Seafood Watch
Seafood Report

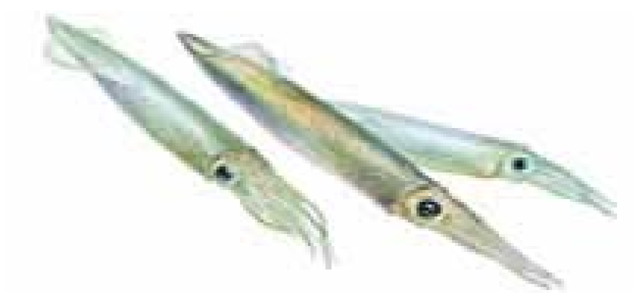
MONTEREY BAY AQUARIUM®

International Squid

With a focus on:

Argentine Shortfin Squid
Illex argentinus

Japanese Flying Squid
Todarodes pacificus



(Image © Monterey Bay Aquarium)

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About Seafood Watch® and the Seafood Reports

Monterey Bay Aquarium's Seafood Watch® program evaluates the ecological sustainability of wild-caught and farmed seafood commonly found in the United States marketplace. Seafood Watch® defines sustainable seafood as originating from sources, whether wild-caught or farmed, which can maintain or increase production in the long-term without jeopardizing the structure or function of affected ecosystems. Seafood Watch® makes its science-based recommendations available to the public in the form of regional pocket guides that can be downloaded from the Internet (seafoodwatch.org) or obtained from the Seafood Watch® program by emailing seafoodwatch@mbayaq.org. The program's goals are to raise awareness of important ocean conservation issues and empower seafood consumers and businesses to make choices for healthy oceans.

Each sustainability recommendation on the regional pocket guides is supported by a Seafood Report. Each report synthesizes and analyzes the most current ecological, fisheries and ecosystem science on a species, then evaluates this information against the program's conservation ethic to arrive at a recommendation of "Best Choices", "Good Alternatives" or "Avoid." The detailed evaluation methodology is available upon request. In producing the Seafood Reports, Seafood Watch® seeks out research published in academic, peer-reviewed journals whenever possible. Other sources of information include government technical publications, fishery management plans and supporting documents, and other scientific reviews of ecological sustainability. Seafood Watch® Fisheries Research Analysts also communicate regularly with ecologists, fisheries and aquaculture scientists, and members of industry and conservation organizations when evaluating fisheries and aquaculture practices. Capture fisheries and aquaculture practices are highly dynamic; as the scientific information on each species changes, Seafood Watch's sustainability recommendations and the underlying Seafood Reports will be updated to reflect these changes.

Parties interested in capture fisheries, aquaculture practices and the sustainability of ocean ecosystems are welcome to use Seafood Reports in any way they find useful. For more information about Seafood Watch® and Seafood Reports, please contact the Seafood Watch® program at Monterey Bay Aquarium by calling 1-877-229-9990.

Disclaimer

Seafood Watch® strives to have all Seafood Reports reviewed for accuracy and completeness by external scientists with expertise in ecology, fisheries science and aquaculture. Scientific review, however, does not constitute an endorsement of the Seafood Watch® program or its recommendations on the part of the reviewing scientists. Seafood Watch® is solely responsible for the conclusions reached in this report.

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I. Executive Summary

More than 2 million metric tons (mt) of squid are landed annually throughout the world. Although almost a hundred species of squid are fished commercially, two species, the Japanese flying squid (*Todarodes* pacificus) and the Argentine shortfin squid (*Illex argentinus*), account for over half the world's squid harvest. In 2003, 49,654 mt of squid were imported into the U.S. from 30 different countries. Five countries ─ China, Taiwan, India, South Korea, and Thailand ─ accounted for 78% of domestic squid imports. With the exception of India, which lands squid solely from the Indian Ocean, these counties simultaneously operate squid fisheries in different regions and ocean basins throughout the world. Despite the availability of some information on regional fishery operations, there are little quantifiable data on regional landings of squid by species. Most countries only report squid catch to the Food and Agriculture Organization of the United Nations (FAO) by region and major taxonomic group, not by species name. This seafood report focuses on the two main regions that produce the majority of squid imported into the U.S.: the Northwest/Western Central Pacific and the Southwest Atlantic. In general, most of the squid landed in these regions is caught in international waters using jigs or trawls. Because squid have short life cycles (6-18 months), little overlap of generations, highly erratic recruitment and show wide fluctuations of abundance, the status of stocks in these regions is currently unknown and extremely unpredictable. The combination of life history characteristics, little or no management, and unreliable fishery data, raises concern regarding possible overfishing of squid stocks.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Inherent Vulnerability	√			
Status of Stocks		√		
Nature of Bycatch	√			
Habitat & Ecosystem Effects		√		
Management Effectiveness			√	

About the Overall Seafood Recommendation:

- A seafood product is ranked **Best Choice** if three or more criteria are of Low Conservation Concern (green) and the remaining criteria are not of High or Critical Conservation Concern.
- A seafood product is ranked **Good Alternative** if the five criteria "average" to yellow (Moderate Conservation Concern) OR if the "Status of Stocks" and "Management Effectiveness" criteria are both of Moderate Conservation Concern.
- A seafood product is ranked **Avoid** if two or more criteria are of High Conservation Concern (red) OR if one or more criteria are of Critical Conservation Concern (black) in the table above.

Overall Seafood Recommendation:

Best Choice ☐ **Good Alternative** ☐ Avoid ☐

II. Introduction

Market Availability

Product Sources
Cephalopods make up only 3% of global fisheries catches, but have the third highest commercial value, after shrimp and tuna (Suauer et al. 2002). Furthermore, the global catch of marine invertebrates, such as squid, is increasing; between 1984 and 1995, the global catch increased by 46%. For comparison, the global catch of pelagic fishes increased by 19%, and the global catch of demersal species decreased by 3% during the same time period (Suauer et al. 2002). It is difficult to determine the source of this increase, however, as squid is now commonly used both for human consumption and as bait for commercial and recreational fisheries. The amount of squid consumed versus the amount used as bait has yet to be quantified. Furthermore, it is difficult to determine species name and fishery of origin for squid sold in the U.S. marketplace, as most imported squid is labeled simply as "squid" by exporting countries (Haimovici et al. 1998; NMFS 2003).

Despite having a large domestic fishery for squid (CDFG 2003), most notably the California market squid fishery, very little squid landed in the U.S. is sold in the domestic market. Most squid landed in the U.S. is exported to China, Japan and Europe (CDFG 2001; CDFG 2001). In 2002, the U.S. exported 71,975 mt of squid landed domestically and imported 49,656 mt of squid from 30 different countries (Fig. 1) (NMFS 2003). In 2002, five countries ─ China, Taiwan, India, South Korea, and Thailand ─ accounted for 78% of U.S. domestic squid imports. Though species names are not available, most of this squid is known to have come from the Northwest/Western Central Pacific and the Southwest Atlantic (Fig. 2) (FAO 2003).

Product Forms:
The majority of squid for human consumption is frozen, but squid is also found fresh or canned (CDFG 2001). Squid is also used fresh or frozen as fishing bait (CDFG 2001).

Market Names:
Squid is also sold as calamari.

Seasonal Availability:
Squid is available year-round.

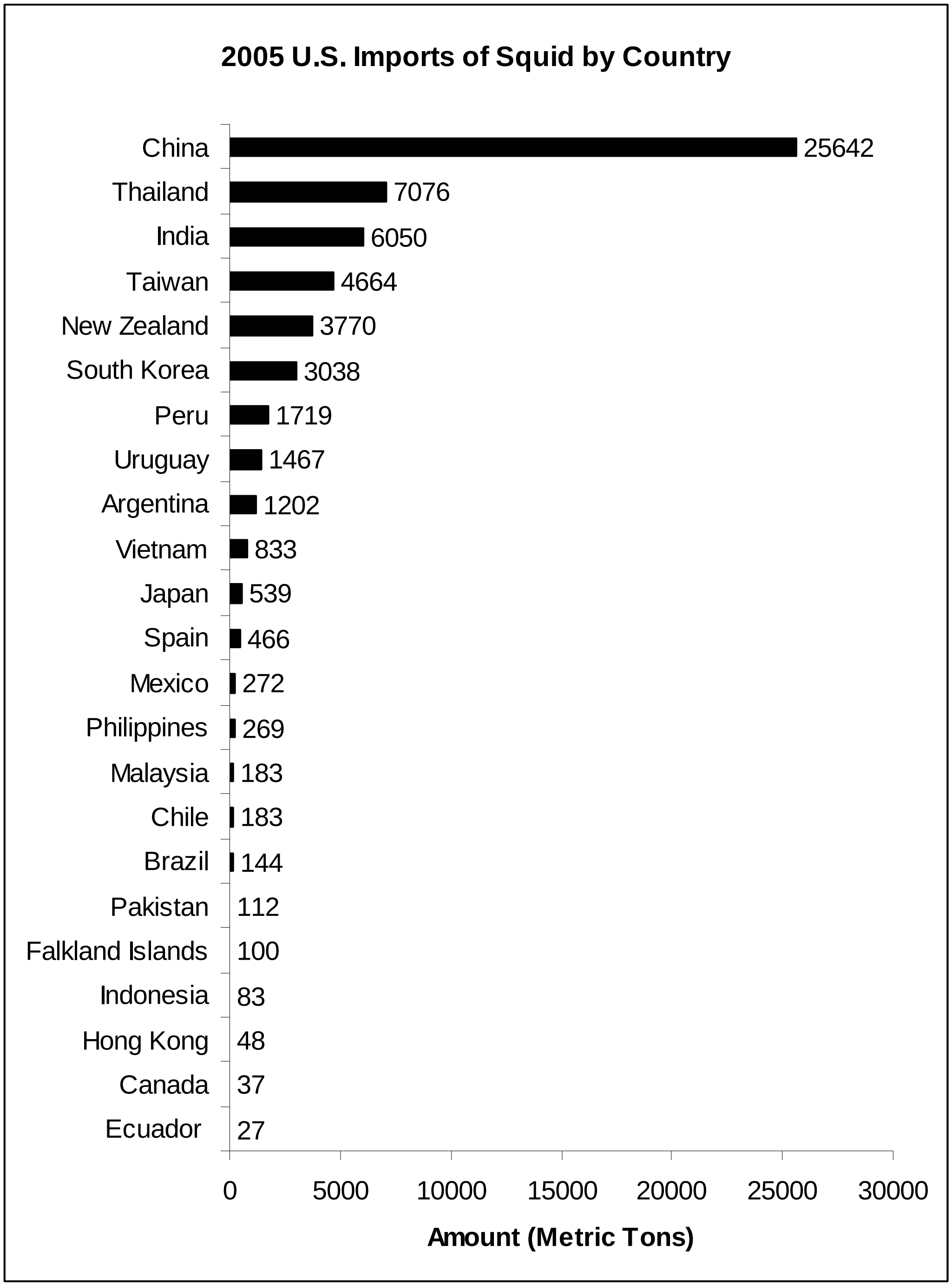

Figure 1. The United Sates imported squid from 30 different countries in 2005. Above are the countries that supplied the U.S. with greater than 20 mt. The breakdown of squid by species is not available from NMFS (NMFS 2006).

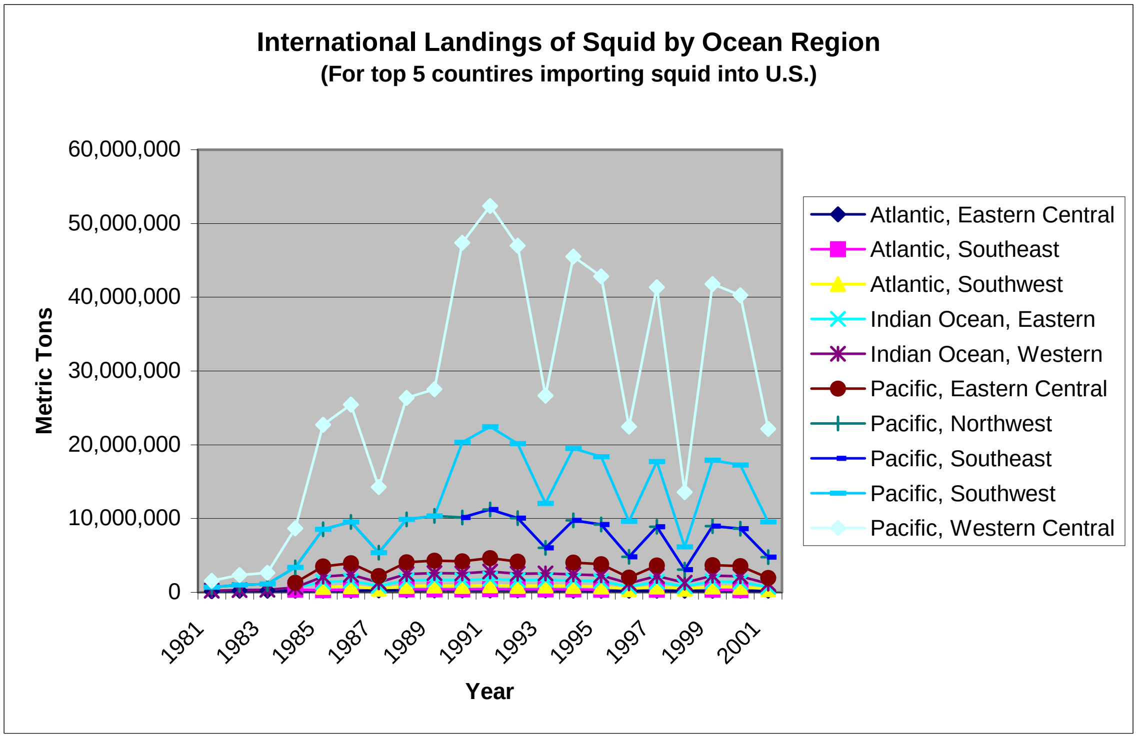

Figure 2. Landings of squid by region for the top five countries that export squid to the U.S. (FAO 2003).

III. Analysis of Seafood Watch® Criteria

Criterion 1: Inherent Vulnerability to Fishing Pressure

Cephalopods generally "live fast and die young" (O'Dor and Webber 1986; Boyle 2002). Their life cycles are short (6-18 months), their recruitment is highly variable and difficult to predict (Pauly 1985; Moltscaniwskyj et al. 2002), and they exhibit wide fluctuations in abundance (Table 1).

Table 1. Life history vulnerability characteristics of commonly landed squid species (O'Dor and Webber 1986; Nesis 2002)

Species	Intrinsic Rate of Increase	Age at 50% Sexual Maturity	Maximum Age	Reproductive Potential	Species Range	Special Behaviors	Population Variability
Ommastrephes bartramii	Unknown	Unknown	12-18 months	Unknown, but thought to be highly fecund	Pacific Ocean/shelf regions	Aggregates to spawn	Susceptible to changes in oceanographic conditions
Todarodes pacificus	Unknown	8-12 months	12-18 months	Unknown, but thought to be highly fecund	Throughout Pacific Ocean	Aggregates to spawn	Susceptible to changes in oceanographic conditions
Illex argentinus	Unknown	6-8 months	10-18 months	Unknown, but thought to be highly fecund	Shelf and oceanic waters off Eastern South America	Aggregates to spawn	Susceptible to changes in oceanographic conditions

This extreme lifecycle is caused by an early maturity, little generational overlap, and wide-ranging migratory patterns. All of these characteristics combine to make squid highly susceptible to changes in oceanographic conditions (Bakun and Csirke 1998; Bower et al. 1999; Hill and Agnew 2002) and overfishing (Jackson 1990; Suauer et al. 2002). According to Moltscaniwskjj et.al (2002), the removal of reproductive individuals from the spawning grounds before and during spawning has the potential to shorten the reproductive period females, reduce lifetime fecundity and jeopardize the size of the next generation.

On the other hand, squid show great resilience to fluctuations in oceanographic conditions and fishing pressure through their capacity to vary growth rates, extend their breeding seasons, vary the depth of their spawning grounds, and maintain complex recruitment patterns (Nesis 2002; Suauer et al. 2002).

Though fecundity data is not available for most squid species, fecundity in some cephalopods is known to be high (Butler 2001). Using a model for potential fecundity, researchers found that a 13 cm female California market squid was able to spawn 3,010 eggs in its short life span of six to twelve months (Jackson 1994; Butler 2001). Spawning squid tend to congregate over sandy bottom in dense schools, where they deposit their eggs (Moltscaniwskyj et al. 2002; CDFG 2003).

Some squid species form the apex of a relatively simple trophic system consisting of upwelling-induced nutrient enrichment, phytoplankton, krill, and squid (Marinovic et al. 2001). Research conducted in Monterey Bay, California show California market squid feed almost exclusively on krill, particularly in nearshore and pelagic feeding grounds (Fig. 3) (Marinovic et al. 2001). Feeding on a single prey increases squid's sensitivity to fluctuations in ocean conditions, as changes in water temperature and nutrient levels can affect the population abundance of their sole source of food.

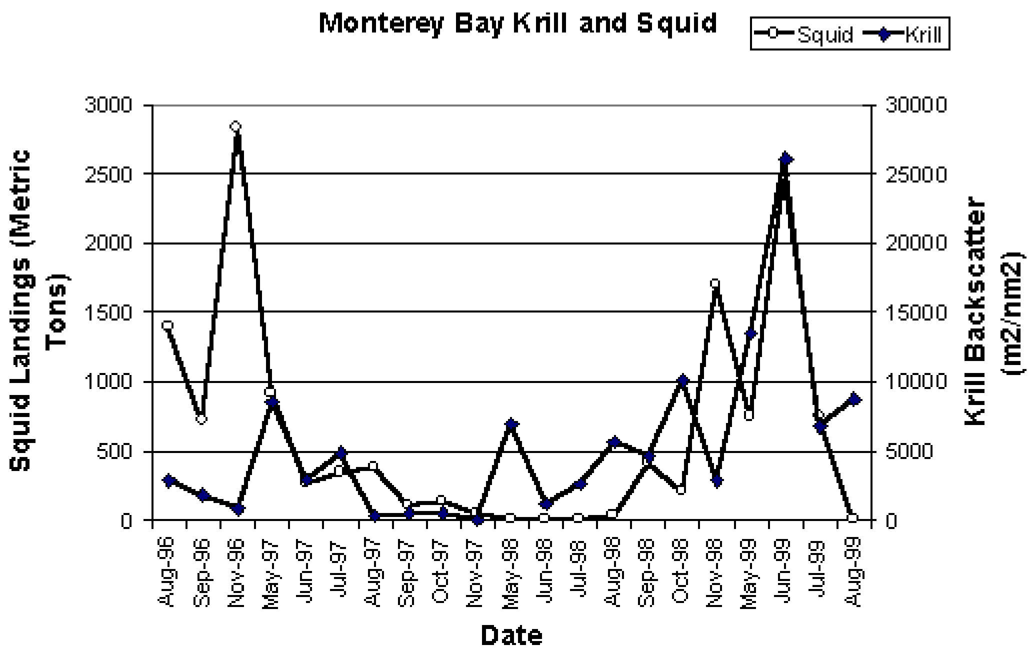

Figure 3. Squid landings compared with krill abundance within Monterey Bay, California (Croll et al. 2000; Nesis 2002).

Synthesis
Although squid exhibit high population variability driven by oceanographic conditions and form dense feeding or spawning aggregations. Squid reach sexual maturity at a young age, are highly fecund, and experience short life spans, making them inherently resilient to fishing pressure.

Inherent Vulnerability Rank:

Resilient Moderately Vulnerable Highly Vulnerable

Criterion 2: Status of Wild Stocks

Most commercial fisheries for squid are associated with large current systems and, according to O'Dor (1992), much of the variation in abundance in such fisheries may be explained by fluctuations in current meanders and eddies. Furthermore, there is increasing evidence that variability in specific stocks of various squid species are associated with oceanographic conditions such as El Niño (Bakun and Csirke 1998) and seasonal events such as spring upwelling phytoplankton blooms (Suauer et al. 2002).

Commercially harvested squid stocks are migratory and appear in fishing areas for only a few months of the year (O'Dor et al. 2002). The *Loligo gahi* population, for example, that is fished around the Falkland Islands in August and September each year appears to consist of a single cohort that recruits to the fishery between April and July and leaves for inshore spawning grounds in October and November (Hill and Agnew 2002).

Though widely speculative, the global biomass (standing stock of adults and sub-adults) of cephalopods in the oceans has been estimated at 193 to 375 million mt (Boyle 2002). Theoretically, according to Boyle (2002), consumption of squid by sperm whales alone could account for 213 to 320 million mt of cephalopods from open ocean areas.

Furthermore, squid landings by commercial fishers continue to rise. According to the FAO (2003), 3.3 million mt of cephalopods were landed in fisheries in 2001, an increase of one million mt over the last decade. Caddy and Rodhouse (1998) have concluded that as groundfish landings declined globally, cephalopod landings increased. They've shown that fishing pressure in the Gulf of Thailand, West Africa and the Adriatic Sea has inversely changed ecological conditions; cephalopod biomass has increased as the populations of predatory fishes have declined.

The two regions with the most concentrated international squid fisheries are the Northwest/Western Central Pacific and the Southwest Atlantic. Though rudimentary information on stock status and structure in the Southwest Atlantic is widely available, little information exists on squid stocks throughout the Pacific.

Table 2. Stock and abundance classifications of commonly landed squid species.

Species	Official Classification Status	Occurrence of Overfishing	Current Population Status Relative to B_{MSY}	Long and Short Term Trends in Abundance	Degree of Uncertainty in Stock Status
Ommastrephes bartramii	No Official Classification	Unknown	Unknown	Unknown	High
Todarodes pacificus	No Official Classification	Unknown	Unknown	Unknown	High
Illex argentinus	No Official Classification	Unknown	Unknown	Unknown	High

Northwest & Western Central Pacific
There are several squid species found in the Northwest/Western Central Pacific, but only two are caught by large-scale commercial fishers: *Ommastrephes bartramii* and *Todarodes pacificus* (Seki 2000). The principal difference between the species is their pattern of intraspecific subdivision (Sakurai et al. 2002). *O. batramii* dwells in the open ocean, and migrates between the eastern parts of its range, which it inhabits in the summer and fall, and the western parts of its range, which it inhabits in the winter and spring. On the contrary, *T. pacificus* is a nerito-oceanic species, which inhabits the continental shelf throughout its life cycle.

Todarodes pacificus
T. pacificus is one of the most heavily exploited squid species in the world (FOA 2003). Up to three or four intraspecific stocks of *T. pacificus* are recognized, based primarily on spawning seasons, spawning sites, growth rates, size at maturity, fecundity, and migration patterns (Katugin 2002). There are two hypotheses concerning population structure of this species: either there is a single integrated gene pool with mixing over areas and between temporal groupings; or intraspecific groups are more or less isolated and may differ in genetic traits.

Landings of *T. pacificus* fluctuated greatly in the 20th century, ranging from 50,000 – 600,000 mt (Fig. 4) (Katugin 2002). According to Katugin (2002), these fluctuations reflect major changes in biomass that may be caused by a combination of periodic shifts in climate and oceanographic conditions and overfishing. Biomass for this species has been estimated at 500,000 mt in coastal areas of the Northwest Pacific during the summer months, nearly 90% of the total biomass of all epipelagic nektonic animals in the region (Katugin 2002). No biomass estimates are available for *T. pacificus* found in international waters.

Though annual landings of *T. pacificus* are not available for most countries, most notably China and Thailand (Fig. 5 and 6), landings for Japan and Korea have markedly increased since the late-1980s and landings in the late-1990s reached between 400,000 and 700,000 mt Pacific-wide (Sakurai et al. 2002). Since the late 1980s, larval abundances have also been higher than observed during the late 1970s and mid-1980s. In the Northwest Pacific, environmental conditions have shifted from warm temperatures, which began in the late 1940s, to cooler temperatures in the late 1970s, and back to warmer temperatures in the late 1980s. Variation in *T. pacificus* catches, including a decrease in total annual catch in the early 1980s and an increase in the late 1980s, corresponded with these temperature changes.

It has been suggested that the winter spawning areas in the East China Sea contracted when adult stocks decreased during a cool period that occurred before 1988, and that fall and winter spawning areas extended and overlapped in the Sea of Japan and East China Sea when adult stocks increased during a warm period that occurred after 1989 (Sakurai et al. 2002).

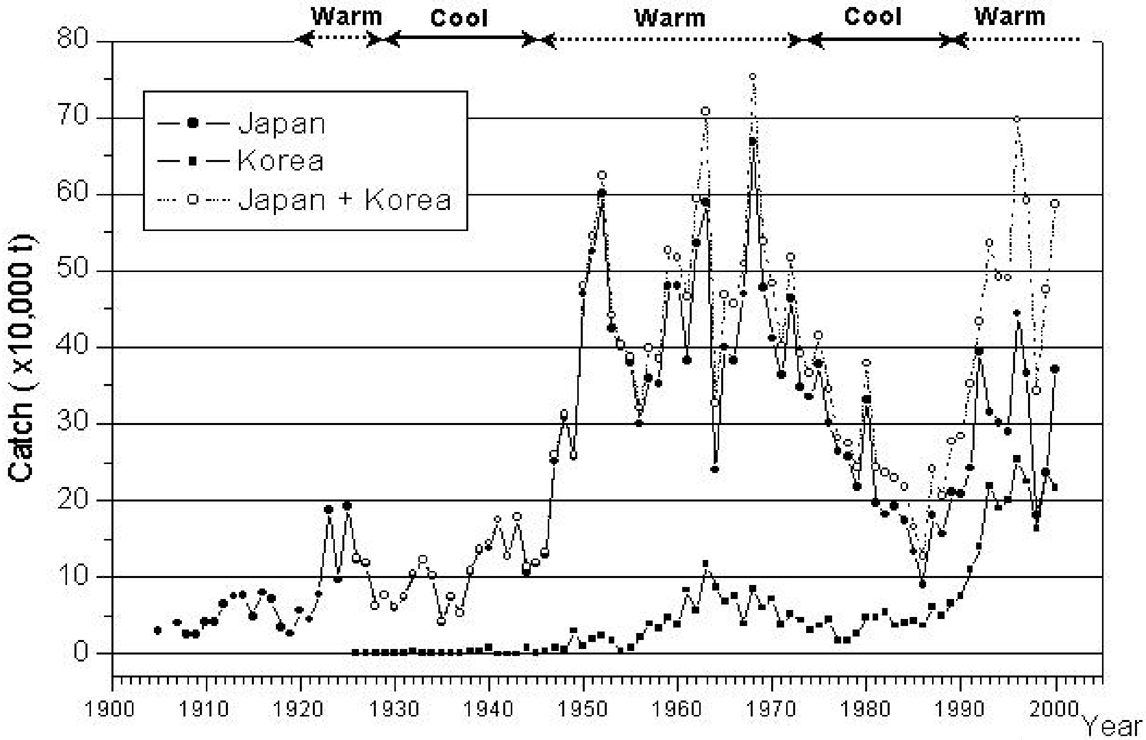

Figure 4. Annual fluctuations in *Todarodes pacificus* catches for Korea and Japan during the 20th century (Minobe 1997).

O. bartramii

O. bartramii, has been commercially harvested since the early 1970s throughout the North Pacific (Chen and Chiu 1999) and aggregations are found throughout the entire Pacific Basin (Katugin 2002). *O. bartramii* undergo extensive seasonal migrations from summer feeding grounds at subarctic fronts or within subarctic waters to and from winter spawning grounds in the subtropics (Seki 2000).

The main fishery for *O. bartramii* operates in the open ocean and usually targets feeding squid (Chen and Chiu 1999). Vessels generally shift northward and eastward towards colder waters in June – September and southward and westward towards warmer water after October (Chen and Chiu 1999).

O. bartramii are found on feeding grounds throughout almost the entire subarctic frontal zone of the North Pacific, though the highest catches are associated with two large areas: west of approximately 175° E. and east of approximately 175° W.

Despite available data on stocks, migrations and landings for some fisheries, no current Pacific-wide stock assessments or biomass estimates are available for either *T. pacificus* or *O. bartramii*.

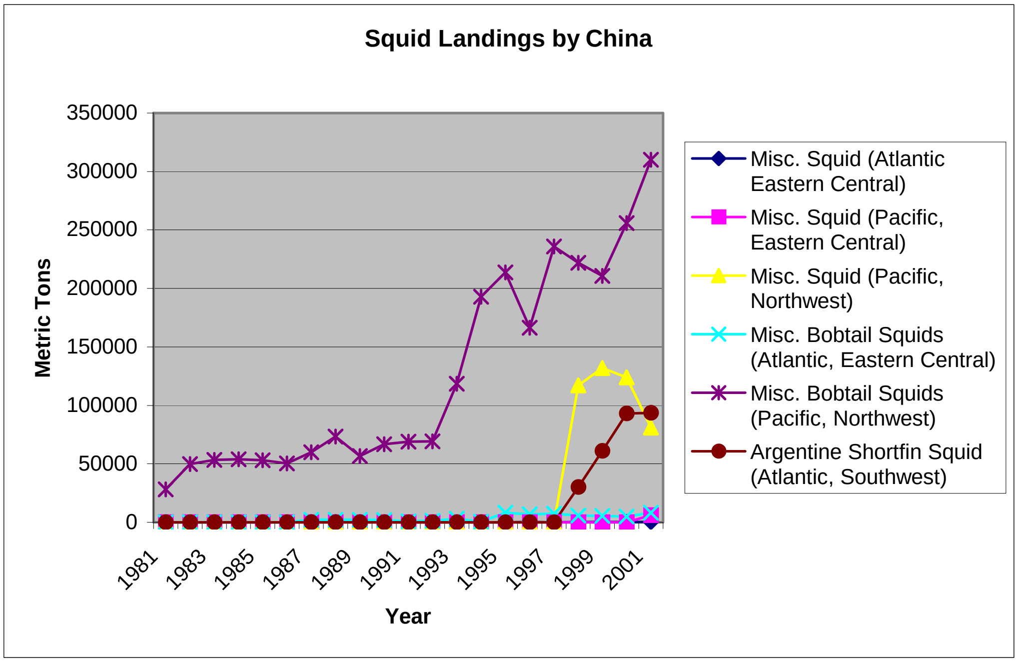

Figure 5. The highest concentration of Chinese squid fishing occurs in the Northwest Pacific. China is the largest supplier of squid to the U.S. seafood market (FAO 2003).

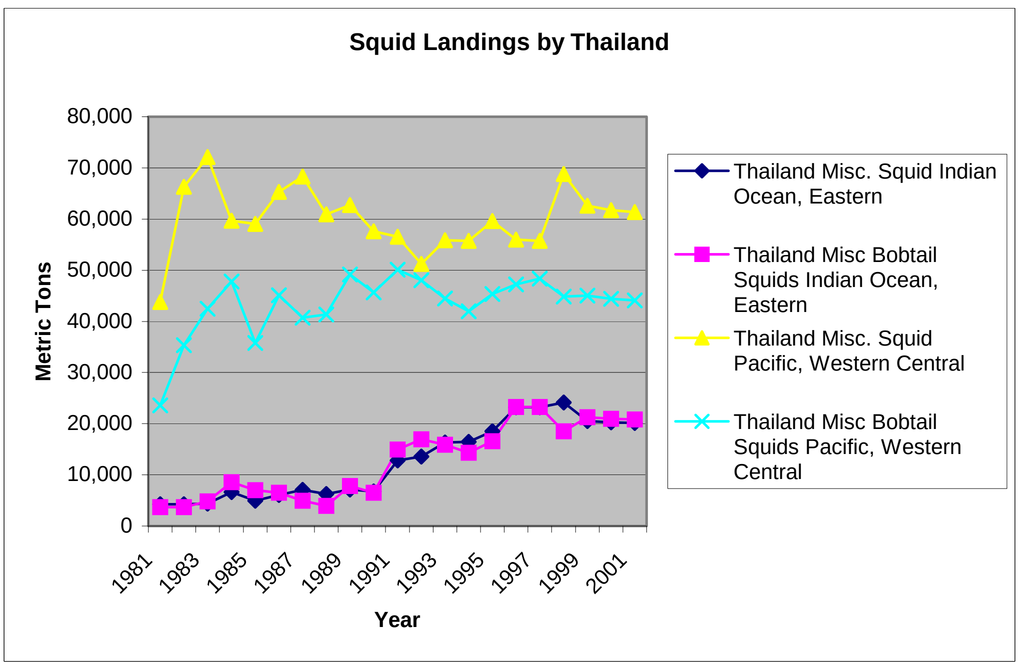

Figure 6. The highest concentration of Thailand's squid fishing occurs in the Northwest Pacific. Thailand is the fifth largest supplier of squid to the U.S. seafood market (FAO 2003).

Southwest Atlantic

The "flying squids" from the genus Illex are representative of the family Ommastrephidae, which accounts for, by volume, most of the world's commercial squid catch (O'Dor and Lipinski 1998). The genus is distributed throughout the Atlantic in a complex of closely related species that occupy diverse habitats along the continental margins (O'Dor and Lipinski 1998). The most abundant species in the Illex commercial fishery is *Illex argentinus*, known as the Argentine shortfin squid.

I. argentinus inhabit both continental shelf and oceanic waters off Eastern South America from 20°–55° S., and eastward to 40–45° W. (Arkhipkin 1999). Within this range, three major intraspecific stocks are recognized: the winter-spawning Southpatagonian stock (SPS), which spawns in continental slope waters; the winter-spawning Bonaerensis-Northpatagonian stock (BNS), which spawns in continental shelf waters; and summer spawning stock (SSS).

The largest proportion of fishing effort directed at *I. argentinus* occurs on the Patagonian Shelf. Jigging vessels fish for squid in the waters around the Falkland Islands and the offshore Patagonian Shelf and Slope between 42° and 48° S (Murphy et al. 1994). Since 1987, the Falkland Islands Fishery has been managed by the Falklands Interim Conservation and Management Zone (FICZ), which covers a 150-mile radius from a point in the center of the islands, excluding an area in the southwest of the management zone (Murphy et al. 1994). The zone has recently been extended to include the Falklands Outer Conservation Zone (FOCZ) (FIGFD 2003). Vessels are licensed to fish within the FICZ between March and May/June, but heavy fishing on the same stock takes place outside the zone in international waters and within the Argentinean Exclusive Economic Zone (EEZ) (Murphy et al. 1994). Within the FICZ, management of the stock is based on a target-proportional escapement policy affected by effort limitation.

A multinational squid fishery operates within the FICZ, FOCZ, and international waters beyond these zones (Laptikhovsky et al. 2001). The countries involved in the greatest fishing effort are Taiwan and South Korean (Fig. 7 and 8), which supply the majority of *I. argentinus* to the U.S.

The bulk of *I. argentinus* catches in international waters is comprised of winter spawning squids, SPS and BNS. The international fishing fleet between 45° and 47° S yields mostly foraging BNS in April-March and pre-spawning migrating SPS in May-June (Haimovici et al. 1998; Laptikhovsky et al. 2001).

I. argentinus migrate annually to the FICZ from north of the zone, arriving between January and March (Murphy et al. 1994). The catch rate peaks in March and April and most Illex are caught north of the Falkland Islands. As the squid grow and mature they migrate out of the FICZ toward the west. By June, catch rates fall to zero as the last squid leave the zone.

I. argentinus is one of the most commercially-important squid species, with annual catch sometimes as much as 550,000 to 750,000 mt (Laptikhovsky et al. 2001). Different estimates of total biomass of *I. argentinus* based on trawl data have ranged from 60,000 to 2.6 million mt (Haimovici et al. 1998).

The year 2002 was unusual for the Falklands fishery. Cold-water temperatures around the Falkland Islands prevented migrations of *I. Argentinus* into the FICZ and FOCZ (FIFD 2002). The total annual catch reached 100,000 mt, which constituted only half of the annual catches observed in the previous worst Falkland fishery years of 1994 and 1996 (FIFD 2002). Moreover, what was reported to be a good fishing season for winter spawning squid in international waters in January gave no indication of the low catches that were to follow (FIFD 2002). Preliminary estimations of squid recruitment from a joint Argentine/British survey, which was carried out in February of 2002, indicated the abundance of the winter-spawned squid was somewhat lower than average (1.3 billion squid) (FIFD 2002).

Unusual patterns of *I. argentinus* migrations in 2002 made it difficult to estimate whether or not the conservation target of 40,000 mt for the Southwest Atlantic had been met. The current estimates range between 15,000 and 50,000 mt. The total Argentinean catch of Illex was recorded to be 176,682 mt, whereas the total FICZ/FOCZ catch was only 13,379 mt (FIFD 2002).

Catches of Illex in 2003 were also at low levels. According to the Falkland Islands Fisheries Department website, the fishery closed early for "conservation reasons." On May 16, 2003 John Barton, the Director of Fisheries wrote "the level of catches and fishing activity in [the FICZ] is at a very low level now, although catches were good for the early part of the season."

No data are available for the international fleet, which consists of jiggers and trawlers, principally from Japan, Korea, Taiwan, Poland, Spain, and Russia (Basson et al. 1996). According to Basson et al. (1996) the fishery generally follows squid migration.

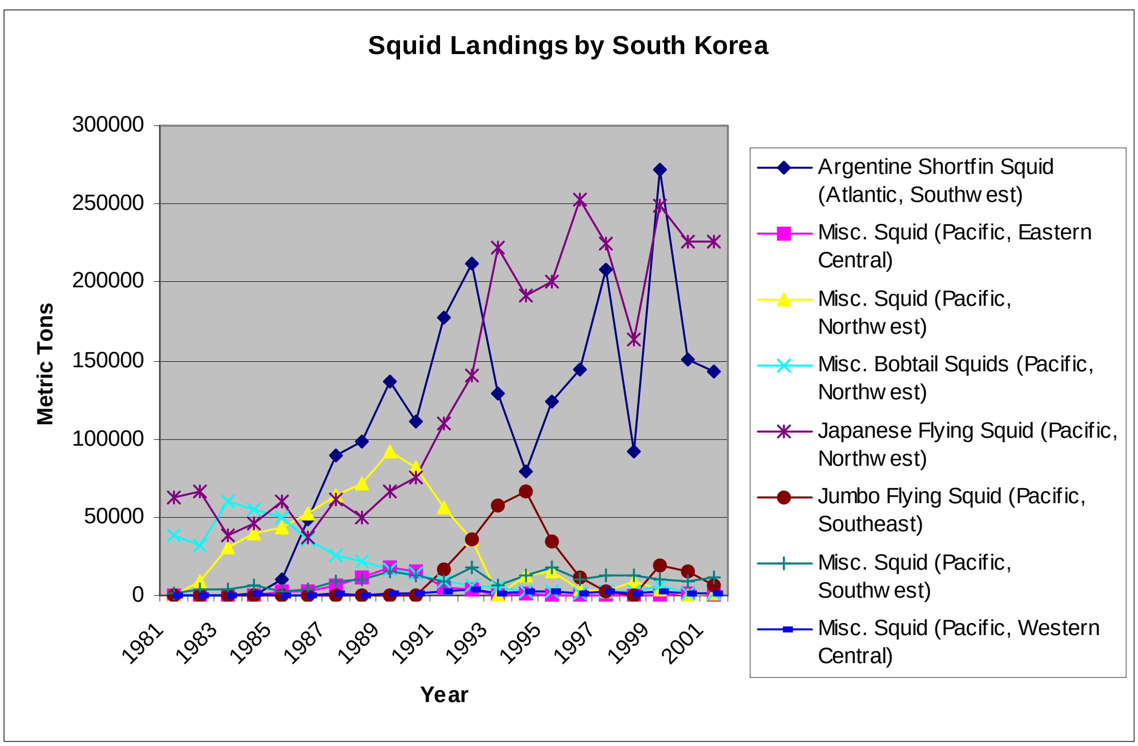

Figure 7. In South Korean squid fisheries, high concentrations of fishing occur in both the Southwest Atlantic and the Northwest Pacific. South Korea is the fourth largest supplier of squid to the U.S. seafood market (FAO 2003).

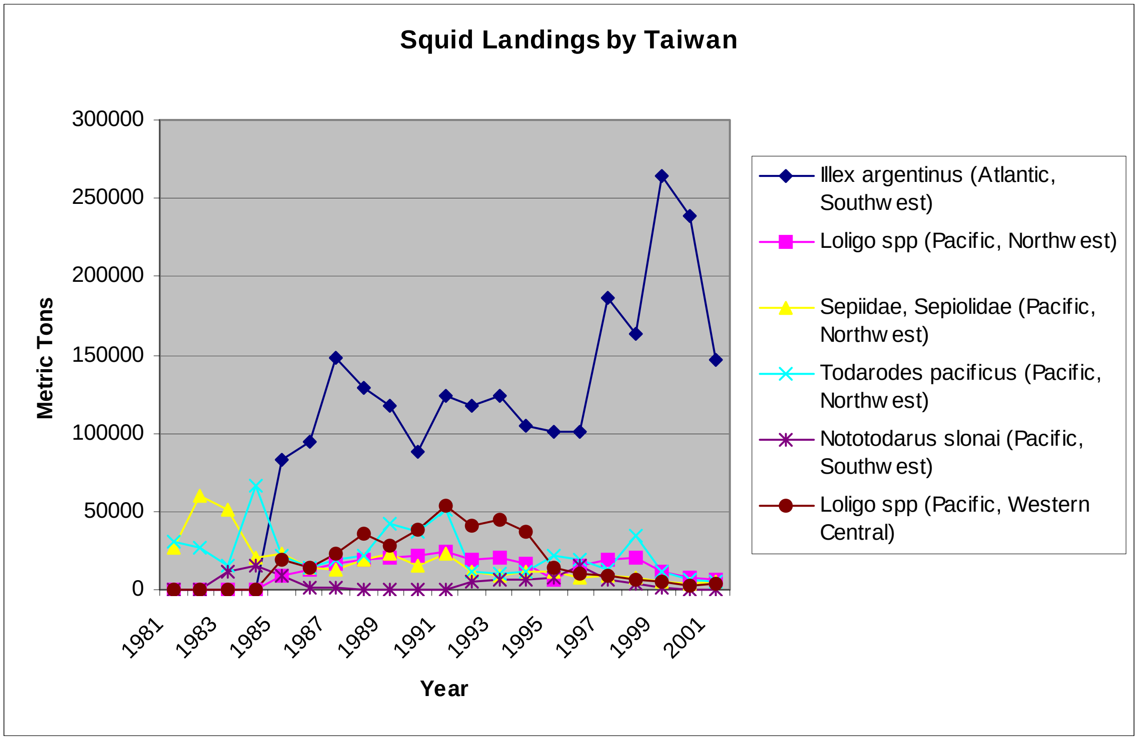

Figure 8. The highest concentration of Taiwanese squid fishing occurs in the Southwest Atlantic. Taiwan is the second largest supplier of squid to the U.S. seafood market (FAO 2003).

Synthesis
Despite some data on stock structure and migrational patterns for many exploited squid species, knowledge of species-specific international landings, stock biomass, and short-term and long-term trends are mostly unreported, unknown or contradictory.

Status of Wild Stocks Rank:

Healthy | **Moderate/Unknown** | Poor | Critical

Criterion 3: Nature and Extent of Bycatch

Historically, drift gillnets were used extensively to catch squid on the high seas. Due to high amounts of bycatch, however, a global moratorium was enacted in 1993 banning the use of gill nets in capturing squid in international waters (Mouat et al. 2001). Today, drift gillnets are still used within the EEZ of some countries, but most international squid fisheries use either jigs or midwater or surface trawls to catch squid (FAO 2003). Since squid fishing gear is most commonly set on tight schools of squid near the surface down to midwater, there is thought to be little bycatch in these fisheries (Chotiyaputta et al. 2002). This supposition, however, has yet to be confirmed.

Much international squid fishing is done with jigs. Fishermen use lures on a vertical line, which is moved up and down, or jigged by hand-operated spools or automatic machines.

Mid and surface water trawlers drag cone shaped nets behind a boat and target various small pelagic fish. Squid trawlers have been implicated in the death of sea lions (RFBPSNZ 2003), but the magnitude of this bycatch is unknown.

Synthesis
Little is known about the nature and extent of bycatch in international squid fisheries. Since the driftnet moratorium, enacted in 1993, most international fisheries have utilized jigs or midwater trawls in the capture of squid, as these gears result in less bycatch than drift gillnets. Though this decrease in bycatch has yet to be confirmed or quantified, the methods used with these gears, namely the targeting of dense schools of squid, has thus far shown to result in a low amount of bycatch.

Nature of Bycatch Rank:

Low	Moderate	High	Critical

Criterion 4: Effect of Fishing Practices on Habitats and Ecosystems

Many of today's squid fisheries target seasonal spawning aggregations and most use jigs, seines, or mid-water trawls to catch squid. Impacts of this gear can range from the removal and disturbance of spawning and mating individuals to the physical damage of eggs by anchors (Moltscaniwskyj et al. 2002). Also, there is evidence that squid jigs selectively remove animals from spawning beds, potentially modifying the process of sexual selection and mating systems of the spawning populations (Moltscaniwskyj et al. 2002).

Cephalopods, especially squids, are generally considered to be voracious, opportunistic predators and play an important role in marine food webs, both as predators of fish (Murphy et al. 1994) and prey to predators higher on the food web (Tricas 1979; Lowry et al. 1990; Croll et al. 2000; Lutz and Pendleton 2000; Overholtz et al. 2000; Marinovic et al. 2001; Mouat et al. 2001; Nesis 2002; Zeidberg and Hammer 2002; CDFG 2003). Fish, seabirds and marine mammals all consume squid, and squid have been shown to be important in the diets of sea otters, elephant seals, northern fur seals, California sea lions (Lowry and Carretta 1999), Dall's porpoises, Pacific striped dolphins, Risso's dolphins, and toothed whales such as short-finned pilot whales, sperm whales, and bottlenose whales (Hacker 1992). In addition, according to the California Department of Fish and Game (CDF&G), seabirds such as common murres, ashy storm-petrels, black storm-petrels, fork-tailed storm petrels, and rhinoceros auklets feed on squid (CDFG 2003). Squid is also the primary prey in the diet of harbor porpoises in Monterey Bay (Lowry and Carretta 1999). In a study done in Monterey Bay, California, nineteen species of fish were found to feed on market squid, including many commercially important species such as Pacific bonito, salmon, halibut, and tuna (CDFG 2003). No cumulative estimate of consumption by these large predators is available, but it has been estimated that sperm whales alone could feed on an annual squid biomass of 213-320 x 10^6 tons from open ocean areas (Boyle 2002).

Synthesis
As squid are pelagic, the fishing methods used in their capture have little impact to marine habitat. Minimal information is available, however, on the effects of the international squid fishery on marine ecosystems. Since squid play a major role in marine ecosystems and are taken in large quantities, it can be assumed that their removal has some negative effects.

Effect of Fishing Practices Rank:

Benign | **Moderate** | Severe | Critical

Criterion 5: Effectiveness of the Management Regime

Northwest & Western Central Pacific
Little information exists regarding management of *O. bartramii* and *T. pacificus* fisheries throughout the Pacific. Squid fisheries around Japan and Korea have in place some limits on fishing effort (Sakurai et al. 2002), but these limits are not based on squid biomass or scientific understanding of the stock. Furthermore, there is no management of *O. bartramii* or *T. pacificus* caught in international waters.

Southwest Atlantic
According to the Falkland Islands Government Fisheries Department, serious conservation problems are experienced with *I. argentinus* as a result of its migratory nature (FIFD 2002). *I. argentinus* spend a period of their life cycle on the high seas where they continue to be subjected to largely uncontrolled fishing effort (FIFD 2002). As a consequence, the FICZ of 150 nautical mile (nm) radius has been reinforced by the introduction of the Falkland Outer Conservation Zone (FOCZ) of 200 nm from coastlines, providing a greater area of protection. Additionally, the Falkland Islands government has used a policy of "voluntary restraint" to try and reduce foreign fishing on the high seas (FIFD 2002).

Management of the *I. argentinus* fishery in the FICZ and FOCZ is currently based largely on in-season assessments using methods based on the Leslie-DeLury depletion analysis (Arkhipkin and Middleton 2002). According to Arkhipkin and Middleton (2002), this method is generally reliable only after the peak of catches and even then, not in all years.

Catch and effort data have been gathered on a daily basis since the beginning of the licensed fishery in the FICZ in 1987 (FIGFD 2003). The catch of squid has varied from year to year, ranging from 64,000 to 266,000 over the period 1990-1999 (FIGFD 2003). These variations in catch are attributable to variations in abundance, the reasons for which are largely unknown (Arkhipkin and Middleton 2002).

All licensed vessels in the FICZ/FOCZ submit daily catch reports identifying midday and midnight position. Jigging vessels that operate at night currently take the majority of the *I. argentinus* catch. Asian jigging vessels landed the majority of the annual catch (94%) in 1999.

Synthesis
Squid stock assessment and fishery management have proven to be difficult tasks because of the high variation in squid abundance from year to year, a complicated population structure, a short life cycle, and unregulated fishing in international waters (Arkhipkin and Middleton 2002). The *I. argentinus* fishery demonstrates the result of failed management of squid. Though squid fishing in the FICZ and the FOCZ is well regulated, the fishery outside this zone, which is fishing on the same stocks, is completely unregulated. Similar situations can be found in squid fisheries in the Pacific. Management is ranked "ineffective" due to this lack of regulation in international squid fisheries.

Effectiveness of Management Rank:

Highly Effective   Moderately Effective   **Ineffective**   Critical

IV. Overall Evaluation and Seafood Recommendation

More than 2 million metric tons (mt) of squid are landed annually throughout the world. Although almost a hundred species of squid are fished commercially, two species, the Japanese flying squid and the Argentine shortfin squid, account for over half the world's squid harvest. In 2003, 49,654 mt of squid were imported into the U.S. from 30 different countries. Five countries ─ China, Taiwan, India, South Korea, and Thailand ─ accounted for 78% of domestic squid imports. With the exception of India, which lands squid solely from the Indian Ocean, these counties simultaneously operate squid fisheries in different regions and ocean basins throughout the world. Despite the availability of some information on regional fishery operations, there is little quantifiable data on regional landings of squid by species. Most countries only report squid catch to the Food and Agriculture Organization of the United Nations (FAO) by region and major taxonomic group, not by species name. This seafood report focuses on the two main regions that produce the majority of squid imported into the U.S.: the Northwest/Western Central Pacific and the Southwest Atlantic. In general, most of the squid landed in these regions are caught in international waters using jigs or trawls. Because squid have short life cycles (6-18 months), little overlap of generations, highly erratic recruitment and show wide fluctuations of abundance, the status of stocks in these regions is currently unknown and extremely unpredictable. The combination of life history characteristics, little or no management, and unreliable fishery data, raises concern regarding possible overfishing of squid stocks.

Table of Sustainability Ranks

	Conservation Concern			
Sustainability Criteria	**Low**	**Moderate**	**High**	**Critical**
Inherent Vulnerability	√			
Status of Stocks		√		
Nature of Bycatch	√			
Habitat & Ecosystem Effects		√		
Management Effectiveness			√	

Overall Seafood Recommendation:

Best Choice ☐ **Good Alternative** ☐ Avoid ☐

V. References

Arkhipkin, A. I. (1999). "Intrapopulation structure of winter-spawned Argentine shortfin squid, *Illex argentinus*, during its feeding period over the Patagonian Shelf." Fisheries Bulletin **98**: 1-13.

Arkhipkin, A. I. and D. A. J. Middleton (2002). "Inverse patterns in abundance *of Illex argentinus* and *Loligo gahi* in Falkland waters: possible interspecific competition between squid?" Fisheries Research **59**: 181-196.

Bakun, J. R. and J. Csirke (1998). Environmental processes and recruitment variability. Squid Recruitment dynamics: the genus Illex as a model, the commercial Illex species and the influences on variability. R. K. O'Dor, FAO Fish Technical Papers. **376:** 105-124.

Basson, M., et al. (1996). "Assessment and management techniques for migratory annual squid stocks: the *Illex aregentinus* fishery in the Southwest Atlantic as an example." Fisheries Research **28**: 3-27.

Bower, J. R. et al. (1999). "Distribution of *Todarodes pacificus* paralarvae near the Kuroshio off southern Kyushu, Japan." Marine Biology **135**: 99-106.

Boyle, P. (2002). "Cephalopod Biomass and Production: An Introduction to the Symposium." Bulletin of Marine Science **71**(1): 13-16.

Butler, J. (2001). Coastal Pelagic Species Annual Report - Market Squid, National Marine Fisheries Service.

Caddy, J. F. and P. G. Rodhouse (1998). Cephalopod and groundfish landings: evidence for ecological change in global fisheries? Reviews in Fish Biology and Fisheries, Chapman & Hall.

CDFGa (2001a). California's Living Marine Resources: A Status Report: California Market Squid, California Department of Fish and Game.

CDFGb (2001b). Press Release: Squid management options to be discussed at upcoming meeting, California Department of Fish and Game.

CDFG (2003). Draft Market Squid Fishery Management Plan, California Department of Fish and Game.

Chen, C.-S. and T.-S. Chiu (1999). "Abundance and Spatial Variation of *Ommastrephes bartramii* in the Eastern North Pacific Observed from an Exploratory Survey." Acta Zoologica Taiwanica **10**(2): 135-144.

Chotiyaputta, C., P. et al. (2002). "Review of Cephalopod Fishery Production and Long Term Changes in Fish Communities in the Gulf of Thailand." Bulletin of Marine Science **71**(1): 223-238.

Croll, D. et al. (2000). Climate Change and Trophic Links in Coastal Upwelling Centers, University of California, Santa Cruz.

FIFD (2002). Fishery Statistics; Volume 7; (1993-2002), Falkland Islands Government Fisheries Department.

FIGFD (2003). Fisheries Department Fisheries Statistics, Volume 4, Falkland Islands Government Fisheries Department.

FOA (2003). Fishstat Database, United Nations.

Hacker, S. E. (1992). "Stomach contents of four short-finned pilot whales (*Globicephala macrorhynchus*) from Southern California Bight." Marine Mammal Science **8**(1): 76-81.

Haimovici, M. et al. (1998). "*Illex argentinus*." Squid Recruitment dynamics: the genus Illex as a model, the commercial Illex species and influences on variability **376**: 27-58.

Hill, S. and D. J. Agnew (2002). "Optimal Harvest Strategies for Single-Cohort Squid Populations." Bulletin of Marine Science **71**(1): 371-381.

Jackson, G. D. (1990). "Age and Growth of the Tropical Nearshore Squid Determined from Statolith Growth-Ring Analysis." Fishery Bulletin **88**(1): 113-118.

Jackson, G. D. (1994). "Statolith Age Estimates of the Loliginid Squid *Loligo opalescens*: Corroboration with Culture Data." Bulletin of Marine Science **54**(2): 554-557.

Katugin, O. N. (2002). "Patterns of Genetic Variability and Population Structure in the North Pacific Squids *Ommastrephes Bartrami*, *Todarodes Pacificus*, and *Berryteuthis Magister*." Bulletin of Marine Science **71**(1): 383-420.

Laptikhovsky, V.V. et al. (2001). "Recruitment strength forecasting of the shortfin squid *Illex argentinus* using satellite SST data, and some consideration of the species population structure." ICES Journal of Marine Science **15**(1).

Lowry, M. S. and J. V. Carretta (1999). "Market Squid (*loligo opalescens*) in the diet of California sea lions (*Salophus californianus*) in southern California (1981-1995)." CalCOFI Report **40**: 196-202.

Lowry, M. S. et al. (1990). "Food Habits of California Sea Lions *Zalophus californianus* at Sa Clemente Island, California, 1981-86." Fishery Bulletin **88**: 509-521.

Lutz, S. and L. Pendleton (2000). An Assessment of the Market Squid and Other major Commercial wetfish Fisheries of Southern California, USC - Southern California Fisheries Project; Wrigley Institute for Environmental Studies**:** 32.

Marinovic, B. et al. (2001). Assessing the impacts of climate change on the California squid fishery: An integrated ecosystem approach, University of California, Santa Cruz, Institute of Marine Sciences.

Moltscaniwskyj, N. et al. (2002). "An Assessment of the Use of Short-term Closures to Protect Spawning Southern Calamary Aggregations from Fishing Pressure in Tasmania, Australia." Bulletin of Marine Science **70**(1): 501-514.

Mouat, B. et al. (2001). "Patterns in the diet of *Illex argentinus* from the Falkland Islands jigging fishery." Fisheries Research **52**: 41-49.

Murphy, E. J. et al. (1994). "Modeling the selective effects of fishing on reproductive potential and population structure of squid." ICES Journal of Marine Science **51**: 299-313.

Nesis, K. N. (2002). "Lifestyle Strategies of Recent Cephalopods: A Review." Bulletin of Marine Science **71**(2): 561-579.

NMFS (2003). Foreign Trade Summary, Fisheries Statistics & Economics Division.

O'Dor, R. K. et al. (2002). "Currents as Environmental Constraints on the Behavior, Energetics and Distribution of Squid and Cuttlefish." Bulletin of Marine Science **71**(2): 601-616.

O'Dor, R. K. and M. R. Lipinski (1998). "The genus *Illex* (Cephalopoda; Ommastrephidae): Characteristics, distribution and fisheries." FAO Technical Paper **376**: 1-12.

O'Dor, R. K. and D. M. Webber (1986). "The Constraints on cephalopods: why squid aren't fish." Canadian Journal of Zoology **64**: 1591-1605.

Overholtz, W. J. et al. (2000). "Consumption of important pelagic fish and squid by predatory fish in the northeastern USA shelf ecosystem with some fishery comparisons." ICES Journal of Marine Science **57**: 1147-1159.

Pauly, D. (1985). "Population dynamics of short-lived species, with emphasis on squids." North Atlantic Fisheries Organization Continued Studies **9**: 143-154.

RFBPSNZ (2003). The Problem for the New Zealand (Hookers) Sea Lion. http://www.forest-bird.org.nz/Marine/sealions.asp, Royal Forest and Bird Protection Society of New Zealand.

Sakurai, Y. et al. (2002). Stock fluctuations of the squid, Todarodes pacificus related to recent climate change. International Commemorative Symposium, 70th Anniversary of the Japanese Society of Fisheries Science.

SB 209, (2001). California State Senate Bill: SB 209, Sher. Commercial fishing; market squid. SB.

Seki, M. P. (2000). North Pacific Ecosystem Report: Transition Zone. Honolulu, National Marine Fisheries Service.

Suauer, W. H. H. et al. (2002). "Squid and Anchovy: Similar Subjects, Different Schools." Bulletin of Marine Science **71**(2): 771-782.

Tricas, T. C. (1979). "Relationships of the Blue Shark, *Prionace glauca*, and its Prey Species Near Santa Catalina, California." Fishery Bulletin **77**(1): 175182.

Zeidberg, L. D. and W. M. Hammer (2002). "Distribution of squid paralarvae, *Loligo opalescens* (Cephalopoda: Myopsida), in the Southern California Bight in the three years following the 1997-1998 El Nino." Marine Biology **141**: 111-122.