum size of dark ghost sharks, with both males and females from the Chatham Rise attaining a maximum size 3–4 cm greater than those in Southland/sub-Antarctic waters.

Horn (1997) proposed that ghost sharks be managed as three Fishstocks, i.e., east coast New Zealand (FMAs 1–4), Stewart-Snares shelf and Campbell Plateau (FMAs 5 and 6), and west coast New Zealand (FMAs 7, 8, and 9). Areas of narrow continental shelf separate these FMA groupings, so they could well provide barriers to stock mixing for pale ghost shark which have a preference for deeper water. This would be less influential for dark ghost shark, however, which are found much shallower. Pale ghost shark were given the QMAs recommended by Horn when introduced into the QMS, but dark ghost shark were already based on the generic FMAs.

4. STOCK ASSESSMENT

No assessment of any stocks of dark ghost shark has been completed. Therefore, no estimates of yield are available.

4.1 Estimates of fishery parameters and abundance

Estimates of fishery parameters are not available for dark ghost sharks. Several time series of relative biomass estimates are available from fishery independent trawl surveys (Table 6), but wide fluctuations between years suggest the need for caution in using these as indicators of relative abundance. The Chatham Rise time series may provide a reasonable index of abundance for GSH 4, but not GSH 3 as the survey does not fish shallower than 200 m where dark ghost shark are abundant. Much of GSH 3 is covered by the winter east coast South Island trawl survey however, which is optimised for dark ghost shark among other species.

4.2 Biomass estimates

Biomass estimates from various trawl surveys are given in Table 6. Of those, ongoing estimates are available from random stratified bottom trawl surveys from the east coast South Island, Chatham Rise, sub-Antarctic, and west coast South Island trawl surveys.

Table 6: Biomass indices (t) and coefficients of variation (CV). Estimates for the Chatham Rise and sub-Antarctic summer surveys on *Tangaroa* are for core strata only (200–800 and 300–800 m respectively). [Continued on next page]

FMA	Area	Vessel	Trip code	Date	Biomass	% CV
3 & 4	Chatham Rise	*Tangaroa*	TAN9106	Jan-Feb 1992	6 700	11.1
			TAN9212	Jan-Feb 1993	5 950	9.2
			TAN9401	Jan-94	10 360	15.3
			TAN9501	Jan-95	3 490	11.2
			TAN9601	Jan-96	6 170	12.4
			TAN9701	Jan-97	6 240	11.7
			TAN9801	Jan-98	6 720	14.1
			TAN9901	Jan-99	12 125	23.4
			TAN0001	Jan-00	9 154	25.2
			TAN0101	Jan-01	10 356	12
			TAN0201	Jan-02	9 997	11.1
			TAN0301	Jan-03	10 341	9.1
			TAN0401	Jan-04	10 471	15
			TAN0501	Jan-05	11 885	16.3
			TAN0601	Jan-06	11 502	12
			TAN0701	Jan-07	7 852	11
			TAN0801	Jan-08	9 391	10.9
			TAN0901	Jan-09	8 445	13.7
			TAN1001	Jan-10	11 596	16.8
			TAN1101	Jan-11	6 588	17
			TAN1201	Jan-12	13 162	20.6
			TAN1301	Jan-13	11 723	11.6
			TAN1401	Jan-14	9 050	18
			TAN1601	Jan-16	11 925	12
5 & 6	Southland Sub-Antarctic	*Tangaroa* (summer)	TAN9105	Nov-Dec 1991	1 030	25.4
			TAN9211	Nov-Dec 1992	710	43.2
			TAN9310	Nov-Dec 1993	1 060	33.6
			TAN0012	Nov-Dec 2000	1 459	89.6
			TAN0118	Nov-Dec 2001	1 391	35.7
			TAN0219	Nov-Dec 2002	175	37.7
			TAN0317	Nov-Dec 2003	382	48.9
			TAN0414	Nov-Dec 2004	843	41.7
			TAN0515	Nov-Dec 2005	517	40
			TAN0617	Nov-Dec 2006	354	32
			TAN0714	Nov-Dec 2007	659	37
			TAN0813	Nov-Dec 2008	1128	32
			TAN0911	Nov-Dec 2009	433	43
			TAN1117	Nov-Dec 2011	3 709	75
			TAN1215	Nov-Dec 2012	1 794	68.3
		Tangaroa (autumn)	TAN9204	Mar-Apr 1992	3 740	48.6
			TAN9304	Apr-May 1993	750	44.7
			TAN9605	Mar-Apr 1996	3 080	47.6
			TAN9805	Apr-May 1998	2 490	44
5	Stewart-Snares#	*Tangaroa*	TAN9301	Feb-Mar 1993	120	44
			TAN9402	Feb-Mar 1994	490	43
			TAN9502	Feb-Mar 1995	790	71
			TAN9604	Feb-Mar 1996	1 870	63
2	East coast North Island	*Kaharoa*	KAH9304	Mar-Apr 1993	450	61.5
			KAH9402	Feb-Mar 1994	40	41.3
			KAH9502	Feb-Mar 1995	10	48.6
			KAH9602	Feb-Mar 1996	80	33.5
3	ECSI winter surveys	*Kaharoa*	KAH9105	May-91	962	42
			KAH9205	May-92	934	44
			KAH9306	May-93	2 911	42
			KAH9406	May-94	2 702	25
			KAH9606	May-96	3 176	23
			KAH0705	May-07	4 483	25
			KAH0806	May-June-08	3 763	20
			KAH0905	May-Jun-09	4 330	24
			KAH1207	Apr-Jun-13	10 704	29
			KAH1402	Apr-Jun-14	13 137	26
			KAH1605	Apr-Jun-16	15 271	26
			KAH1803	Apr-Jun-18	6 485	23

Table 6: [continued]

FMA	Area	Vessel	Trip code	Date	Biomass	% CV
3	ECSI	*Kaharoa*	KAH9618	Dec '96 - Jan '97	3 066	18
	summer surveys		KAH9704	Dec '97 - Jan '98	5 870	33
			KAH9809	Dec '98 - Jan '99	7 416	27
			KAH9917	Dec '99 - Jan '00	2 512	19
			KAH0014	Dec '00 - Jan '01	2 950	18
7	West coast	*Kaharoa*	KAH9204	Mar-Apr 1992	380	20
	South Island		KAH9404	Mar-Apr 1994	720	14.3
			KAH9504	Mar-Apr 1995	770	23.7
			KAH9701	Mar-Apr 1997	1 590	21.2
			KAH0004	Mar-Apr 2000	2 260	9
			KAH0304	Mar-Apr 2003	540	15
			KAH0503	Mar-Apr 2005	830	22
			KAH0704	Mar-Apr 2007	2 215	21
			KAH0904	Mar-Apr 2009	900	17
			KAH1104	Mar-Apr 2011	2 363	23
			KAH1305	Mar-Apr 2013	981	23

East coast South Island winter trawl surveys

Total biomass in the east coast South Island winter surveys core strata (30–400 m) increased 16-fold between 1992 and 2016, but declined substantially in 2018 to 6485 t (Table 6, Figure 2) (MacGibbon et al. 2019). All surveys had a large component of pre-recruit biomass ranging from 30–61%. In 2018 the pre-recruit biomass was 42% of total biomass. The juvenile and adult biomass (based on length-at-50% maturity) of both sexes have generally increased proportionately over the time series and juvenile biomass comprised about half of the total biomass. In 2018 the juvenile biomass was 40% of total biomass.

Distribution over the ECSI winter trawl survey time series was similar and was confined to the continental slope and edge mainly in the Canterbury Bight, although the larger biomass from 2007 to 2016 is commensurate with a slightly expanded distribution throughout the survey area in this depth range and into Pegasus Bay. The size distributions in each of the last eleven surveys (1993–2016) were similar and generally bimodal (Beentjes et al 2016). The 2012, 2014 and 2016 length frequency distributions were distinct from previous years with relatively large numbers of adults or mature fish. These larger fish still account for a large proportion of the total in 2018 although overall numbers are lower than in 2016. The distributions differ from those of the Chatham Rise and Southland/Sub-Antarctic surveys (O'Driscoll & Bagley 2001, Livingston et al. 2002, Stevens et al. 2015, Bagley et al. 2017) in that ECSI has a large component of juvenile fish, suggesting that this area may be an important nursery ground for dark ghost shark.

Chatham Rise winter trawl surveys

The Chatham Rise trawl survey time series is not optimised for dark ghost shark and there has been some year-to-year variation between surveys, particularly for the first ten years (Figure 3). This time series may provide a reasonable index of abundance for that part of the eastern fishery (see Section 5) covered by GSH 4. However the survey extends into GSH 3 where commercial catches of dark ghost shark are significant but shallower than the survey's starting depth of 200 m.

Sub-Antarctic winter trawl surveys

Biomass indices from the sub-Antarctic trawl survey time series are significantly lower than those for the east coast South Island and Chatham Rise surveys. Indices have fluctuated somewhat (Figure 4). The large spike seen in 2011 is due to randomly allocated stations within stratum 6 (300–600 m) being located at the shallower, northern end of the stratum where dark ghost shark are more likely to be encountered. The starting depth of 300 m may mean that this survey is unlikely to be a reliable index of abundance.

West coast South Island winter trawl surveys

Biomass estimates from the west coast South Island inshore trawl survey are lower than those from the east coast South Island and Chatham Rise surveys. Estimates fluctuate considerably and are unlikely to reflect real changes in abundance (Figure 5).

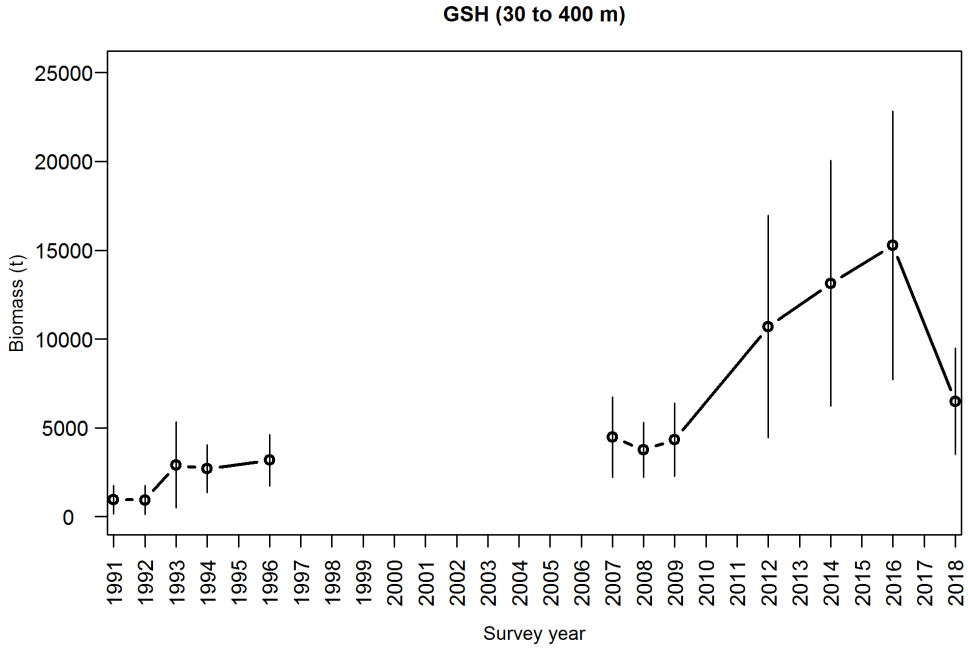


Figure 2: Biomass for dark ghost shark from the east coast South Island winter trawl surveys in core strata (30–400 m). Error bars are ±2 standard errors.

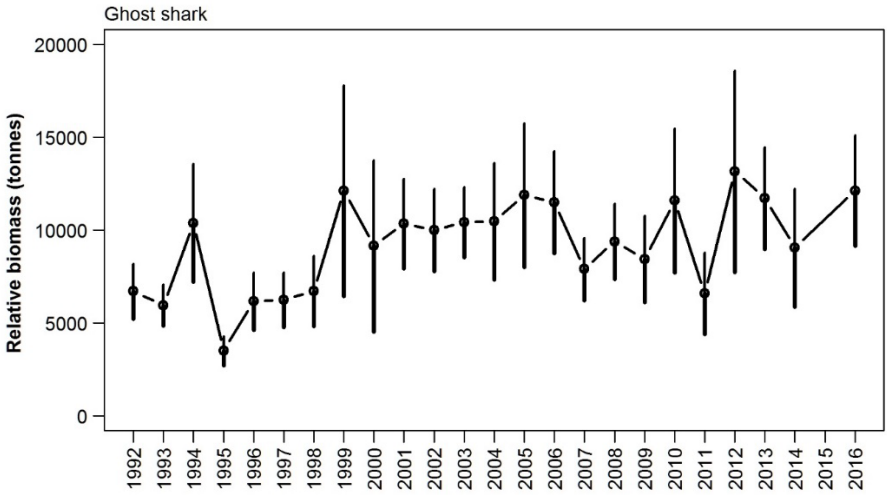


Figure 3: Biomass for dark ghost shark from the Chatham Rise trawl survey. Error bars are ± 2 standard errors.

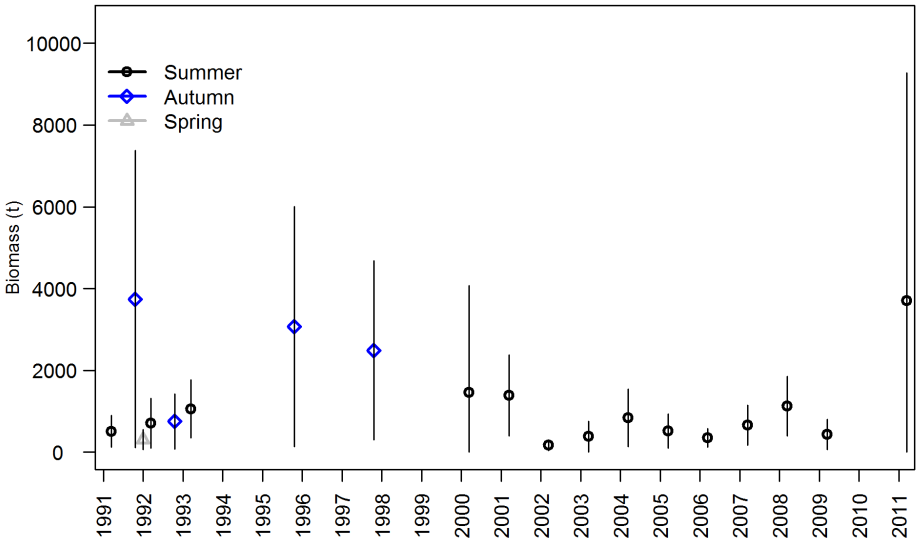


Figure 4: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the Sub-Antarctic trawl survey.

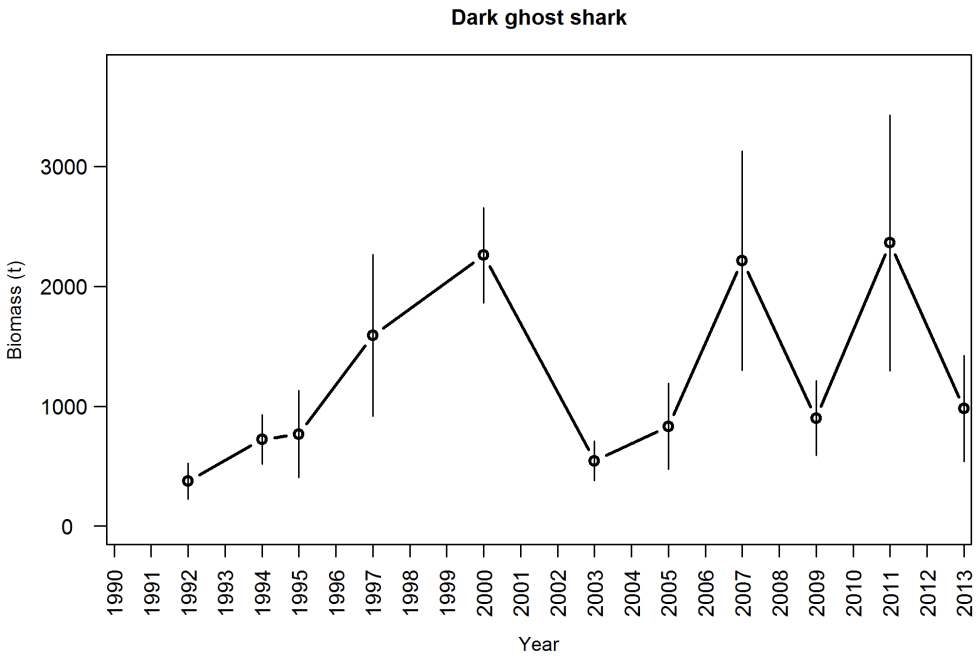


Figure 5: Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the West Coast South Island trawl survey.

4.3 Estimation of Maximum Constant Yield (*MCY*)

As there are no available estimates of biomass or harvest rates, the only possible method of calculating maximum constant yield is $MCY = cY_{AV}$ (Method 4). However, it was decided that no estimates of *MCY* would be presented because:

i. *M* (and hence, the natural variability factor *c*) is unknown;

ii. the level of discarding is unknown and may have been considerable; and

iii. no sufficiently long period of catches was available where there were no systematic changes in catch or effort (noting that the period of catches from which Y_{AV} is derived should be at least half the exploited life span of the fish).

4.4 Estimation of Current Annual Yield (*CAY*)

In the absence of estimates of current biomass, *CAY* has not been estimated.

4.5 Other yield estimates and stock assessment results

No other yield estimates are available.

4.6 Other factors

Elasmobranchs are believed to have a strong stock-recruit relationship; the number of young born is related directly to the number of adult females. Ghost shark fecundity is unknown, but is probably low. Assuming a strong stock-recruit relationship, Francis & Francis (1992) showed that the estimates of *MCY* obtained using the equations in current use in New Zealand stock assessments were overly optimistic for rig, and it is likely that they are also unsuitable for ghost sharks.

A data informed qualitative risk assessment was completed on all chondrichthyans (sharks, skates, rays and chimaeras) at the New Zealand scale in 2014 (Ford et al 2015). Dark ghost shark was ranked seventh highest in terms of risk of the eleven QMS chondrichthyan species. Data were described as existing but poor for the purposes of the assessment and consensus over this risk score was achieved by the expert panel. This risk assessment does not replace a stock assessment for this species but may influence research priorities across species.

5. STATUS OF THE STOCKS

Stock Structure Assumptions

Based on differences in length frequency distributions between the sub-Antarctic and Chatham Rise trawl surveys, and the location of commercial catches, there are most likely two main stocks of dark ghost shark.

1. The eastern fishery; extending from the upper east coast of the South Island and out east across the Chatham Rise.
2. The southern fishery; extending from the lower east coast of the South Island, south around the Stewart/Snares Shelf, Campbell Plateau, and Puysegur trench.

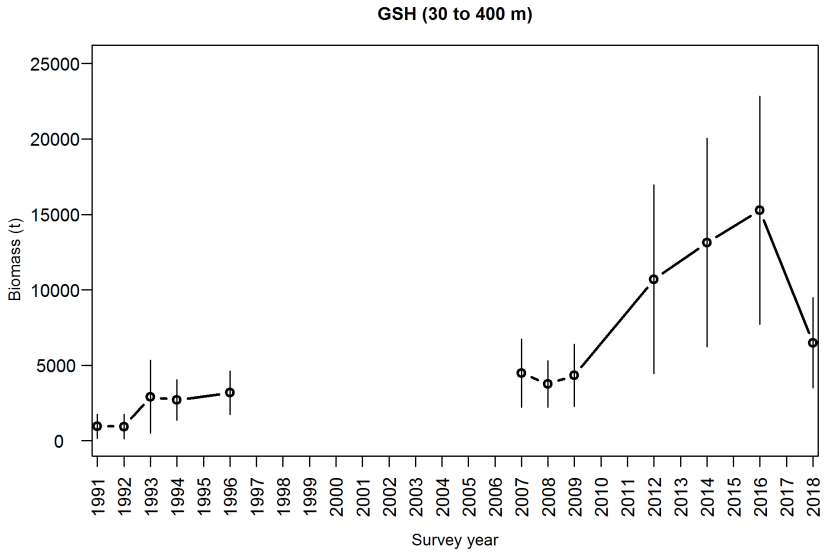
Further work needs to be done to investigate what if any relationship there is between dark ghost shark caught on the west coast of the South Island, around both coasts of the North Island, and the eastern and southern stocks.

- **Chatham Rise and ECSI**

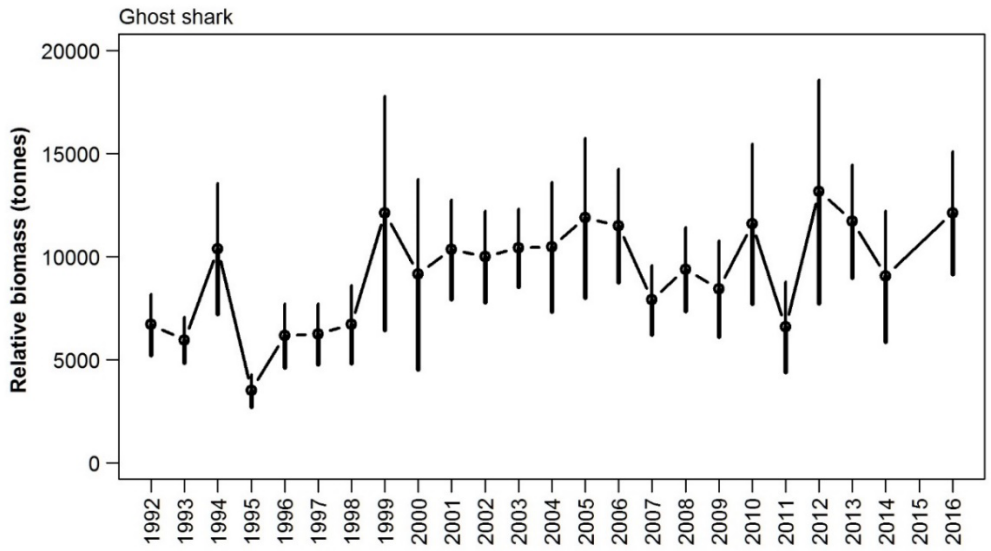
Stock Status	
Year of Most Recent Assessment	2016
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status

ECSI core strata



Biomass trajectory for dark ghost shark from the ECSI trawl survey. Error bars are ± 2 standard errors.



Biomass for dark ghost shark from the Chatham Rise trawl survey. Error bars are ± 2 standard errors.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass indices from the east coast South Island inshore trawl survey time series have been steadily increasing since 2009 but decline substantially in 2018. Biomass indices from the Chatham Rise have fluctuated somewhat over the time series. Estimates from the last ten years have been more stable.
Recent Trend in Fishing Intensity or Proxy	Landings have been stable for the last five years from GSH 3, and relatively stable from GSH 4, apart from a small spike in the 2007–08 fishing year.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown, but there is no evidence of a systematic decline in biomass indices from either the east coast of the South Island or the Chatham Rise.

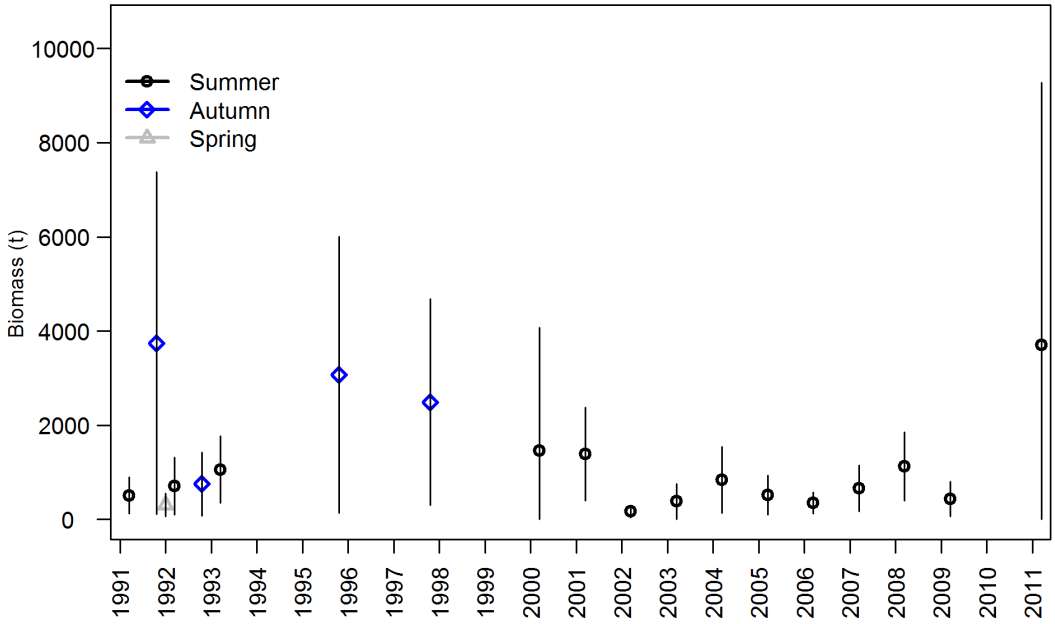
Qualifying Comments
-

Fishery Interactions
Dark ghost shark in the eastern fishery is caught exclusively as bycatch in other target fisheries with the two most important ones being hoki followed by arrow squid. For both target fisheries, incidental interactions and associated mortalities are noted for New Zealand fur seals and seabirds, and low productivity species taken in the fisheries include basking sharks and deepsea skates.

- **Southern stock**

Stock Status	
Year of Most Recent Assessment	2011
Assessment Runs Presented	-
Reference Points	Management Target: 40% B_0 Soft Limit: 20% B_0 Hard Limit: 10% B_0 Overfishing threshold: Not defined
Status in relation to Target	Unknown
Status in relation to Limits	Unknown
Status in relation to Overfishing	Unknown

Historical Stock Status Trajectory and Current Status



Biomass trends ±95% CI (estimated from survey CVs assuming a lognormal distribution) from the Sub-Antarctic trawl survey.

Fishery and Stock Trends	
Recent Trend in Biomass or Proxy	Biomass indices from the summer sub-Antarctic trawl survey time series have been relatively flat for the last few years apart from a large spike in 2011 due to a number of randomly allocated stations occurring at the shallower end of the depth range for dark ghost shark.
Recent Trend in Fishing Intensity or Proxy	Unknown. Landings have fluctuated somewhat from GSH 5 in recent years, and have been relatively stable from GSH 6.
Other Abundance Indices	-
Trends in Other Relevant Indicators or Variables	-

Projections and Prognosis	
Stock Projections or Prognosis	Unknown
Probability of Current Catch or TACC causing Biomass to remain below or to decline below Limits	Soft Limit: Unknown Hard Limit: Unknown
Probability of Current Catch or TACC causing Overfishing to continue or to commence	Unknown, but there is no evidence of a systematic decline in biomass indices from the sub-Antarctic survey.

Qualifying Comments
-

Fishery Interactions
Dark ghost shark in the southern fishery is caught exclusively as bycatch in other target fisheries with the two most important ones being arrow squid followed by hoki. For both target fisheries, incidental interactions and associated mortalities have been recorded for New Zealand fur seals and seabirds, and low productivity species taken in the fisheries include basking sharks and deepsea skates. Interactions with other species are currently being characterised.

6. FOR FURTHER INFORMATION

Bagley, N W; O'Driscoll, R L; Oeffner, J (2013) Trawl survey of hoki and middle-depth species in the Southland and Sub-Antarctic areas, November–December 2011 (TAN1117). *New Zealand Fisheries Assessment Report 2013/23*. 70 p.

Bagley, N.W.; Ladroit, Y.; O'Driscoll, R.L. (2017). Trawl survey of hoki and middle-depth species in the Southland and Sub-Antarctic areas, November–December 2014 (TAN1412) *New Zealand Fisheries Assessment Report 2017/58*. 69 p.

Beentjes, M P; MacGibbon, D; Parkinson, D (2016) Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2016 (KAH1605). *New Zealand Fisheries Assessment Report 2016/61*. 135 p.

Ford, R B; Galland, A; Clark, M R; Crozier, P; Duffy, C A J; Dunn, M R; Francis, M P; Wells, R (2015) Qualitative (Level 1) Risk Assessment of the impact of commercial fishing on New Zealand Chondrichthyans. *New Zealand Aquatic Environment and Biodiversity Report No. 157*. 111 p.

Francis, M P; Francis, R I C C (1992) Growth, mortality, and yield estimates for rig (*Mustelus lenticulatus*). New Zealand Fisheries Assessment Research Document 1992/5. 32 p. (Unpublished document held by NIWA library, Wellington.)

Francis, M P; McMillan, P; Lasenby, R; Didier, D (1998) How to tell dark and pale ghost sharks apart. *Seafood New Zealand 6 (11)*: 29–30.

Francis, M P; Ó Maolagáin, C O (2001) Development of ageing techniques for dark ghost shark (*Hydrolagus novaezelandiae*). Final Research Report for Ministry of Fisheries Research Project MOF2000/03C. 10 p. (Unpublished report held by Fisheries New Zealand Wellington.)

Francis, M P.; Paul, L J (2013) New Zealand inshore finfish and shellfish commercial landings, 1931–82. *New Zealand Fisheries Assessment Report 2013/55.* 136 p.

Horn, P L (1997) A summary of biology and commercial landings, and a stock assessment of ghost sharks (*Hydrolagus* spp.) in New Zealand waters. New Zealand Fisheries Assessment Research Document 97/3. 36 p. (Unpublished document held by NIWA library, Wellington.)

Livingston, M.E.; Bull, B.; Stevens, D.W.; Bagley, N.W. (2002). A review of hoki and middle depths trawl surveys of the Chatham Rise, January 1992–2001. *NIWA Technical Report 113*. 146 p.

MacGibbon, D J; Stevenson, M L (2013) Inshore trawl survey of the west coast South Island and Tasman and Golden Bays, March-April 2013 (KAH1305) *New Zealand Fisheries Assessment Report 2013/66*. 115 p.

MacGibbon, D.J.; Beentjes, M.P.; Lyon, W.L.; Ladroit, Y. (2019). Inshore trawl survey of Canterbury Bight and Pegasus Bay, April–June 2018 (KAH1803). *New Zealand Fisheries Assessment Report 2019/03.* 136 p.

O'Driscoll, R.L.; Bagley, N.W. (2001). Review of summer and autumn trawl survey time series from the Southland and Sub-Antarctic areas, 1991–98. *NIWA Technical Report 102*. 115 p.

O'Driscoll, R L; MacGibbon, D; Fu, D; Lyon, W; Stevens, D W (2011) A review of hoki and middle depth trawl surveys of the Chatham Rise, January 1992–2010. *New Zealand Fisheries Assessment Report 2011/47.*

Stevens, D; Livingston, M; Bagley, N (2001) Trawl survey of hoki and middle depth species on the Chatham Rise, January 2001 (TAN0101). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2001 (TAN0101). *NIWA Technical Report 116.* 61 p

Stevens, D W; O'Driscoll, R L; Ballara, S L; Bagley, N; Horn, P L (2011) Chatham Rise Trawl Survey, 2 Jan - 28 Jan 2011 (TAN1011). WG-HOK-2011/X. (Unpublished report held by Fisheries New Zealand, Wellington.)

Stevens, D.W.; O'Driscoll, R.L.; Oeffner, J.; Ballara, S.L.; Horn, P.L. (2014). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2013 (TAN1301). *New Zealand Fisheries Assessment Report 2014/02.* 110 p.

Stevens, D.W.; O'Driscoll, R.L.; Ladroit, Y.; Ballara, S.L.; MacGibbon, D.J.; Horn, P.L. (2015). Trawl survey of hoki and middle depth species on the Chatham Rise, January 2014 (TAN1401). *New Zealand Fisheries Assessment Report 2015/19.* 119 p.

Stevens, D W; O'Driscoll, R L; Ballara, S L; Ladroit, Y (2017) Trawl survey of hoki and middle-depth species on the Chatham Rise, January 2016 (TAN1601). *New Zealand Fisheries Assessment Report 2017/08*. 131 p.