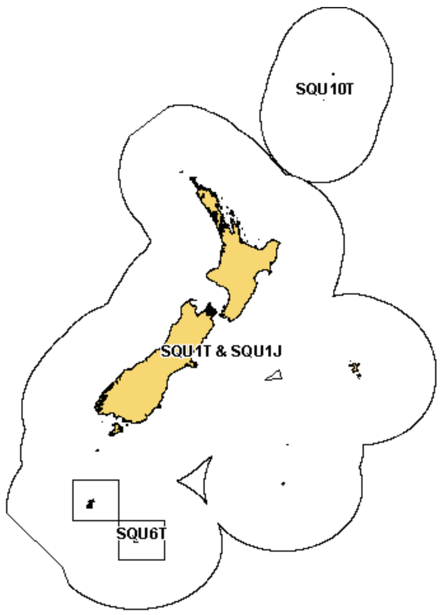
ARROW SQUID (SQU)

(*Nototodarus gouldi*, *N. sloanii*)
Wheketere



1. FISHERY SUMMARY

1.1 Commercial fisheries

The New Zealand arrow squid fishery is based on two related species. *Nototodarus gouldi* is found around mainland New Zealand north of the Subtropical Convergence, whereas *N. sloanii* is found in and to the south of the convergence zone.

Except for the Southern Islands fishery, for which a separate TACC is set, the two species are managed as a single fishery within an overall TACC. The Southern Islands fishery (SQU 6T) is almost entirely a trawl fishery. Although the species (*N. sloanii*) is the same as that found around the south of the South Island, there is evidence to suggest that the Auckland Island shelf stock is different from the mainland stocks. Because the Auckland Island shelf squid are readily accessible to trawlers, and because they can be caught with little finfish bycatch and are therefore an attractive resource for trawlers, a quota has been set separately for the Southern Islands. Total reported landings and TACCs for each stock are shown in Table 1, while historical landings and TACC are depicted in Figure 1.

The New Zealand squid fishery began in the late 1970s and reached a peak in the early 1980s when over 200 squid jigging vessels came to fish in the New Zealand EEZ. The discovery and exploitation of the large squid stocks in the southwest Atlantic substantially increased the supply of squid to the Asian markets causing the price to fall. In the early 1980s, Japanese squid jiggers would fish in New Zealand for a short time before continuing on to the southwest Atlantic. In the late 1980s, the jiggers stopped transit fishing in New Zealand and the number of jiggers fishing declined from over 200 in 1983 to around 15 in 1994. The jig catch in SQU 1J declined from 53,872 t in 1988–89 to 4865 t in 1992–93 but increased significantly to over 30,000 t in 1994–95, before declining to just over 9000 t in 1997–98. The jig catch declined to low levels for the next 4 years but then increased back up to almost 9000 t in 2004–05, before declining again to 1370 t in 2007–08.

From 1986 to 1998 the trawl catch fluctuated between about 30,000–60,000 t, but in the last few years in SQU 6T the impact of management measures to protect the Hooker's sea lion *(Phocarctos hookeri*) restricted the total catch to much lower levels.

Catch and effort data from the SQU 1T fishery show that the catch occurs between December and May, with peak harvest from January to April. The catch has been taken from the Snares shelf on the south coast of the South Island right through to the Mernoo Bank (east cost), but statistical area 28 (Snares shelf and Snares Island region) has accounted for over 77% of the total in recent years. Based on observer data, squid accounts for 67% of the total catch in the target trawl fishery, with bycatch principally of barracouta, jack mackerel, silver warehou and spiny dogfish.

For 2005–06 a 10% in-season increase to the SQU 1T TACC was approved by the Minister of Fisheries. The catch for December - March was 40% higher than the average over the previous eight years and catch rates were double the average, indicating an increased abundance of squid. Previously, in 2003–04, a 30% in-season increase to the TACC was agreed, but catches did not reach the higher limit. Note that the TACC automatically reverts to the original value at the end of the fishing year.

Table 1: Reported catches (t) and TACCs (t) of arrow squid from 1986–87 to 2007–08. Source – QMS.

Fishstock	SQU1J*		SQU1T*		SQU6T†		SQU10T‡		Total	
	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC	Landings	TACC
1986–87	32 394	57 705	25 621	30 962	16 025	32 333	0	10	74 040	121 010
1987–88	40 312	57 705	21 983	30 962	7 021	32 333	0	10	69 316	121 010
1988–89	53 872	62 996	26 825	36 081	33 462	35 933	0	10	114 160	135 080
1989–90	13 895	76 136	13 161	47 986	19 859	42 118	0	10	46 915	166 250
1990–91	11 562	46 087	18 680	42 284	10 658	30 190	0	10	40 900	118 571
1991–92	12 985	45 766	36 653	42 284	10 861	30 190	0	10	60 509	118 571
1992–93	4 865	49 891	30 862	42 615	1 551	30 369	0	10	37 278	122 875
1993–94	6 524	49 891	33 434	42 615	34 534	30 369	0	10	74 492	122 875
1994–95	33 615	49 891	35 017	42 741	30 683	30 369	0	10	99 315	123 011
1995–96	30 805	49 891	17 823	42 741	14 041	30 369	0	10	62 668	123 011
1996–97	20 792	50 212	24 769	42 741	19 843	30 369	0	10	65 403	123 332
1997–98	9 329	50 212	28 687	44 741	7 344	32 369	0	10	45 362	127 332
1998–99	3 240	50 212	23 362	44 741	950	32 369	0	10	27 553	127 332
1999–00	1457	50 212	13 049	44 741	6 241	32 369	0	10	20 747	127 332
2000–01	521	50 212	31 297	44 741	3 254	32 369	<1	10	35 071	127 332
2001–02	799	50 212	35 872	44 741	11 502	32 369	0	10	48 173	127 332
2002–03	2 896	50 212	33 936	44 741	6 887	32 369	0	10	43 720	127 332
2003–04	2 267	50 212	48 060	58 163#	34 635	32 369	0	10	84 962	127 332
2004–05	8 981	50 212	49 780	44 741	27 314	32 369	0	10	86 075	127 332
2005–06	5 844	50 212	49 149	49 215#	17 425	32 369	0	10	72 418	127 332
2006–07	2 278	50 212	49 495	44 741	18 479	32 369	0	10	70 253	127 332
2007–08	1 371	50 212	36 171	44 741	18 493	32 369	0	10	56 035	127 332

* All areas except Southern Islands and Kermadec.
† Southern Islands.
‡ Kermadec.
# In season increase of 30% for 2003-04 and 10% for 2005-06

Sea lion interactions

New Zealand (or Hooker's) sea lions are sometimes caught by arrow squid trawl vessels, most frequently in the SQU6T fishery around the Auckland Islands. The Minister of Fisheries has set a fishery-related mortality limit (FRML) since 1992. Table 2 shows the estimates of sea lion mortalities and the FRML set for each year.

FRML was set using PBR methods from 1992. For 2003–04 onwards, several versions of a stochastic Bayesian population model have been used to explore the effects of New Zealand (or Hooker's) sea lion bycatch in the arrow squid fishery. These models also projected the effects of alternative bycatch control rules on the sea lion population, in order to advise the Minister in his decisions regarding the FRML for each fishery year.

Since 1995–96, the FRML has been reached in nine fishing years. Sea Lion Exclusion or Escape Devices (SLEDs) were introduced from 2000–01. In 2000–01 the industry voluntarily withdrew most vessels before the FRML was met. In 2004–05, the industry withdrew from the fishery when the FRML was reached on the 15th of April. In 2002–03 and 2003–04, the FRML was reached and the fishery closed under the operational plan in place, only to be subsequently reopened by court decisions (High Court, Court of Appeal respectively).

The Minister of Fisheries set the FRML at 113 for the 2008–09 fishing year. However following reports from the Department of Conservation research team monitoring the breeding populations on the Auckland Islands that pup production had reduced by 31%, the fishing industry volunteered to lower the FRML to 95.

Table 2: Squid 6T fishery – estimated mortalities of sea lions from 1987–88 to 2008–09.

	SQU6T Landings	Sea lion FRML	Sea lion mortalities[f]	Closure date
1987–88	7 021	-	33	
1988–89	33 462	-	141	
1989–90	19 859	-	117	
1990–91	10 658	-	21	
1991–92	10 861	32	82	
1992–93	1551	63	17	
1993–94	34 534	63	32	
1994–95	30 683	69	109	
1995–96	14 041	73	101	4-May
1996–97	19 843	79	123	28-May
1997–98	7344	63	62	27-Mar
1998–99	950	64	14	
1999–00	6241	65	71	8-Mar
2000–01	3254	75	67	a
2001–02	11 502	79	84	13-Apr
2002–03	6887	70	39	b
2003–04	34 635	62	118	c
2004–05	27 314	115	115	20 Apr[d]
2005–06	17 425	97/150	110	e
2006–07	17 479	93	56	
2007–08	18 493	81	46	
2008–09	-	113/95		g

a The fishery was not officially closed in 2000/01. Industry voluntarily withdrew most vessels on 7 March 2001.

b Under the Operational Plan the SQU 6T fishery was closed on 29 March 2003 when the FRML count reached 79 sea lions. A High Court ruling in April 2003 allowed for continued fishing in SQU 6T and established a separate procedure for estimating sea lion mortalities resulting in the 39 mortalities indicated. Fishers had voluntarily withdrawn from SQU 6T as at the end of June.

c Under the Operational Plan the SQU 6T fishery was closed on 22 March 2004 when the FRML count reached 62 sea lions. A Court of Appeal ruling in April 2004 set aside the 2003-04 Operational Plan and allowed for continued fishing in SQU 6T providing incidental NZSL captures did not exceed 124. Industry withdrew from the SQU 6T fishery before they reached the Court established mortality limit as estimated using the procedures set out in the 2003-04 Operational Plan.

d Fishers voluntarily withdrew from the SQU 6T fishery upon reaching the 115 animal FRML on 17 April 2005.

e In 2005–06 the FRML was initially set at 97 animals, and the Minister chose to increase this mid-season to 150, on the basis of there being a squid utilisation opportunity. Fishing had practically ceased by early May 2006.

f The method of determining the 'mortalities' of sea lions, varies over the history of the fishery. In early years determination of sea lion mortality was estimated based on observer data. The use of SLEDs in recent years has resulted in few sea lion mortalities being observed. Therefore 'mortalities' for 2003-04 to 2006-07 are assumed based on a pre-determined strike rate (assumed mortalities per tow) of 5.3% and a discount rate of 20% for tows that met the requirements of the operational plan. Assumed mortalities in 2007-08 are based on a pre-determined strike rate of 5.65% and a discount rate of 35% for tows that met the requirements of the operational plan.

g In 2008-09 the FRML was set at 113, but was voluntarily reduced to the equivalent of 95 in response to unexpectedly low pup numbers,

Interactions with seabirds

Vessels targeting arrow squid also incidentally catch seabirds. Seabird species returned for necropsy from the squid fishery, in decreasing numbers, were: for 2006–07; sooty shearwater, white-capped albatross, white-chinned petrel and Buller's albatross (Thompson 2008); and for 2007–08; sooty shearwater, white-capped albatross, white-chinned petrel, Buller's albatross, cattle egret, Southern Royal albatross and white-faced storm petrel (Thompson 2009). Baird (2005a) summarised observed seabird captures in the arrow squid target fishery for the fishing years 1998–99 to 2002–03 and calculated total seabird captures for the areas with adequate observer coverage using ratio based estimations. Baird and Smith (2007 and 2008) summarised observed seabird captures and used both ratio-based and model-based predictions to estimate the total seabird captures for 2003–04, 2004–05 and 2005–06. Abraham and Thompson (in press) summarised the bycatch of protected species and used ratio-based predictions to estimate the total seabird captures for estimations for 2006–07 and 2007–08 (Table 3).

Table 3: Estimates of total seabird capture in the arrow squid fishery 1998–99 to 2004–05 (1998–99 to 2002–03 from Baird 2005a, 2003–04 to 2004–05 from Baird & Smith 2007, 2005–06 from Baird & Smith 2008). CV.s in parentheses; + birds were observed caught but totals were not estimated as coverage was less than 10%, * indicates where estimates were made and observer coverage was less than 10%, - no seabirds were observed caught, # indicates where number of seabirds are from where observed effort covered 100% of fishery effort. All estimates are ratio-estimators except those denoted with ^{m} which are model-based. Note that the 2007–08 figures are provisional.

Fishing year	PUYS	SQU 6T	STEW	CHAT	ECSI	PUKA
1998–99	+	+	268 (20)	+	+	-
1999–00	-	82 (19)	93 (34)	+	+	-
2000–01	+	42#	276 (5)	+	+	-
2001–02	+	195 (19)	515 (13)	-	+	-
2002–03	53 (39)	129 (16)	612 (16)	+	+	-
2003–04	-	325 (16) ^{m}	502 (17) ^{m}	-	-	19 (93)*
2004–05	33 (36)	414 (15) ^{m}	877 (12) ^{m}	-	-	-
2005–06	34 (98)	369 (21) ^{m}	854 (19) ^{m}	-	201 (58)	-
2006–07	-	98 (11)	324 (11)	+		
2007–08	-	131 (8)	274 (13)	-		

Mitigation methods such as tori lines, Brady bafflers and offal management are being used in the arrow squid trawl fishery. Warp mitigation was voluntarily introduced from around 2004 and then made mandatory in April 2006.

During the 2005–06 fishing year a large trial of mitigation devices was conducted in the squid fishery. 18 vessels were involved in the trial which used observations of seabird heavily contacting the trawl warps (‘warp strikes’) to quantify the effect of using three mitigation devices; paired tori lines, four boom bird bafflers and warp scarers. Few warp strikes occurred in the absence of offal discharge. When offal was present the tori lines were most effective at reducing warp strikes. All mitigation devices were more effective for reducing large birds warp strikes than for small birds. There was however a large number of strikes of birds on the tori lines, similar to the number of strikes on unmitigated warps (Abraham *et al.* in press).

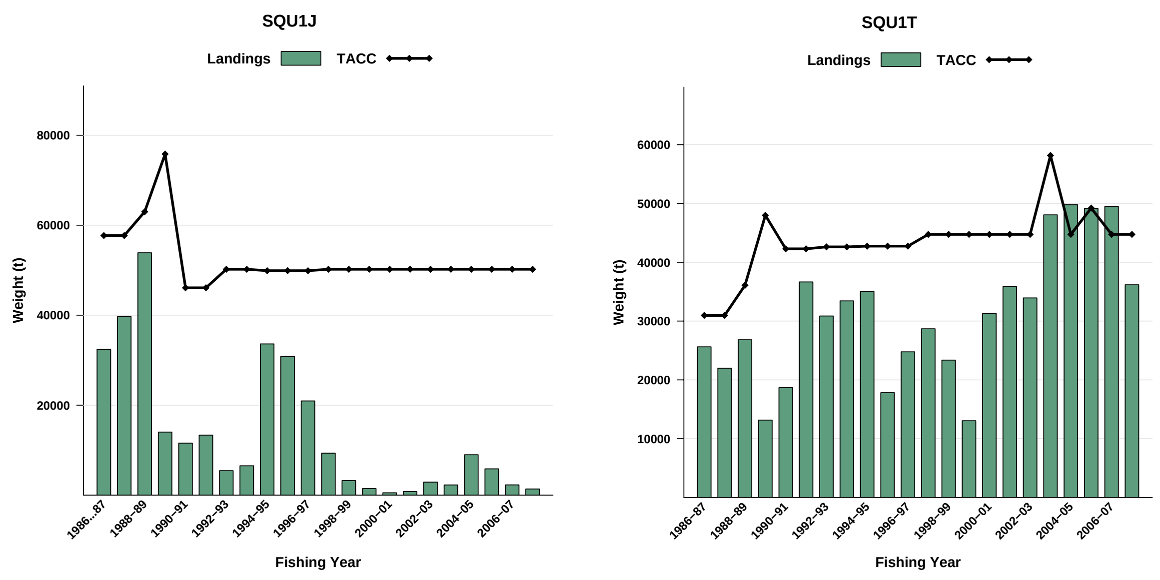


Figure 1: Historical landings and TACC for the three main SQU stocks. Left to right: SQU1J (All Waters Except 10T and 6T, Jigging) and SQU1T (All Waters Except 10T and 6T, All Other Methods). [Continued on next page]...

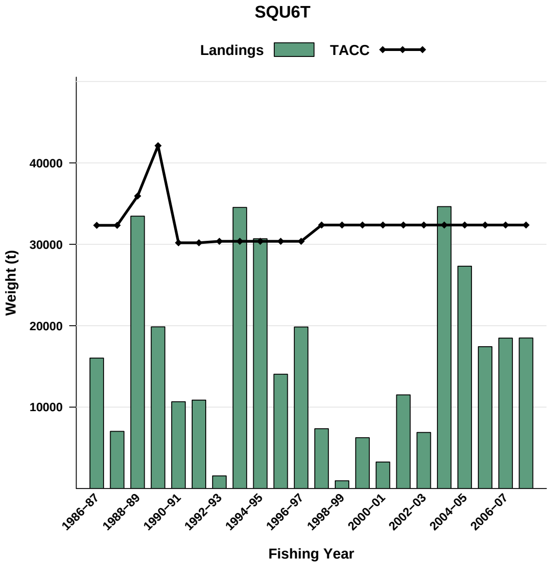


Figure 1 [Continued]: Historical landings and TACC for the three main SQU stocks. SQU6T (Southern Islands, All Methods). Note that these figures do not show data prior to entry into the QMS.

1.2 Recreational fisheries
The amount of arrow squid caught by recreational fishers is not known.

1.3 Customary non-commercial fisheries
No quantitative information is available on the current level of customary non-commercial take.

1.4 Illegal catch
There is no quantitative information available on the level of illegal catch.

1.5 Other sources of mortality
No information is available on other sources of mortality.

2. BIOLOGY

Two species of arrow squid are caught in the New Zealand fishery. Both species are found over the continental shelf in water up to 500 m depth, though they are most prevalent in water less than 300 m depth. Both species are sexually dimorphic, though similar in biology and appearance. Individuals can be identified to species level based on sucker counts on Arm I and differences in the hectocotylized arm of males.

Recent work on the banding of statoliths from *N. sloanii* suggests that the animals live for around 1 year. Growth is rapid. Modal analysis of research data has shown increases of 3.0–4.5 cm per month for Gould's arrow squid measuring between 10 and 34 cm Dorsal Mantle Length (DML).

Estimated ages suggest that *N. sloanii* hatches in July and August, with spawning occurring in June and July. It also appears that *N. gouldi* may spawn one to two months before *N. sloanii*, although there are some indications that *N. sloanii* spawns at other times of the year. All squid taken by the fishery do not appear to have spawned.

Tagging experiments indicate that arrow squid can travel on average about 1.1 km per day with a range of 0.14–5.6 km per day.

Biological parameters relevant to stock assessment are shown in Table 4.

Table 4: Estimates of biological parameters.

Fishstock		Estimate		Source
1. Weight = a (length)^b (Weight in g, length in cm dorsal length)				
		a	b	
N. gouldi	≤ 12 cm DML	0.0738	2.63	Mattlin *et al*. (1985)
N. sloanii	≥ 12 cm DML	0.029	3	
2. von Bertalanffy growth parameters				
	K	t_0	L_∞	
N. gouldi	2.1–3.6	0	35	Gibson & Jones (1993)
N. sloanii	2.0–2.8	0	35	

3. STOCKS AND AREAS

There are no new data which would alter the stock boundaries given in previous assessment documents. It is assumed that the stock of *N. gouldi* (the northern species) is a single stock, and that *N. sloanii* around the mainland comprises a unit stock for management purposes, though the detailed structure of these stocks is not fully understood. The distribution of the two species is largely geographically separate but those occurring around the mainland are combined for management purposes. The Auckland Islands Shelf stock of *N. sloanii* appears to be different from the mainland stock and is managed separately.

4. STOCK ASSESSMENT

Arrow squid live for one year, spawn once then die. Every squid fishing season is therefore based on what amounts to a new stock. It is not possible to calculate reliable yield estimates from historical catch and effort data for a resource which has not yet hatched, even when including data which are just one year old. Furthermore, because of the short life span and rapid growth of arrow squid, it is not possible to estimate the biomass prior to the fishing season. Moreover, the biomass increases rapidly during the season and then decreases to low levels as the animals spawn and die.

4.1 Estimates of fishery parameters and abundance
No estimates are available.

4.2 Biomass estimates
Biomass estimates are not available for squid.

4.3 Estimation of Maximum Constant Yield (MCY)
It is not possible to estimate MCY.

4.4 Estimation of Current Annual Yield (CAY)
It is not possible to estimate CAY.

4.5 Other yield estimates and stock assessment results
There are no other yield estimates of stock assessment results available for arrow squid.

4.6 Other factors
N. gouldi spawns one to two months before *N. sloanii*. This means that at any given time *N. gouldi* is older and larger than *N. sloanii*. The annual squid jigging fishery begins on *N. gouldii* and at some time during the season the biomass of *N. sloanii* will exceed that of *N. gouldi* and the fleet will move south. If *N. sloanii* are abundant the fleet will remain in the south fishing for *N. sloanii*. If *N. sloanii* are less abundant the fleet will return north and resume fishing *N. gouldi*.

5. STATUS OF THE STOCKS

No estimates of current and reference biomass are available. There is also no proven method at this time to estimate yields from the squid fishery before a fishing season begins based on biomass estimates or CPUE data.

Because squid live for about one year, spawn and then die, and because the fishery is so variable, it is not practical to predict future stock size in advance of the fishing season. As a consequence, it is not possible to estimate a long-term sustainable yield for squid, nor determine if recent catch levels or the current TACC will allow the stock to move towards a size that will support the MSY. There will be some years in which economic or other factors will prevent the TACC from being fully taken, while in other years the TACC may be lower than the potential yield. It is not known whether New Zealand squid stocks have ever been stressed through fishing mortality.

There is continuing concern about the bycatch of sea lions in the Southern Islands trawl squid fishery (SQU 6T) that has been addressed by a management plan restricting the total number of kills per season.

TACCs and reported landings for the 2007–08 fishing year are summarised in Table 5.

Table 5: Summary of TACCs (t) and reported landings (t) of arrow squid for the most recent fishing year.

Fishstock	2007–08 Actual TACC	2007–08 Reported landings
SQU 1J	50 212	1 371
SQU 1T	44 741	36 171
SQU 6T	32 369	18 493
SQU 10T	10	0
Total	127 332	56 035

6. FOR FURTHER INFORMATION

Abraham ER., Middleton DAJ., Waugh SM, Pierre JP, Walker NA, Schroder C. (in press). A comparison of devices used for reducing the incidental capture of seabirds in a trawl fishery.

Anderson OF. Fish discards and non-target fish catch in the trawl fisheries for arrow squid, jack mackerel, and scampi in New Zealand Waters. New Zealand Fisheries Assessment Report. 2004/10

Baird SJ. 2005a. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2002-03. New Zealand Fisheries Assessment Report 2005/2. 50p.

Baird SJ. 2005b. Incidental capture of *Phocarctos hookeri* (New Zealand sea lions) in New Zealand commercial fisheries, 2001-02. New Zealand Fisheries Assessment Report. 2005/08.

Baird SJ. 2005c. Incidental capture of *Phocarctos hookeri* (New Zealand sea lions) in New Zealand commercial fisheries, 2002-03. New Zealand Fisheries Assessment Report. 2005/09.

Baird SJ., Doonan IJ. 2005. *Phocarctos hookeri* (New Zealand sea lions): incidental captures in New Zealand commercial fisheries during 2000-01 and in-season estimates of captures during squid trawling in SQU 6T in 2002. New Zealand Fisheries Assessment Report, 2005/17.

Baird SJ., Smith, MH. 2007. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2003-04 and 2004-05. New Zealand Aquatic Environment and Biodiversity Report No. 9. 108p.

Baird, S.J.; Smith, M.H. 2008. Incidental capture of seabird species in commercial fisheries in New Zealand waters, 2005-06. New Zealand Aquatic Environment and Biodiversity Report No. 18 124p.

Doonan IJ. 1995. Incidental catch of Hooker’s sea lion in the southern trawl fishery for squid, summer 1994. Fisheries Assessment Research Document. 1995/22.

Doonan IJ. 2000. Estimation of Hooker’s sea lion *Phocarctos hookeri* captures in the southern squid trawl fisheries, 2000. New Zealand Fisheries Assessment Report. 2000/41.

Doonan IJ. 2001. Estimation of Hooker’s sea lion *Phocarctos hookeri* captures in the southern squid trawl fisheries, 2001. New Zealand Fisheries Assessment Report. 2001/67.

Förch EC. 1983. Squid – current research. *In:* Taylor, J.L. and Baird, G.G. (eds.) New Zealand finfish fisheries: the resources and their management, pp. 33–34. Trade Publications Ltd., Auckland.

Gibson D., Jones JB. 1993. Fed up with parasites? — old fish are. Marine Biology 117: 495–500.

Gibson DJM. 1995. The New Zealand Squid Fishery, 1979–93. MAF Fisheries Technical Report No 42. 43 p.

Langley AD. 2001. Summary of catch and effort data from the SQU 1J, SQU 1T, and SQU 6T fisheries for 1989-90 to 1999-2000. New Zealand Fisheries Assessment Report. 2001/51.

Mattlin RH. 1983. Squid. Taylor, J.L. and Baird, G.G. (eds.) New Zealand finfish fisheries: the resources and their management, pp. 30–32. Trade Publications Ltd., Auckland.

Mattlin RH, Colman JA. 1988. Arrow squid. N.Z. Fisheries Assessment Research Document 88/34. 16 p.

Mattlin RH., Scheibling RE., Förch EC. 1985. Distribution, abundance and size structure of arrow squid (*Nototodarus* sp.) off New Zealand. NAFO Scientific Council Studies 9: 39–45.

Smith MH., Baird SJ. 2005. Represenativeness of past observer coverage, and future coverage required for estimation of New Zealand sea lion (*Phocarctos hookeri*) captures in th SQU 6T fishery. New Zealand Fisheries Assessment Report. 2005/05.

Smith MH., Baird SJ. 2005. Factors that may influence the level of incidental mortality of New Zealand sea lions (*Phocarctos hookeri*) in the squit (*Notodarus* spp.) trawl fishery in SQU 6T. New Zealand Fisheries Assessment Report 2005/20.

Smith MH., Baird SJ. 2007. Incidental captures of New Zealand sea lions (*Phocarctos hookeri*) in New Zealand fisheries in 2003-04, with particular reference to the SQU 6T squid fishery. New Zealand Fisheries Assessment Report, 2007/07.

Smith PJ., Mattlin RH., Roeleveld MA., Okutani T. 1987. Arrow squids of the genus *Nototodarus* in New Zealand waters: systematics, biology and fisheries. N.Z. Journal of Marine and Freshwater Research 21: 315–326.

Thompson, D.R., 2008. Autopsy report for seabirds killed and returned from New Zealand fisheries, 1 October 2006 to 30 September 2007. Report prepared for the Conservation Services Programme, Department of Conservation: Contract INT2006/02. Available on www.doc.govt.nz

Thompson, D.R., 2009. Seabird Autopsy Project: Summary Report for the 2007-08 Fishing Year. Report prepared for the Conservation Services Programme, Department of Conservation: Contract INT2007/02. Available on www.doc.govt.nz

Uozumi Y., Ohara H. 1992. Age and growth of *Nototodarus sloanii* (Cephalopoda: Oegopsida) based on daily increment counts in statoliths. Nippon Suisan Gakkaishi 59: 1469–1477.