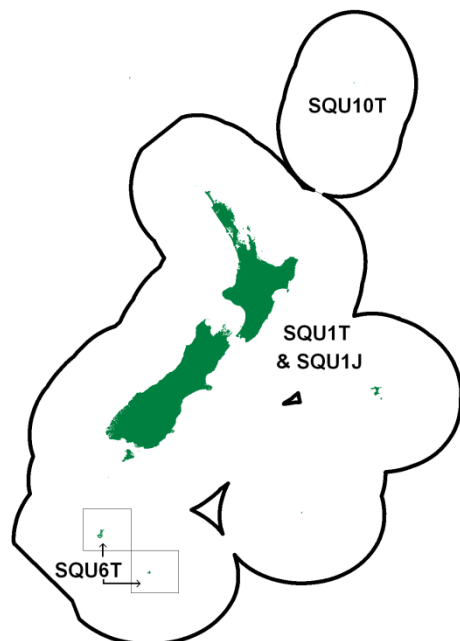# ARROW SQUID (SQU)

(*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 four years but then increased back up to almost 9000 t in 2004–05, before declining again to 891 t in 2009–10. The 2010–11 and 2011–12 fishing years have seen an increase from this eight year low to 1811 t.

From 1987 to 1998 the trawl catch fluctuated between about 30 000–70 000 t, but in SQU 6T the impact of management measures to protect the Hooker's sea lion (*Phocarctos hookeri*) restricted the total catch in some years between 1999 and 2005.

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 028 (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 2012–13. Source - QMS.

| Fishstock | SQU 1J* | | SQU 1T* | | SQU 6T† | | SQU 10T‡ | | 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 |
| 2008–09 | 1 032 | 50 212 | 16 407 | 44 741 | 28 872 | 32 369 | 0 | 10 | 46 311 | 127 332 |
| 2009–10 | 891 | 50 212 | 16 759 | 44 741 | 14 786 | 32 369 | 0 | 10 | 32 436 | 127 332 |
| 2010–11 | 1 414 | 50 212 | 14 957 | 44 741 | 20 934 | 32 369 | 0 | 10 | 37 304 | 127 332 |
| 2011–12 | 1 811 | 50 212 | 18 969 | 44 741 | 14 427 | 32 369 | 0 | 10 | 35 207 | 127 332 |
| 2012–13 | 741 | 50 212 | 13 951 | 44 741 | 9 944 | 32 369 | 0 | 10 | 24 637 | 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

## 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.
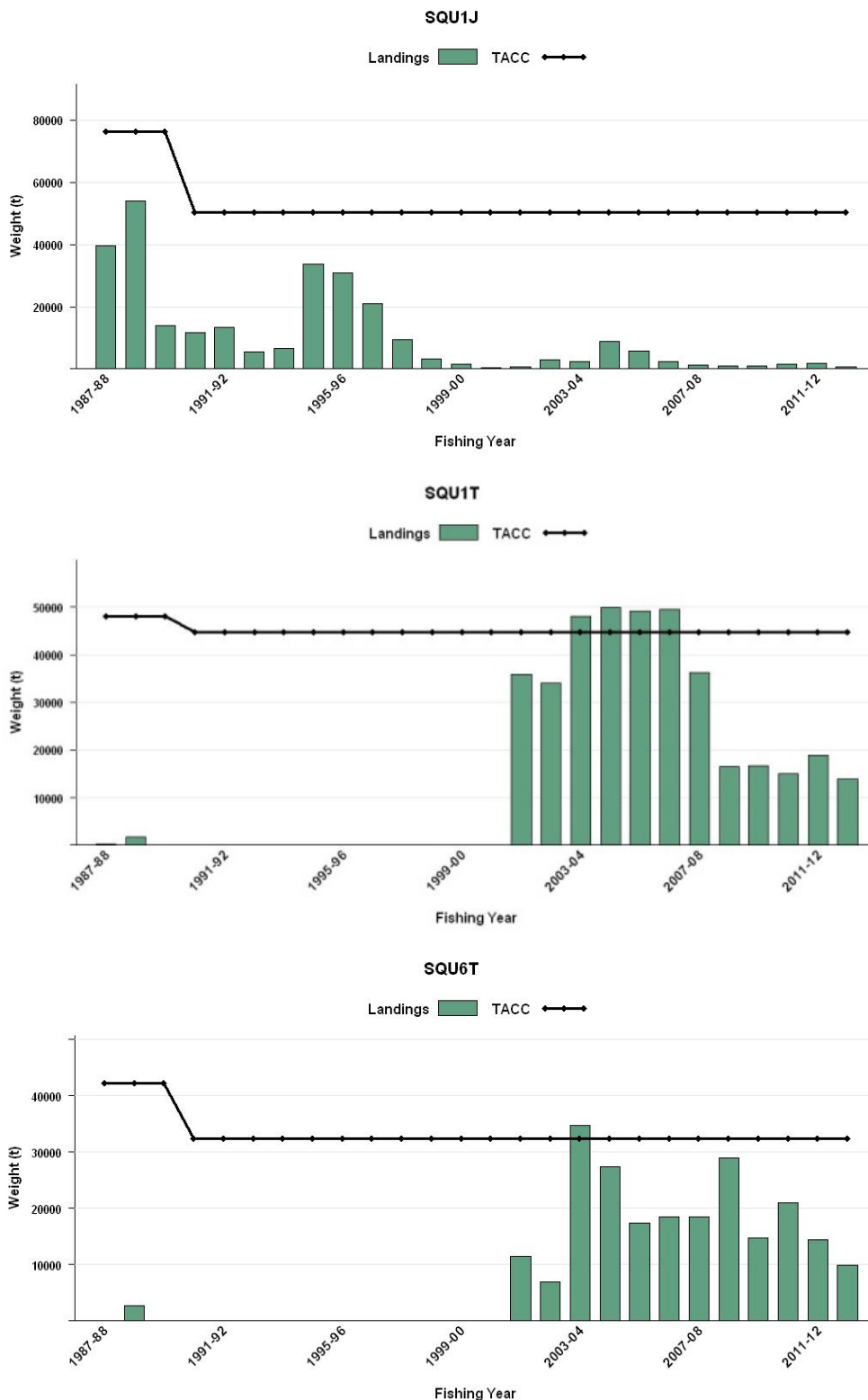


**Figure 1:  Historical landings and TACC for the three main SQU stocks.  Top to bottom:  SQU 1J (All Waters Except 10T and 6T, Jigging), SQU 1T (All Waters Except 10T and 6T, All Other Methods) and SQU 6T (Southern Islands, All Methods).  Note that these figures do not show data prior to entry into the QMS.**

Recent work on the banding of statoliths from *N. sloanii* suggests that the animals live for around one 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. The 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 2.

**Table 2:  Estimates of biological parameters.**

| Fishstock | | | Estimate | | Source |
|---|---|---|---|---|---|
| 1. Weight = a (length)[b] (Weight in g, length in cm dorsal length) | | | | | |
| | | | a | b | |
| *N. gouldi* | $\leq$ 12 cm DML | | 0.0738 | 2.63 | Mattlin et al (1985) |
| *N. sloanii* | $\geq$ 12 cm DML | | 0.029 | 3 | |
| | | | | | |
| 2. von Bertalanffy growth parameters | | | | | |
| | | $K$ | $t_0$ | $L\infty$ | |
| *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.    ENVIRONMENTAL AND ECOSYSTEM CONSIDERATIONS

This section was last reviewed by the Aquatic Environment Working Group for the May 2012 Fishery Assessment Plenary. Tables were updated and minor corrections to the text were made for the May 2013 Fishery Assessment Plenary. This summary is from the perspective of the squid trawl fishery; a more detailed summary from an issue by issue perspective is available in the Aquatic Environment & Biodiversity Annual Review (www.mpi.govt.nz/Default.aspx?TabId=126&id=1644).

**4.1 Role in the ecosystem**
Arrow squid are short-lived and highly variable between years (see Biology section). Hurst et al (2012) reviewed the literature and noted that arrow squid are an important part of the diet for many species. Stevens et al (2012) reported that, between 1960 and 2000, squids (including arrow squid) were important in the diet of banded stargazer (59% of non-empty stomachs), bluenose (26%), giant stargazer (34%), gemfish (43%), and hapuku (21%), and arrow squid were specifically recorded in the diets of alfonsino, barracouta, hake, hoki, ling, red cod, red gurnard, sea perch, and southern blue whiting. In a detailed study on the Chatham Rise (Dunn et al 2009), cephalopods were identified as prey of almost all demersal fish species, and arrow squid were identified in the diet of hake, hoki, ling, Ray's bream, shovelnose spiny dogfish, sea perch, smooth skate, giant stargazer and silver warehou, and was a significant component (over 10% prey weight) of the diet of barracouta and spiny dogfish.

Arrow squid have been recorded as important in the diet of marine mammals such as NZ fur seals and NZ sea lions, particularly during summer and autumn (Fea et al 1999, Harcourt et al 2002, Chilvers 2008, Boren 2008) and in the diet of common dolphins (Meynier et al 2008, Stockin 2008). They are also important in the diet of seabirds such as shy albatross in Australia (Hedd & Gales 2001) and Buller's albatross at the Snares and Solander Islands (James & Stahl 2000). Cephalopods in general

are important in the diet of a wide range of Australasian albatrosses, petrels and penguins (Marchant & Higgins 2004).

Arrow squid in New Zealand waters have been reported to feed on myctophids, sprats, pilchards, barracouta, euphausiids, mysids, isopods and squid, probably other arrow squid (Yatsu 1986, Uozumi 1998). Uozumi found that the importance of various food items changed between years, and the percentage of empty stomachs was influenced by area, season, size, maturation, and time of day. In Australia, *N. gouldi* was found to feed mostly on pilchard, barracouta, and crustaceans (O'Sullivan & Cullen 1983). Cannibalism was also recorded.

### 4.2 Incidental catch (fish and invertebrates)

Based on models using observer and fisher-reported data, total bycatch in the arrow squid trawl fishery ranged from 4500 to 25 000 t per year between 1991 and 2010–11 (Anderson 2013). Over that time period arrow squid comprised about 80% of the total estimated catch recorded by observers in this fishery (Figure 2). The remainder of the observed catch comprised mainly the commercial fish species barracouta (8.5%), spiny dogfish (1.7%), and jack mackerel (1.1%). Invertebrate species made up a much smaller fraction of the bycatch overall (about 1%), but crabs (0.8%), especially the smooth red swimming crab (*Nectocarcinus bennetti*, 0.5%), were frequently caught.

Estimated total annual discards ranged from just over 200 t in 1995–96 to about 5500 in 2001–02 and, like bycatch, peaked in the early 1990s and were at relatively low levels after 2006–07 (Anderson 2013). Most discards were QMS species (about 62% over all years), followed by non-QMS species (19%), invertebrate species (11%), and arrow squid (7%). Absolute levels of discards increased in all categories over the 21-year period; this increase was strongly significant for non-QMS species and total discards, and also marginally significant for QMS species and invertebrates. The species discarded in the greatest amounts were spiny dogfish, redbait, rattails, and silver dory. Discards peaked at 0.13 kg of discarded fish for every 1 kg of arrow squid caught in the early 1990s and declined to 0.02–0.07 kg after 2002–03.
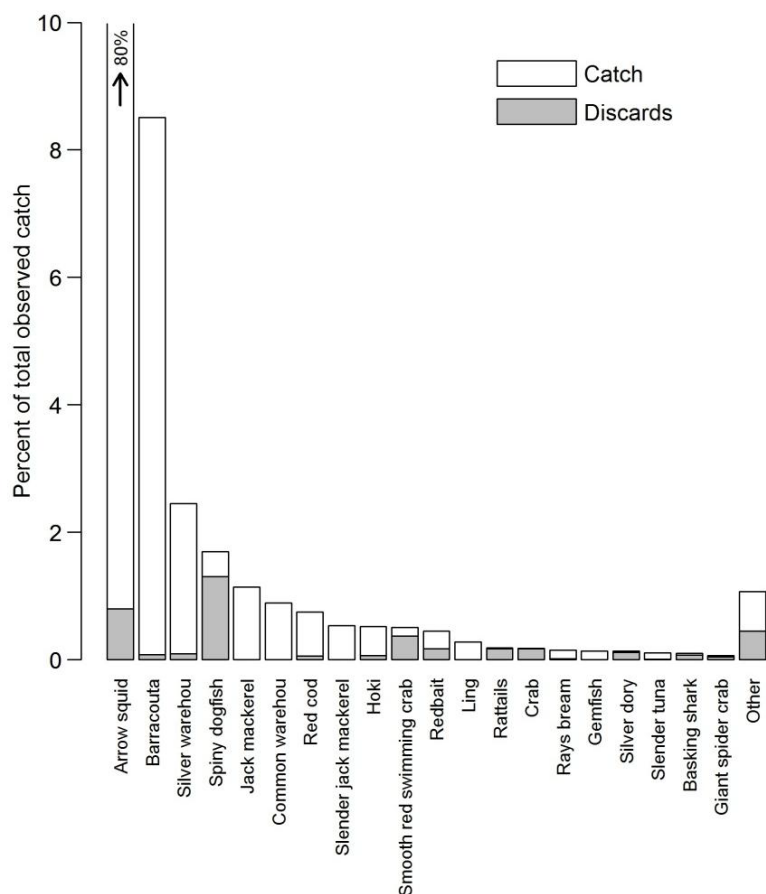


**Figure 2: Percentage of the total catch contributed by the main bycatch species (those representing 0.05% or more of the total catch) in the observed portion of the arrow squid fishery, and the percentage discarded. The Other category is the sum of all bycatch species representing less than 0.05% of the total catch (Anderson 2013).**

**4.3 Incidental catch (seabirds, mammals, and protected fish)**

For protected species, capture estimates presented here include all animals recovered to the deck (alive, injured or dead) of fishing vessels but do not include any cryptic mortality (e.g., seabirds struck by a warp but not brought onboard the vessel, Middleton & Abraham 2007).

**4.3.1 NZ sea lion interactions**

The New Zealand (or Hooker's) sea lion was classified in 2008 as "Vulnerable" by the International Union for Conservation of Nature (IUCN) and in 2010 as "Nationally Critical" under the NZ Threat Classification System (Baker et al 2010). Pup production at the main Auckland Island rookeries shows a steady decline since the late 1990s.

NZ sea lions are sometimes caught by vessels trawling for arrow squid (Smith & Baird 2005a, 2007a & b, Thompson & Abraham 2010a, Abraham & Thompson 2011). The trend in observed and estimated captures is downwards. Until recently, captures occurred most frequently in the SQU 6T fishery around the Auckland Islands, and a limit on the number of fishery-related mortalities in this fishery has been set since 1992 (Table 3). These limits have been determined using various approaches, but the current approach is to limit the number of sea lions estimated to have been captured using control rules calculated using the number of pups born in the previous two years. Estimated captures for a year are calculated from the estimated strike rate per tow and the number of tows. The average length of tows has increased substantially over the past decade, but this should be incorporated in the estimated strike rate per tow, albeit with high uncertainty. The likely performance of candidate control rules has been tested using an integrated population and fishery model (Breen et al 2010). Candidate rules are assessed against management criteria developed and agreed in 2003 by a Technical Working Group comprising Ministry of Fisheries, DOC, NIWA, squid industry representatives, and environmental groups (details can be found in the Aquatic Environment and Biodiversity Annual Review 2012).

Sea Lion Exclusion Devices (SLEDs) were introduced into the SQU 6T fishery in 2001–02 and were in widespread use by 2004–05 leading to a sharp drop in observed incidental captures (Table 4). SLEDs are designed to allow sea lions to escape from a trawl and consist of a grid of steel bars that prevents sea lions entering the codend and an escape hole. From their introduction, SLEDs were subject to continuous design improvements for 10–15 years and, since 2007, a standard Mark 3/13 version has been used by all vessels in the SQU 6T fishery. Tows undertaken using an approved SLED receive a discount on the pre-determined sea lion strike rate, based on the assumption that some sea lions that encounter a trawl equipped with a SLED that would have drowned in the absence of a SLED will survive. This discount was originally set at 20%, was increased to 35% in 2007–08, and further increased to 82% in August 2012. The recent increase in discount rate was made to acknowledge recent research indicating that a high proportion of sea lions encountering a SLED are likely to survive the encounter (summarised in Abraham 2011). There is some remaining uncertainty, including the unknown probability that a sea lion that enters a net but is not subsequently captured will exceed its breath holding limit and die after exiting the trawl via the SLED or the front of the net. This uncertainty is discussed in the 2012 Aquatic Environment and Biodiversity Annual Review (MPI 2012).

Smaller numbers of NZ sea lions are captured in the squid trawl fishery on the Stewart-Snares shelf (SQU 1T, Table 5). Formal estimates of total captures in this fishery have not been calculated but captures across all trawl fisheries on the Stewart-Snares shelf were estimated by Thompson & Abraham (2010a) to vary from 3 to 9 sea lions each year.

**ARROW SQUID (SQU)**

**Table 3: Fisheries-related mortality limit (FRML) from 1991 to 2012 (♀ = females; numbers in parentheses are FRMLs modified in-season). Direct comparisons among years are not useful because the assumptions underlying the FRML changed over time.**

| Year | FRML | Discount rate | Management actions |
|------|------|------|--------------------|
| 1991–92 | 16 (♀) | | |
| 1992–93 | 63 | | |
| 1993–94 | 63 | | |
| 1994–95 | 69 | | |
| 1995–96 | 73 | | Fishery closed by MFish (4 May) |
| 1996–97 | 79 | | Fishery closed by MFish (28 Mar) |
| 1997–98 | 63 | | Fishery closed by MFish (27 Mar) |
| 1998–99 | 64 | | |
| 1999–00 | 65 | | Fishery closed by MFish (8 Mar) |
| 2000–01 | 75 | | Voluntary withdrawal by industry |
| 2001–02 | 79 | | Fishery closed by MFish (13Apr) |
| 2002–03 | 70 | | Fishery closed by MFish (29 Mar), overturned by High Court |
| 2003–04 | 62 (124) | 20% | Fishery closed by MFish (22 Mar), overturned by High Court |
| 2004–05 | 115 | 20% | Voluntary withdrawal by industry on reaching the FRML |
| 2005–06 | 97 (150) | 20% | FRML increased in mid-March due to abundance of squid |
| 2006–07 | 93 | 20% | |
| 2007–08 | 81 | 35% | |
| 2008–09 | 113 (95) | 35% | Lower interim limit agreed following decrease in pup numbers |
| 2009–10 | 76 | 35% | |
| 2010–11 | 68 | 35% | |
| 2011–12 | 68 | 35% | |
| 2012–13 | 68 | 82% | |

**Table 4: Annual trawl effort, observer coverage, observed numbers of sea lions captured, observed capture rate (sea lions per 100 trawls), estimated sea lion captures, interactions, and the estimated strike or capture rate (with 95% confidence intervals) for the squid trawl fisheries operating in SQU 6T (Auckland Islands). Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 1995–96 to 2001–02 and all estimated strike rates data are from Thompson at al 2013). Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.**

| Year | Tows | % obs. | Obs. captures No. | Obs. captures Rate | Est. captures Mean | Est. captures 95% c.i. | Est. interactions Mean | Est. interactions 95% c.i. | Est. strike rate Mean | Est. strike rate 95% c.i. |
|------|------|--------|------|------|------|------|------|------|------|------|
| 1995–96 | 4 467 | 12 | 13 | 2.4 | 131 | 69–226 | 131 | 67–244 | 2.9 | 1.6–5.0 |
| 1996–97 | 3 716 | 19 | 28 | 3.9 | 142 | 91–208 | 142 | 89–210 | 3.8 | 2.6–5.5 |
| 1997–98 | 1 441 | 22 | 13 | 4.2 | 60 | 33–102 | 60 | 31–104 | 4.2 | 2.5–6.9 |
| 1998–99 | 402 | 38 | 5 | 3.2 | 14 | 7–27 | 15 | 5–29 | 3.6 | 2.1–5.9 |
| 1999–00 | 1 206 | 36 | 25 | 5.7 | 69 | 45–107 | 69 | 41–108 | 5.8 | 4.0–8.6 |
| 2000–01 | 583 | 99 | 39 | 6.7 | 39 | 39–40 | 61 | 39–87 | 10.4 | 8.6–13.1 |
| 2001–02* | 1 648 | 34 | 21 | 3.7 | 43 | 30–64 | 73 | 43–116 | 4.4 | 3.0–6.6 |
| 2002–03 | 1 466 | 28 | 11 | 2.6 | 19 | 13–28 | 46 | 24–77 | 3.2 | 2.0–5.1 |
| 2003–04 | 2 594 | 31 | 16 | 2.0 | 40 | 26–60 | 200 | 98–370 | 7.5 | 4.0–13.5 |
| 2004–05^ | 2 693 | 30 | 9 | 1.1 | 31 | 17–53 | 165 | 73–320 | 5.9 | 2.7–11.1 |
| 2005–06 | 2 459 | 22 | 10 | 1.8 | 27 | 15–45 | 149 | 63–309 | 6.0 | 2.7–12.5 |
| 2006–07 | 1 317 | 41 | 7 | 1.3 | 16 | 9–26 | 89 | 28–200 | 6.6 | 2.3–14.8 |
| 2007–08 | 1 265 | 47 | 5 | 0.9 | 12 | 6–21 | 116 | 21–489 | 8.0 | 1.6–30.9 |
| 2008–09 | 1 925 | 40 | 2 | 0.3 | 7 | 3–16 | 97 | 12–441 | 4.6 | 0.7–18.4 |
| 2009–10 | 1 188 | 26 | 3 | 1.0 | 13 | 5–26 | 124 | 19–508 | 9.0 | 1.7–33.6 |
| 2010–11 | 1 583 | 34 | 0 | 0.0 | 4 | 0–11 | 60 | 4–278 | 3.5 | 0.4–14.9 |
| 2011–12 | 1 281 | 45 | 0 | 0.0 | 2 | 0–7 | 43 | 2–206 | - | - |
| 2012–13† | 1 027 | 86 | 3 | 0.3 | - | - | - | - | - | - |

* SLEDs were introduced. ^ SLEDs were standardised and in widespread use. † Provisional data, no model estimates available.

**Table 5: Number of tows by fishing year and observed NZ sea lion captures in squid trawl fisheries on the Stewart-Snares shelf, 2002–03 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.**

|  | | Fishing effort | | Observed captures | | Estimated interactions | | |
|---|---|---|---|---|---|---|---|---|
|  | Tows | No. obs | % obs | Captures | Rate | Mean | 95% c.i. | % included |
| 2002–03 | 3 281 | 506 | 15.4 | 0 | 0.00 | 2 | 0–5 | 100.0 |
| 2003–04 | 4 534 | 957 | 21.1 | 1 | 0.10 | 3 | 1–7 | 100.0 |
| 2004–05 | 5 861 | 1 581 | 27.0 | 3 | 0.19 | 6 | 3–11 | 100.0 |
| 2005–06 | 4 481 | 537 | 12.0 | 1 | 0.19 | 4 | 1–8 | 100.0 |
| 2006–07 | 2 925 | 706 | 24.1 | 1 | 0.14 | 2 | 1–5 | 100.0 |
| 2007–08 | 2 412 | 864 | 35.8 | 0 | 0.00 | 1 | 0–4 | 100.0 |
| 2008–09 | 1 809 | 531 | 29.4 | 0 | 0.00 | 1 | 0–3 | 100.0 |
| 2009–10 | 2 258 | 764 | 33.8 | 1 | 0.13 | 2 | 1–4 | 100.0 |
| 2010–11 | 2 176 | 685 | 31.5 | 0 | 0.00 | 1 | 0–3 | 100.0 |
| 2011–12 | 1 985 | 801 | 40.4 | 0 | 0.00 | - | - | - |
| 2012–13† | 1 530 | 1 344 | 87.8 | 0 | 0.00 | - | - | - |

† Provisional data, no model estimates available.

## 4.3.2 NZ fur seal interactions

The New Zealand fur seal was classified in 2008 as "Least Concern" by IUCN and in 2010 as "Not Threatened" under the NZ Threat Classification System.

Vessels targeting arrow squid incidentally catch fur seals (Baird & Smith 2007a, Smith & Baird 2009, Thompson & Abraham 2010b, Baird 2011), mostly off the east coast South Island, on the Stewart-Snares shelf, and close to the Auckland Islands. In the 2012–13 fishing year there were six observed captures of New Zealand fur seal in squid trawl fisheries. In the 2011–12 fishing year, there were 25 (95% c.i.: 12–53) estimated captures, with the estimates made using a statistical model (Thompson et al 2013, Table 6). Total estimated captures in squid trawl fisheries varied from 21 to 168 between 2002–03 and 2011–12, representing about 9% of the total estimated captures in trawl fisheries over those years (noting that less than 50% of all trawl effort is included in the estimates, except for the most recent year). The rate of capture over this period varied from 0.08 to 0.96 captures per hundred tows without obvious trend (Table 6), a rate that is about 40% of the rate for all trawl fisheries.

**Table 6: Number of tows by fishing year and observed and model-estimated total NZ fur seal captures in squid trawl fisheries, 2002–03 to 2012–13. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Thompson et al (2013) and available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Data for 2002–03 to 2011–12 are based on data version 20130304 and provisional data for 2012–13 are based on data version 20140131.**

|  | | | | Observed | | Estimated | | |
|---|---|---|---|---|---|---|---|---|
|  | Tows | No. obs | % obs | Captures | Rate | Captures | 95% c.i. | % inc. |
| 2002–03 | 8 410 | 1 308 | 15.6 | 8 | 0.61 | 59 | 27 – 115 | 100.0 |
| 2003–04 | 8 336 | 1 771 | 21.2 | 17 | 0.96 | 94 | 49 – 174 | 100.0 |
| 2004–05 | 10 489 | 2 511 | 23.9 | 16 | 0.64 | 168 | 83 – 312 | 100.0 |
| 2005–06 | 8 576 | 1 103 | 12.9 | 4 | 0.36 | 103 | 45 – 209 | 100.0 |
| 2006–07 | 5 904 | 1 289 | 21.8 | 8 | 0.62 | 44 | 21 – 83 | 100.0 |
| 2007–08 | 4 236 | 1 457 | 34.4 | 6 | 0.41 | 34 | 15 – 71 | 100.0 |
| 2008–09 | 3 867 | 1 298 | 33.6 | 1 | 0.08 | 21 | 6 – 49 | 100.0 |
| 2009–10 | 3 789 | 1 070 | 28.2 | 8 | 0.75 | 36 | 16 – 76 | 100.0 |
| 2010–11 | 4 213 | 1 261 | 29.9 | 8 | 0.63 | 24 | 12 – 46 | 100.0 |
| 2011–12 | 3 508 | 1 382 | 39.4 | 8 | 0.58 | 25 | 12 – 53 | 100.0 |
| 2012–13 | 2 648 | 2 275 | 85.9 | 6 | 0.26 | - | - | - |

† Provisional data, no model estimates available

### 4.3.3 Seabird interactions

Vessels targeting arrow squid incidentally catch seabirds. 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 & Smith (2007b, 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 & Thompson (2011) summarised captures of protected species and used model and ratio-based predictions of the total seabird captures for 1989–90 and 2008–09.

In the 2012–13 fishing year there were 450 observed captures of birds in squid trawl fisheries. In the 2011–12 fishing year, there were 327 (95% c.i.: 261–422) estimated captures, with the estimates made using a statistical model (Table 7).

Table 7: **Number of tows by fishing year and observed and model-estimated total bird captures in squid trawl fisheries, 2002–03 to 2011–12. No. obs, number of observed tows; % obs, percentage of tows observed; Rate, number of captures per 100 observed tows, % inc, percentage of total effort included in the statistical model. Estimates are based on methods described in Abraham et al (2013) and are available via http://www.fish.govt.nz/en-nz/Environmental/Seabirds/. Estimates from 2002–03 to 2010–11 are based on data version 20120531 and preliminary estimates for 2011–12 are based on data version 20130304.**

| | | | | Observed | | | Estimated | |
|---|---|---|---|---|---|---|---|---|
| | Tows | No. obs | % obs | Captures | Rate | Captures | 95% c.i. | % inc. |
| 2002–03 | 8 410 | 1 308 | 15.6 | 159 | 12.16 | 985 | 761 – 1 293 | 100.0 |
| 2003–04 | 8 336 | 1 771 | 21.2 | 204 | 11.52 | 810 | 682 – 964 | 100.0 |
| 2004–05 | 10 489 | 2 511 | 23.9 | 384 | 15.29 | 1 397 | 1 199 – 1 647 | 100.0 |
| 2005–06 | 8 575 | 1 103 | 12.9 | 200 | 18.13 | 1 172 | 906 – 1 546 | 100.0 |
| 2006–07 | 5 904 | 1 289 | 21.8 | 127 | 9.85 | 534 | 414 – 658 | 100.0 |
| 2007–08 | 4 236 | 1 457 | 34.4 | 162 | 11.12 | 514 | 408 – 658 | 100.0 |
| 2008–09 | 3 868 | 1 298 | 33.6 | 259 | 19.95 | 599 | 503 – 725 | 100.0 |
| 2009–10 | 3 788 | 1 070 | 28.2 | 92 | 8.60 | 372 | 287 – 484 | 100.0 |
| 2010–11 | 4 213 | 1 261 | 29.9 | 141 | 11.18 | 5 82 | 447 – 770 | 100.0 |
| 2011–12 | 3 505 | 1 380 | 38.4 | 106 | 7.68 | 327 | 261 – 422 | 100.0 |
| 2012–13† | 2 648 | 2 275 | 85.9 | 450 | 19.78 | - | - | - |

† Provisional data, no model estimates available.

Total estimated seabird captures in squid trawl fisheries varied from 327 to 1397 between 2002–03 and 2011–12 at a rate of 8.6 to 20.0 captures per hundred tows without obvious trend (Table 7). These estimates include all bird species and should be interpreted with caution because trends by species can be masked. The average capture rate in squid trawl fisheries over the last ten years is about 13.79 birds per 100 tows, a high rate relative to trawl fisheries for scampi (5.57 birds per 100 tows) and hoki (2.16 birds per 100 tows) over the same years. The squid fishery accounted for about 58% of seabird captures in the trawl fisheries modelled by Abraham et al (2013).

Observed seabird captures since 2002–03 have been dominated by four species: white-capped and southern Buller's albatrosses make up 85% and 9% of the albatrosses captured, respectively; and white-chinned petrels and sooty shearwaters make up 48% and 45% of other birds, respectively, the total and fishery risk ratios presented in Table 8. Most captures occur on the Stewart-Snares shelf (60%) or close to the Auckland Islands (37%). These numbers should be regarded as only a general guide on the distribution of captures because observer coverage is not uniform across areas and may not be representative.

**Table 8: Risk ratio of seabirds predicted by the level two risk assessment for SLL fisheries (grouped by vessel size) and all fisheries included in the level two risk assessment, 2002–03 to 2011–12, showing seabird species with a risk ratio of at least 0.001 of PBR$_1$. The risk ratio is an estimate of aggregate potential fatalities across trawl and longline fisheries relative to the Potential Biological Removals, PBR$_1$ (from Richard and Abraham 2013 where full details of the risk assessment approach can be found). PBR$_1$ applies a recovery factor of 1.0. Typically a recovery factor of 0.1 to 0.5 is applied (based on the state of the population) to allow for recovery from low population sizes as quickly as possible. This should be considered when interpreting these results. The DOC threat classifications are shown (Robertson et al 2013 at http://www.doc.govt.nz/documents/science-and-technical/nztcs4entire.pdf).**

| | | Risk ratio | | | |
| Species name | PBR$_1$ (mean) | Squid target trawl | TOTAL | Risk category | DoC Threat Classification |
|---|---|---|---|---|---|
| Salvin's albatross | 975 | 0.035 | 2.756 | Very high | Threatened: Nationally Critical |
| Flesh-footed shearwater | 590 | 0.001 | 1.321 | Very high | Threatened: Nationally Vulnerable |
| Southern Buller's albatross | 513 | 0.292 | 1.292 | Very high | At Risk: Naturally Uncommon |
| Chatham Island albatross | 159 | 0.004 | 1.291 | Very high | At Risk: Naturally Uncommon |
| NZ white-capped albatross | 4 044 | 0.229 | 0.700 | Very high | At Risk: Naturally Uncommon |
| Northern Buller's albatross | 617 | 0.002 | 0.678 | High | At Risk: Naturally Uncommon |
| Gibson's albatross | 260 | 0.018 | 0.467 | High | Threatened: Nationally Critical |
| Cape petrel | 840 | 0.007 | 0.303 | High | At Risk: Naturally Uncommon |
| Antipodean albatross | 295 | 0.005 | 0.301 | High | Threatened: Nationally Critical |
| Northern royal albatross | 396 | 0.011 | 0.271 | Medium | At Risk: Naturally Uncommon |
| Southern royal albatross | 441 | 0.012 | 0.264 | Medium | At Risk: Naturally Uncommon |
| Westland petrel | 241 | 0.003 | 0.263 | Medium | At Risk: Naturally Uncommon |
| Northern giant petrel | 217 | 0.008 | 0.215 | Medium | At Risk: Naturally Uncommon |
| White-chinned petrel | 7 925 | 0.066 | 0.211 | Medium | At Risk: Declining |
| Campbell black-browed albatross | 1 017 | 0.002 | 0.189 | Medium | At Risk: Naturally Uncommon |
| Grey petrel | 2 172 | 0.001 | 0.114 | Medium | At Risk: Naturally Uncommon |
| Light-mantled sooty albatross | 237 | 0.002 | 0.028 | Low | At Risk: Declining |
| Grey-headed albatross | 333 | 0.001 | 0.018 | Low | Threatened: Nationally Vulnerable |
| Sooty shearwater | 348 096 | 0.002 | 0.005 | Low | At Risk: Declining |

Mitigation methods such as streamer (tori) lines, Brady bird bafflers, warp deflectors, and offal management are used in the squid trawl fishery. Warp mitigation was voluntarily introduced from about 2004 and made mandatory in April 2006 (Ministry of Fisheries 2006). The 2006 notice mandated that all trawlers over 28 m in length use a seabird scaring device while trawling (being "paired streamer lines", "bird baffler" or "warp deflector" as defined in the notice). During the 2005–06 fishing year a large trial of mitigation devices was conducted in the squid fishery (Middleton & Abraham 2007). Eighteen 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 streamer/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 bird warp strikes than small bird. There were, however, about as many bird strikes on the tori lines as the number of strikes on unmitigated warps. The effect of these strikes has not been assessed (Middleton & Abraham 2007).

In the four complete fishing years after mitigation was made mandatory, the average rate of capture for white-capped albatross (90% of albatross captures in this fishery) was 3.2 birds per 100 tows compared with 7.9 per 100 tows in the three complete years before mitigation was made mandatory. This trend is masked in Table 7 by continued captures of smaller birds, mostly in trawl nets as opposed to on trawl warps (where mitigation is focused).

## 4.4 Benthic interactions

Between 1989–90 and 2004–05, 131 973 trawl tows for squid on or within 1 m of the seabed were reported, comprising 13.7% of all trawl tows on or within 1 m of the seabed reported on TCEPR forms in those years (range 8–23% by year, Baird et al 2011). Black et al (2013) estimated that hoki arrow squid has accounted for 13.5% of all tows reported on TCEPR forms since 1989–90. Between 2006–07 and 2010–11, 95% of arrow squid catch was reported on TCEPR forms. The great majority of tows are conducted on the Stewart-Snares shelf or north and east of the Auckland Islands, with smaller numbers off the east coast of the South Island and the Chatham Rise. Tows were located in Benthic Optimised Marine Environment Classification (BOMEC, Leathwick et al 2009) classes E (outer shelf), F, H (upper slope), I, J, L, and M (mid-slope) (Baird & Wood 2012), and 92% were between 100 and 300 m depth (Baird et al 2011). Tables 4–7 show that the number of trawl tows for squid varies between years, largely without trend and presumably in response to variations in the abundance of squid and management measures to limit the number of sea lions caught. The average duration of trawls has increased over this time so the trend in aggregate swept area will not be the same.

Bottom trawling for squid, like trawling for other species, is likely to have effects on benthic community structure and function (e.g., see Rice 2006 for an international review) and there may be consequences for benthic productivity (e.g., Jennings 2001, Hermsen et al 2003, Hiddink et al 2006, Reiss et al 2009). These are not considered in detail here but are discussed in the 2012 Aquatic Environment and Biodiversity Annual Review.

## 4.5    Other considerations

A substantial decline in the west coast jig fishery for squid will have reduced any trophic implications of that fishery.

# 5.    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.

## 5.1    Estimates of fishery parameters and abundance

No estimates are available.

## 5.2    Biomass estimates

Biomass estimates are not available for squid.

## 5.3    Yield estimates and projections

It is not possible to estimate *MCY*.

It is not possible to estimate *CAY*.

## 5.4    Other yield estimates and stock assessment results

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

## 5.5    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*.

# 6.    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.

TACCs and reported landings for the 2012–13 fishing year are summarised in Table 9.

**Table 9:  Summary of TACCs (t) and reported landings (t) of arrow squid for the most recent fishing year.**

| Fishstock | 2012–13<br>Actual<br>TACC | 2012–13<br>Reported<br>landings |
|---|---|---|
| SQU 1J | 50 212 | 741 |
| SQU 1T | 44 741 | 13 951 |
| SQU 6T | 32 369 | 9 941 |
| SQU 10T | 10 | 0 |
| Total | 127 332 | 24 637 |

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