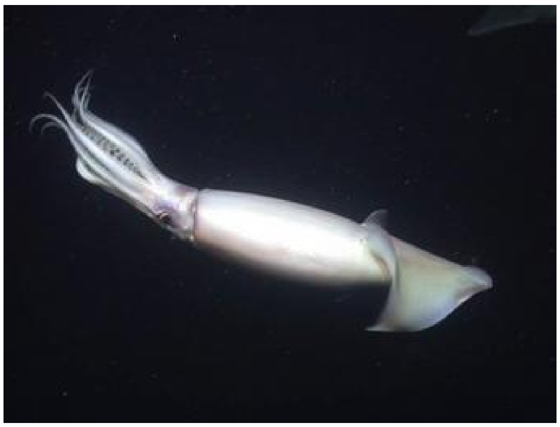
Information describing *Dosidicus gigas* fisheries relating to the South Pacific Fisheries Management Organisation



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WORKING DRAFT

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Jumbo flying squid (*Dosidicus gigas*)

1. <u>Overview</u>

Dosidicus gigas is the largest ommastrephid squid and occurs only within the Eastern Pacific Ocean from northern California to southern Chile. Within the equatorial area the range is stretched westward as a strip, narrowing to the west and reaching 140˚ W (Figure 1). *D. gigas* supports a major fishery off Chile, Peru and the Gulf of California, with combined cephalopod landings of 772 156 tonnes in 2004 (FAO 2004). *D. gigas* is monocyclic and dies after spawning, therefore populations are highly variable. The abundance of *D. gigas* is thought to be largely influenced by environmental variables such as ENSO events. During El Nino years populations have decreased and landings have reflected this by declining sharply.

The Chilean fishery for *D. gigas* is small and generally the result of bycatch, occurring predominantly within the EEZ. The Peruvian and Korean fisheries are the largest within the South Pacific, starting in 1991 and 1977 respectively. *D. gigas* are mainly caught by jigging at night with large lights to attract the squid.

D. gigas are fast growing and relatively short lived therefore biological productivity is high and extractions can potentially be large.

With their ~1 year lifespan, every *D. gigas* squid fishing season is based on incoming recruitment which is highly dependent on environmental conditions and typically variable. Accordingly, it is not possible to calculate reliable yield estimates from historical catch and effort data.

Squid jig is a very selective fishing method. The extent of the adverse impacts on the ecosystem from squid fishing is unknown. However, as with any large extraction of resources from the system, ecosystem effects are likely. The loss of fishing gear from squid fisheries may also have some minimal adverse effect. There is likely to be negligible damage to the habitat due to the fishing methods employed.

There are currently no known management measures in place for *D. gigas*.

This is a living document. It is a draft report and requires additional information to complete.

2. Taxonomy

2.1 Phylum
Mollusca

2.2 Class
Cephalopoda

2.3 Order
Teuthida

2.4 Family
Ommastrephidae

2.5 Genus and species
Dosidicus gigas

2.6 Scientific synonyms
None.

2.7 Common names

Humboldt squid, jumbo flying squid, jibia, pota.

2.8 Molecular (DNA or biochemical) bar coding

No information available.

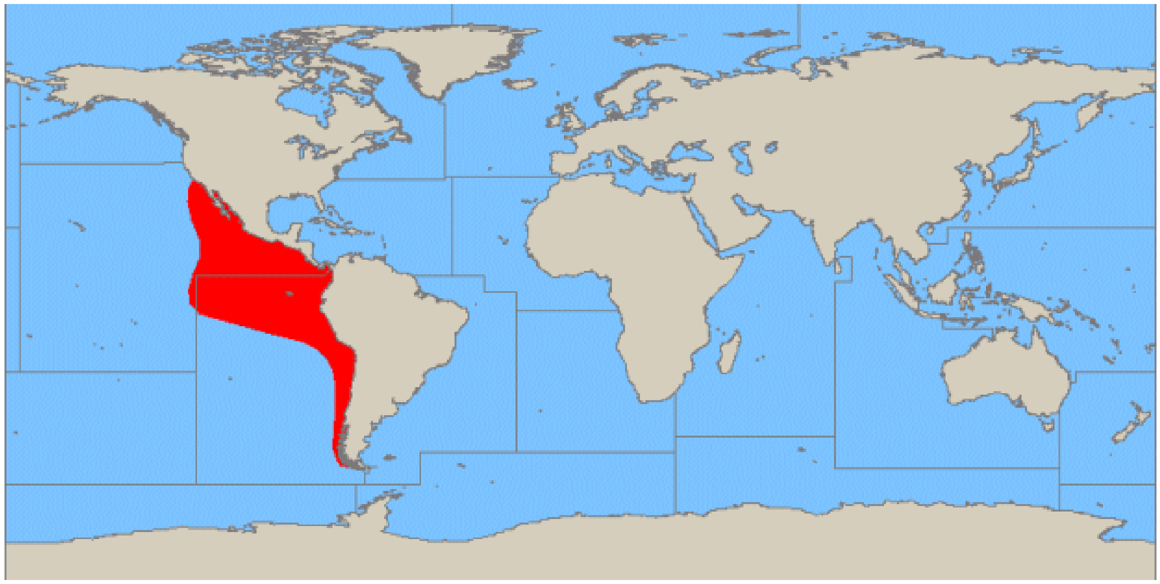
3. Species characteristics

3.1 Global distribution and depth range

D. gigas is endemic to the Eastern Pacific, ranging from Northern California to Southern Chile, and to 140 ˚W at the equator (Figure 1). It is trans-boundary and straddling along the whole coast. Between 36 ˚S and 38 ˚S *D. gigas* are found from 400 to 600 nm offshore. Mating, spawning and early development all occur within the area of the San Pedro Martir Basin (Gilly et al. 2006). Adult squid undergo diel vertical migrations with a night lift to the 0-200 m water layer, plunging in the daytime to 800-1000 m and deeper (Yatsu et al. 1999).

Its range is limited by the isoline of phosphate concentration of 0.8 mg-at $P\text{-}PO_4^{3-}/m^2$ in the 0-100m layer (Aleksandronets et al. 1983, as cited by Nigmatullin et al. 2001).

Figure 1: Known distribution of *D. gigas*. *Source: Fabio Carocci. Food and Agriculture Organization of the United Nations (FAO). Marine Resources Service (FIRM).*



3.2 Distribution within South Pacific area

Large concentrations occur along the coast of northern Peru (Taipe et al. 2001). Straddling stocks occur off the coasts of Peru, Chile and Ecuador. Proportions inside and outside EEZs are unknown but trends have shown an increase of abundance in the high seas when coastal numbers are high. Large aggregations have been found in the zone of divergence of the Peruvian Oceanic current (17-22˚ S) (Nigmatullin 2002).

3.2.1 Inter-annual and/or seasonal variations in distribution

D. gigas are capable of performing large-scale migrations as part of their life cycle (O.Dor 1988; Mangold 1976). Russian data from exploratory trips in the late 50's to the 80's suggest that there are massive feeding migrations of growing squid occurring in the austral summer and autumn. Ehrhardt et al. (1983; as cited in Taipe et al. 2001) propose that *D. gigas* move towards the coast for feeding and spawning, mainly in autumn, winter and spring, forming dense aggregations along the northern Peruvian coast. Squid migrating from their feeding to spawning grounds form large dense schools comprising thousands of animals and can move with a speed ranging from 5-25 km/h (Nesis 1970 & Sabirov 1983; as cited in Nigmatullin et al. 2001). Off the coast of Peru, *D. gigas* tracked with acoustic telemetry were observed to migrate up to 14 km a day (Yatsu et al. 1999).

ENSO cycles have been observed to have substantial effects on the abundance of *D. gigas* (Nigmatullin et al. 2001; Taipe et al. 2001; Waluda et al. 2004; 2006). Inter-annual changes in abundance, size range, composition and quantitative relations within the three groups of *D. gigas* are considerable. *D. gigas* are larger and mature later during the periods of strong trade winds than during a slackening of the Peruvian up-welling. In warmer years (El Nino) the large size group decreases in abundance and the squid are driven into near-shore areas, whereas the medium and small sized groups become more common (Nigmatullin et al. 2001).

The cold La Nina event in 1996 caused *D. gigas* to migrate to northern, warmer waters (Taipe et al. 2001). Anderson and Rodhouse (2001) proposed that warm waters associated with El Nino favour the retention of eggs and squid larvae off Peru, thus increasing squid density and catches in that region (Markaida 2006b). Large abundances of putative larvae have been observed in El Nino years (Vecchione 1999). Nesis (1983; as cited in Nigmatullin et al. 2001) proposed that the invasions of migrating *D. gigas* into coastal zones of central Chile are mainly the result of active feeding migrations in the years of high abundance.

3.2.2 Other potential areas where the species may be found

None known.

3.3 General habitat

D. gigas are nektonic squid that live in the epi-pelagic zone. *D. gigas* are associated with Californian and Peruvian currents.

3.4 Biological characteristics

The reproductive part of the species range is located between 25˚ N and 20-25˚ S, mostly not further than 50-150 nm from the shore. However, from 10˚ N to 15-20˚ S it stretches from 200-450 nm offshore (Nigmatullin et al. 2001) (Figure 1). Spawning is known to occur in the San Pedro Martir Basin and along the entire coast of Peru with the greatest numbers spawning in the northern zone between 3˚ S and 8˚ S and the central zone between 12˚ S and 17˚ S. The Costa Rica Dome (a permanent feature in the ocean density structure relatively consistently located near latitude 9°N and longitude 89°N) could potentially be a common spawning ground for both northern and southern stocks of *D. gigas* as when catches are poor in Peruvian waters they appear higher off the coast of California.

D. gigas are monocyclic so they have only one reproductive season during their life. There is a distinct peak in spawning during spring and summer in the southern hemisphere (Nigmatullin et al. 2001; Tapie et al. 2001), and a secondary peak from July to August (Tafur & Rabi 1997; Tafur et al. 2001). Individual spawning periods are long and intermittent (batch spawning) (Nigmatullin et al. 2001). Spawning takes place both over the continental slope and in adjacent oceanic areas. It is presumed that spawning takes place in the near-surface water layer, but egg masses are unknown.

Studies of age and growth, using analyses of mantle length frequency distributions and aging analyses using statoliths, show *D. gigas* grows quickly and does not live for more than 2 years having an average life span of ~1 year (Masuda et al. 1998; Hernandez-Herra et al. 1998; Arguelles et al. 2001; Nigmatullin et al. 2001). Hernandez-Herrera et al. (1998) observed that *D. gigas* can grow to 52 cm in the first year. Squid hatched in different seasons have different growth rates, with the highest rates being observed in those that hatched in winter (Masuda et al. 1998). *D. gigas* can reach a mantle length of up to 120 cm and can weight up to 65 kg (Nigmatuulin et al. 2001). Statolith ageing studies confirmed high growth rates but also found that some very large individuals can live for 18 months to 2 years (Nigmatullin et al. 2001).

The size at first maturity, in *D. gigas* from Peruvian waters, fluctuated between the years 1991 and 1995 (Tafur et al. 2001). Males matured faster than females and had a size at first maturity between 136 and 474 mm between 1991 and 1995. The range of size at first maturity for females from Peruvian waters was between 285 and 327 mm (Tafur et al. 2001). Hernandez-Herrera et al. (1996) and Markaida et al. (2004) showed that populations within the Gulf of California mature at a larger size; 510 mm for females and 420 mm for males.

Embryonic development lasts for 6-9 days at 18˚C. The mantle length (ML) at hatching averages 1.1 mm (Yatsu et al. 1999). Ontogenesis includes the following phases: paralarvae (1-10 mm ML), juvenile (15-100mm ML), sub adult (150-350 mm ML) and adult (400-1000 mm ML), with three transitional periods. During these periods the morphology, food spectrum and ecological status of the squid change (see Nigmatullin et al. 2001).

3.5 Population structure

It is unknown if the *D. gigas* stock off the Peruvian coast is the same population of squid that inhabit the Gulf of California north of the equator.

Within the Gulf of California the population structure is complicated and comprises of 3 groups of size at maturity. A small group predominantly occurs on the equatorial area, a medium-sized group occurs over the whole species range, and a large size group occurs at the northern and southern peripheries of the range (10-15˚ N and 10-15˚ S (Markaida, 2006b). Genetic differentiation between the different size at maturity aggregations is unknown, although Yokawa (1995) showed by isozyme comparison that the three size at maturity groups belonged to the same population.

Arguelles et al. (2001) investigated age and growth by reading daily increments of statoliths and found two size groups in the exploited Peruvian stock. Their results support those of Tafur & Rabi (1997), who suggested the presence of two sub-populations in the Peruvian EEZ.

3.6 Biological productivity

Productivity is very high. Onset of maturity is early, fecundity is high and the species is very short lived ~1 year, which indicates that the proportion of the total biomass that can be harvested is very large.

3.7 Role of species in the ecosystem

D. gigas is thought to play an important role in oceanic food webs. They are prey to a variety of predators such as pelagic fish, marine birds and mammals. Juveniles are preyed upon by large carnivorous fish, small tuna, squid and gulls; sub-adults are preyed upon by dorado, snake mackerel, yellowfin tuna and other large tunas, fur seals; and adults by sharks, swordfish, striped marlin, sperm whales and pilot whales (Nigmatullin et al. 2001). Sperm whale stomach contents from the south-east Pacific have shown that *D. gigas* is their main prey (Clarke et al.1988). Before the moratorium on commercial whaling, the biomass of *D. gigas* consumed by exploited sperm whales in the eastern Pacific was estimated to be nearly 10 million tonnes (Clarke et al. 1998).

Studies in the Gulf of California have reported that the jumbo squid feeds predominantly on mesopelagic fishes such as myctophids. Pteropods, micronektonic squid, megalopae and euphausiids have also been reported in the stomachs of jumbo squid (Markaida 2006a).

D. gigas prey in the Southeast Pacific appears similar to that in the Gulf of California. A predominance of myctophids was observed, however, the gonostomatid *Vinciguerria lucetia* was the second in fish prey importance (Shchetinnikov 1989).

The feeding habits of *D. gigas* change during ontogeny with a shift in preference from crustaceans to fish. Prey size increases as the squid grows (Schchetinnikov, 1989). Prey size, on average, is commonly between 5-7 cm and occasionally larger 10-15 cm for larger adult squid (Markaida & Sosa-Nishizaki 2003). A high occurrence of cannibalism (up to 70%) has been observed (Markaida 2006a).

Stable isotope analyses have complemented stomach content studies, suggesting that larger adult squid consumed prey of a higher trophic position than myctophids (Ruiz-Cooley et al. 2006).

4. Fisheries characterisation

NOTE: Need to incorporate information received from Japan and Chinese-Taipei

4.1 Distribution of fishing activity

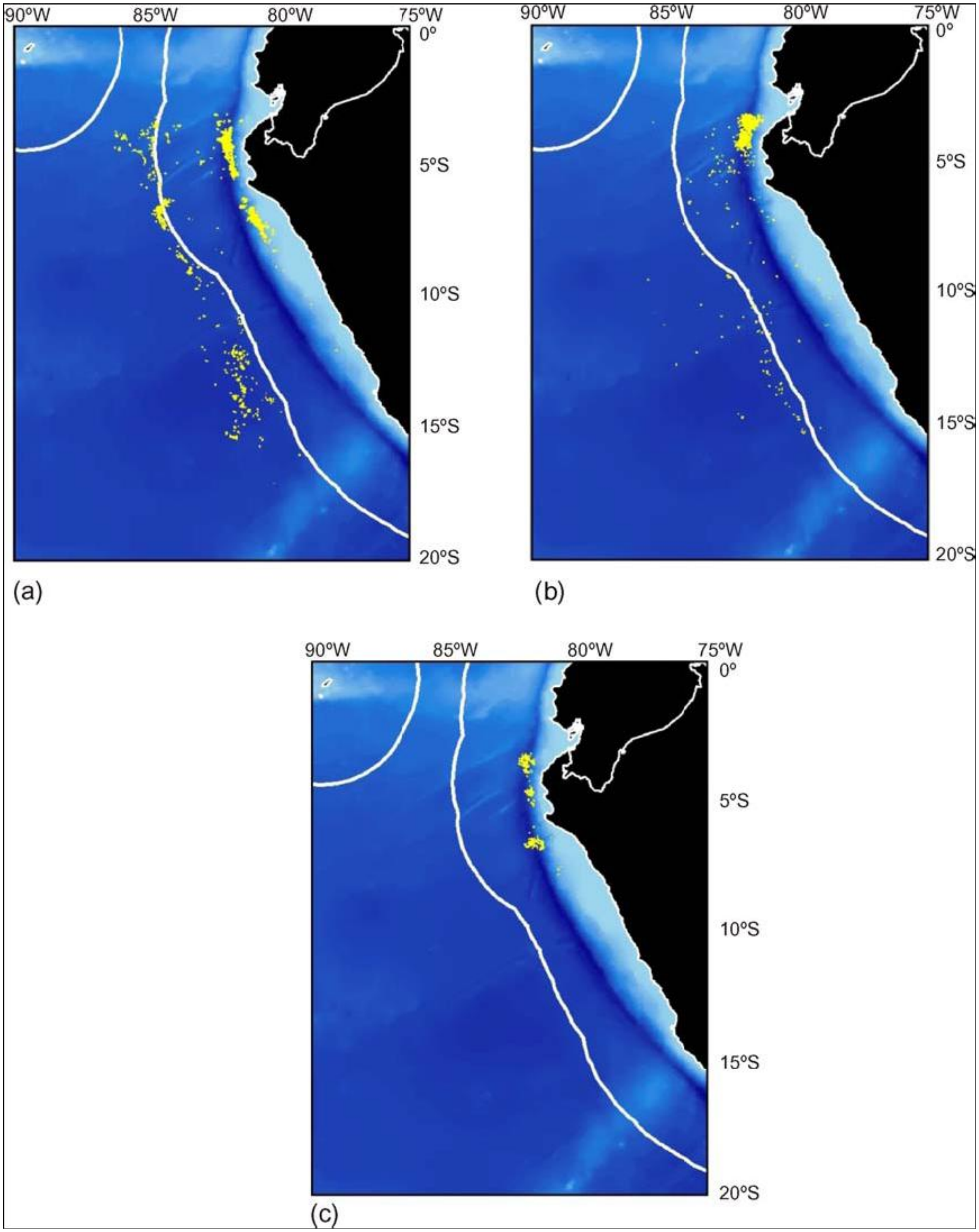
D. gigas supports an important fishery in the eastern Pacific Ocean, mostly off the Peruvian coast in the southern hemisphere, in the Gulf of California and off the coast of central America (close to Costa Rica Dome) in the northern hemisphere. Between 1994 and 1997 the Peruvian fishery was distributed between 3˚ S and 16˚ S in both coastal and high seas waters, over depths of greater than 1000 m (Waluda et al. 2006). Catch distribution on the high seas, off the shores of Chile, was investigated with results clearly indicating that the catch mainly concentrated in the waters near 28 - 30˚ S, 76 - 78˚ W (Xinjun and Xiaohu 2005).

4.2 Fishing technology

Two kinds of fleet exploit squid in Peruvian waters. The industrial fleet (since the early 1990’s) that comprises Japanese and Korean jigging vessels of 300-1000 t holding capacity, and the artisanal fleet comprising of small boats less than 30 t holding capacity. They use drift nets, purse-seine nets, manual jigs and handlines.

The fishery for *D. gigas* in the Gulf of California comprises of three fleets: an artisanal fleet and an artisanal and vessel fleet adapted to take 6-10 fishermen. In all three fleets the fishing gear is hand jigs with 4-6 rings of barbless hooks. Jigging vessels operate at night using powerful lights to attract the squid (Rodhouse 2001).

Figure 2: Annual distribution of the Peruvian *Dosidicus gigas* fleet (a) 1994, (b) 1996, and (c) 1997, shown in yellow. Blue shaded area represents gridded bathymetric data. Solid white line indicates the EEZ boundary (200 nm from shore). *Taken from Waluda et al. (2006).*



4.3 Catch history

Squid fishing began in the North-eastern Pacific in the early 1950's and in the Southeast Pacific in the early 1960's. *D. gigas* supports a major fishery off Chile, Peru and the Gulf of California, with combined cephalopod landings of 772 156 tonnes in 2004 (Table 2).

The start of the Peruvian fishing began in 1991 and catches increased from 57 703 tonnes to a peak of 190 000 tonnes in 1994 (Nevarez-Martinez et al. 2006). During 1994, high catches were made off Peru while low catches were made off Chile and Mexico (Table 1). Catches were low during 1996-1998 but increased during 1999-2002 (Waluda et al. 2006). The level of high seas fishing has mirrored patterns of coastal fishing, with higher numbers observed on the high seas in 1994 (Waluda et al. 2006).

In the Gulf of California during 1996 and 1997, total catch reached about 140 000 tonnes. This fishery vanished during 1998 following the 1997-1998 El Nino (Markaida, 2006b).

The Chilean catch is predominantly taken inside the EEZ (for catch data see Rocha & Vega 2003) and there is no fishery dedicated solely to the capture of *D. gigas*. Since 1960 catches have been sporadic. The *D. gigas* fishery recommenced in 1991 after 20 years without commercial landings (Fernandez & Vasquez 1995) and has been mainly concentrated around 29-34˚ S. *D. gigas* is usually caught as bycatch in trawls or gillnets. Factory ships that fish in both national and international waters also take *D. gigas* although their take is small. The most recent data for Chile give within EEZ landings of 296 819 t and high seas FAO Area 87 landings of 135 t (total 296 954 t) in 2005 (http://www.sernapesca.cl/paginas/publicaciones/anuarios).

In 2002 China entered the fishery and at present are the next largest catchers of squid after Peru. Most of the Peruvian catch comes from inside the EEZ (Figure 3).

Table 1: Catches (tonnes) of *Dosidicus gigas* in the eastern Pacific Ocean.

	1994	1995	1996
Eastern central Pacific (north of 5°N)[a]	1 800	121 063	104 868
Mexico (gulf of California)[b]	10 000	140 000	150 000
Peru[c]	165 000	1 650	5 800
Chile[d]	205	2	0
Southeast Pacific (south of 5°N)[e]	193 429	21 123	21 636

a FAO (2000; data for FAO area 77).
b Morales-Boj´orquez et al. (2001).
c This paper; Taipe et al. (2001).
d Rocha and Vega (2003).
e FAO (2000; data for FAO area 87).
(Taken from Waluda et al. 2006).

Table 2: Catch data for *D. gigas*. Note that FAO area 77 includes the South and North Pacific and those catches are most likely from off the Gulf of California in the North Pacific. Note that some *D. gigas* catches may be reported to the FAO under a general squid code hence this catch data is likely to be incomplete.

Country	FAO Area	1965	1966	1967	1968	1969	1970	1971	1972
Japan	77	-	-	-	-	-	-	-	-
Mexico	77	100	200	100	-	200	100	100	200
Japan	87	<0.5	-	-	-	200	-	-	-
Peru	87	-	-	-	-	-	500	400	-
Total		100	200	100	0	400	600	500	200

Country	FAO Area	1973	1974	1975	1976	1977	1978	1979	1980
Japan	77	-	-	-	-	-	-	-	-
Mexico	77	100	90	365	897	658	1 635	4 522	19 068
Japan	87	-	-	-	-	-	7	-	-
Peru	87	-	-	-	717	1	-	59	-
Total		100	90	365	1 614	659	1 642	4 581	19 068

Country	FAO Area	1981	1982	1983	1984	1985	1986	1987	1988
Japan	77	-	-	-	-	-	-	-	-
Mexico	77	9 726	264	89	364	177	269	225	885
Japan	87	-	-	<0.5	9	15 503	94	-	-
Peru	87	61	888	2	7	206	870	84	852
Total		9 787	1 152	91	380	15 886	1 233	309	1 737

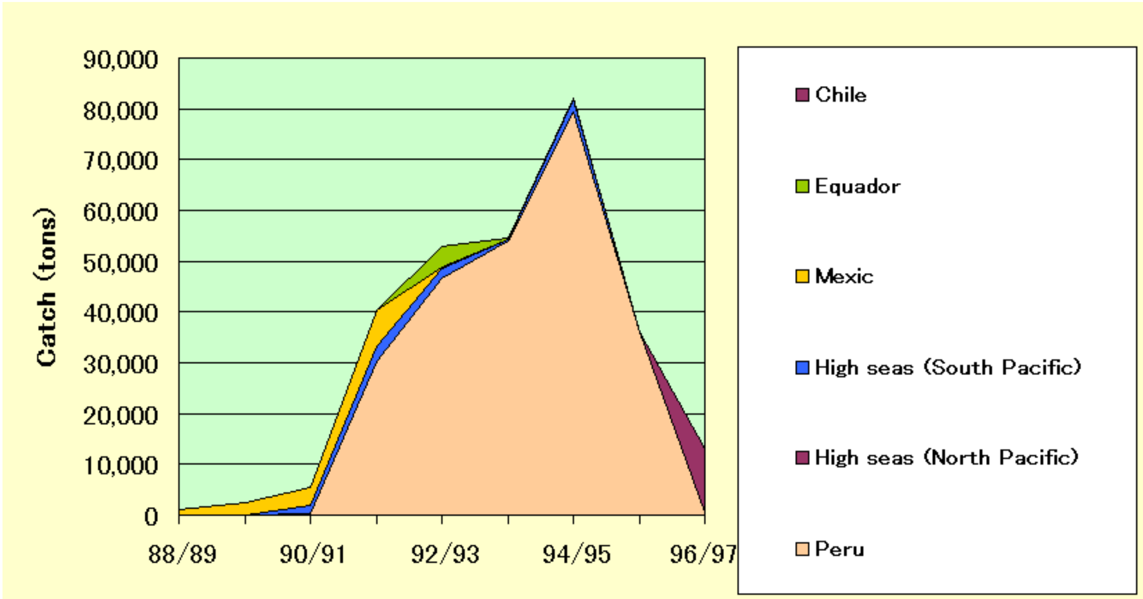
Country	FAO Area	1989	1990	1991	1992	1993	1994	1995	1996
Japan	77	-	-	-	828	-	-	-	13 096
Mexico	77	7 380	5 630	5 846	8 549	3 043	1 800	39 657	107 967
Chile	87	-	-	445	9 400	7 442	205	-	2
Japan	87	<0.5	1 348	2 223	51 187	55 800	84 205	36 515	1 201
Korea, Republic of	87	-	474	17 034	36 101	57 778	66 386	34 440	11 784
Peru	87	2 992	7 441	20 657	12 695	7 769	42 838	25 676	8 138
Total		10 372	14 893	46 205	118 760	131 832	195 434	136 288	142 188

Country	FAO Area	1997	1998	1999	2000	2001	2002	2003	2004
Japan	77	-	-	348	25 904	211	181	3	-
Mexico	77	120 877	26 611	57 985	56 153	73 741	115 896	97 391	110 262
United States of America	77	3	107	18	1	-	4	4	-
Chile	87	-	5	6	9	-	-	-	366
Chile EEZ		-	-	-	-	3 476	5 589	15 191	174 768
China	87	-	-	-	-	-	50 483	81 000	205 600
Japan	87	13 221	-	46	33 878	72 201	60 246	27 059	27 000 [F]
Korea, Republic of	87	2 384	201	18 813	15 625	5 797	21 382	4 722	10 787
Peru	87	16 061	547	54 652	53 795	71 834	146 390	153 727	270 368
Total		152 546	27 471	131 868	185 365	227 260	400 171	379 097	772 151

Source: FAO 2006

[F] = FAO estimate

Figure 3: Proportions of *Dosidicus gigas* catch on the high seas and inside EEZs.



Source: http://www.enyo.affrc.go.jp/sqd-sec/sqdstat.html

4.4 Status of stocks

Not known or uncertain – Insufficient information is available to make a judgment.

4.5 Threats

No threats status known.

4.6 Fishery value

The major component of the $18US million of Chile's income from cephalopod exports between 1991 and 1993 was *D. gigas* (Fernandez & Vasquez 1995).

5. Current Fishery Status and Trends

5.1 Stock size

No estimates are available.

5.2 Estimates of relevant biological reference points

No estimates are available.

5.2.1 Fishing mortality

No estimates are available.

5.2.2 Biomass

In the open waters of Peru (5-20˚ S and west of 95˚ W to the boundary of the EEZ; 1.01-1.21 million^2 km) in 1982, the biomass of *D. gigas* was estimated at 820 000 -1 620 000 tonnes, including 175 000 -1 250 000 tonnes of dense aggregations (Nigmatullin et al. 1991; as cited by Nigmatullin et al. 2001). In the equatorial zone (1˚ S - 1˚ N, 95 - 103˚ W) during 1981-83 the biomass of *D. gigas* was estimated at around 90 000 - 150 000 tonnes (Nigmatullin & Parfenjuk 1988; as cited by Nigmatullin et al. 2001).

The total species biomass within the species range is estimated at around 7 - 10 million tonnes, including around 2 - 4 million tonnes in the open ocean beyond the EEZs. Approximately 1 - 1.5 million tonnes of squid occur in aggregations (Nigmatullin et al. 2001, Nigmatullin 2002).

5.2.3 Other relevant biological reference points

No information available.

6. <u>Impacts of Fishing</u>

6.1 Incidental catch of associated and dependent species

There is no information available for the jig fishery, but it is assumed to catch only squid.

6.2 Unobserved mortality of associated and dependent species

This is likely to be negligible due to the selectivity of the jig fishing method.

6.3 Bycatch of commercial species

No information is available, but some other squids (*Todares angolensis* and *Stenoteuthis oualaniensis*) may be taken.

6.4 Habitat damage

There is likely to be minimal if any damage to the habitat due to the fishing methods employed.

7. <u>Management</u>

7.1 Existing management measures

There are currently no known management measures in place for D. gigas.

7.2 Fishery management implications

The life cycle characteristics of squid present particular problems for fishery management. After one generation of squid have spawned and died there is initially no information on which to base an assessment of the potential recruitment strength and abundance of the next generation. It has been proposed that squid fisheries could be assessed and managed in real-time. An example of this approach can be seen by *Illex argentinus* in the South Atlantic (see Rodhouse, 2001). In a review of the stock assessment approach modelled on *I. argentinus,* Morales-Bojorquez et al. (2001) suggest further improvements towards better managing a highly dynamic and variable species.

ENSO weather patterns have substantial effects on the recruitment and abundance of jumbo flying squid. During La Nina years big catches have been sustained, however, during El Nino years the fisheries have vanished. Because squid have large inter-annual variability in exploitable biomass a suitable management regime is required.

Markaida (2006b) suggested that for management purposes it is essential to conduct and report size at maturity studies. Size at maturity can change rapidly therefore impacting on recruitment. Documentation of this could lead to better management measures, such as bans on catching medium sized jumbo squid of unknown maturity, as has happened in the Gulf of California in 1999.

7.3 Ecosystem Considerations

Squid jigging is assumed to be a very selective fishing method. The extent of adverse impacts on the ecosystem from squid fishing is unknown. However, as with any large extraction of resources from a system, changes in community structure are likely. The abundance of this species is marked by large natural fluctuations and large catches can only during times of peak abundance. Accordingly, it is difficult to predict the system response to large catches. The loss of fishing gear from squid fisheries may also have an adverse effect although the extent of that effect has not been explored.

8. Research

8.1 Research underway

Chile (Fondo de Investigación Pesquera - www.fip.cl) has a project underway to explore the *D. gigas* fishery, with a preliminary report now available which contains new fisheries and biological information about this species (Arancibia et al. 2006).

8.2 Research needs

Despite the general acceptance of the one increment per day hypothesis statolith growth increments have not yet been validated (Nigmatullin et al. 2001).

Stock structure needs to be investigated to ensure sound management practices.

9. Additional remarks

Sthenoteuthis oualaniensis is the only other adult ommastrephid species found in areas of the Eastern Pacific where *D. gigas* is abundant (Nigmatullin et al. 2001). Interspecific competition between *D. gigas* and S. *oualaniensis* has the potential to be acute as the food spectra overlap extensively for the middle sized *D. gigas* and the large *S. oualaniensis.* However, competition for food is decreased by preferences for different water temperatures (*S. oualaniensis* prefer warmer waters) and vertical distributions (at night *D. gigas* occur at shallower depths than *S. oualaniensis*). Despite possible competition for food *D. gigas* and *S. oualaniensis* commonly form mixed schools (Nigmatullin et al. 2001).

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