CORRECTION: The original publication of this report, released in January 2011, had some incorrect values in the silver hake, *Loligo* squid, and red hake chapters. On February 23, 2011 the report was corrected. The changes did not affect any conclusions about stock status that were given in the original report. For silver hake, the overfishing threshold for the southern area was changed from 52.30 kt/kg to 34.19 kt/kg. The wrong set of years was used in the calculation (1965 – 1974 instead of 1973 – 1982). For Loligo squid, the median biomass over the time series was changed from 25,578 mt to 27,578 mt, and the terminal year for that calculation was changed from 2009 to 2008. For red hake, the nominal discards in the southern area were corrected, which also required the catch and relative exploitation rate to be corrected in a table and figure.

B. *LOLIGO* ASSESSMENT SUMMARY FOR 2010

State of Stock

Based on the current reference point, overfishing was not occurring in the longfin inshore squid (*Loligo pealeii)* stock in 2009 because the exploitation index (estimated with the methods of SARC-34) was 0.063, compared to $F_{THRESHOLD}$ (75th percentile of exploitation indices during 1987-2009) which is 0.277. Currently, there is no biomass reference point for longfin inshore squid, and as a result, overfished status cannot be determined. The 2010 assessment concluded that the current *F* reference point is inappropriate for this lightly exploited stock.

Based on a new proposed biomass reference point from the 2010 assessment, the longfin inshore squid stock was not overfished in 2009, but overfishing status cannot be determined because no overfishing threshold was recommended. The biomass estimate, which is based on the two-year average of catchability-adjusted spring and fall survey biomass during 2008-2009, was 54,442 mt (80% CI = 38,452-71,783 mt). This is greater than the proposed $B_{THRESHOLD}$ of 21,203 mt (Figure B1). The stock exhibits very large fluctuations in abundance (from variation in reproductive success and recruitment) which is expressed as large inter-annual changes (2-3 fold) in survey biomass.

A new threshold reference point for fishing mortality was not recommended in the 2010 assessment because there was no clear statistical relationship between *Loligo* catch and annual biomass estimates during 1975-2009. Furthermore, annual catches were low relative to annual estimates of minimum consumption by a subset of fish predators. The stock appears to be lightly exploited. The 2009 exploitation index of 0.176 (catch in 2009 divided by the average of the spring and fall survey biomass during 2008-2009; 80% CI = 0.124-0.232) was slightly below the 1987-2008 median of 0.237 (Figure B2).

Forecasts

Forecasts of stock size were not possible because there is no accepted 2010 assessment model, and like most squid stocks, the short, sub-annual lifespan and semelparous life history (squid die after spawning) of this species result in rapid changes in stock size in response to environmental conditions (Hendrickson and Showell 2010; Dawe *et al.* 2007; Boyle and Rodhouse 2005).

Stock Distribution and Identification

Longfin inshore squid are distributed primarily in continental shelf waters located between Newfoundland and the Gulf of Venezuela (Cohen 1976; Dawe *et al*. 1990). In the northwest Atlantic Ocean, longfin squid are most abundant in the waters between Georges Bank and Cape Hatteras, North Carolina. Relative abundance in the Gulf of Maine is low in the fall, and annual occurrences there are infrequent during spring. However, abundance south of Cape Hatteras is unknown because the species' range overlaps with the congener, *L. pleii*, throughout the year and the two species cannot be distinguished using gross morphology (Cohen 1976). Catches of *L. pealeii* in NEFSC spring and fall surveys decline with depth and catches in seasonal depth transect surveys are also low in deeper waters (> 366 m); but the data for deeper waters were limited. The geographic distribution of the species is dependent on seasonal migrations which are influenced by the environment (Dawe *et al*. 2007). Migrations are offshore and south during late fall through winter (generally October-March) and inshore and north during spring through fall (generally April-September). Three genetics studies indicate that the population between Cape Cod Bay, MA and Cape Hatteras, NC is a single stock (Garthwaite *et al.*1989; Herke & Foltz, 2002; Shaw *et al*. 2010), but Buresch *et. al.* (2006) concluded that there are multiple stocks.

Catch and Status Table: *Loligo* (wts in 000s mt)

Year	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009[4]	Min.[5]	Max[5]	Mean[5]
Landings	17.5	14.3	16.9	11.9	15.7	16.7	15.9	12.3	11.4	9.3	9.3	23.7	16.6
Discards	0.1	0.1	0.4	0.2	0.3	0.7	1.1	0.1	0.1	0.3	0.1	2.1	0.6
Catch	17.7	14.4	17.2	12.1	16.0	17.4	17.1	12.5	11.5	9.6	9.6	24.6	17.2
Jan-June	10.0	6.5	8.6	5.9	9.3	12.3	9.8	7.7	5.8	4.6	4.5	16.2	9.1
July-Dec	7.6	7.8	8.5	6.2	5.8	5.4	7.2	4.7	5.7	4.9	2.4	15.8	7.3
Quota[1]	15.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	19.0	15.0	44.0	28.1
Annual Biomass[2]	175.9	59.7	154.3	80.6	51.1	63.9	141.9	74.9	69.1	39.8	25.8	175.9	80.6
Sept-Oct Biomass	330.1	92.5	253.9	151.7	93.3	107.9	249.4	109.6	122.7	68.8	30.3	330.1	143.3
Mar-Apr Biomass	21.6	26.9	54.6	9.4	9.0	19.8	34.4	40.3	15.5	10.8	8.1	81.7	29.1
Annual Exploitation Indices[3]	0.10	0.24	0.11	0.15	0.31	0.27	0.12	0.17	0.17	0.13	0.10	0.66	0.27
Jan-June Exploitation Indices	0.46	0.24	0.16	0.63	1.04	0.62	0.29	0.19	0.38	0.43	0.16	1.26	0.48
July-Dec Exploitation Indices	0.02	0.08	0.03	0.04	0.06	0.05	0.03	0.04	0.05	0.07	0.02	0.16	0.07

[1] Annual quotas were allocated by trimester, during 2000 and 2007-2009, and by quarter during 2001-2006.
[2] Annual biomass is the annual mean of the q-adjusted biomass estimates from the NEFSC spring and fall surveys. The biomass estimates depend directly on the value for "q". Other values of "q" would provide different absolute values but the same trends.
[3] Annual exploitation indices are the annual catch divided by the annual biomass.
[4] The 2009 annual biomass and annual exploitation indices in the table were not used for stock status determination. Overfished stock status was based on the mean of the 2008-2009 annual biomass estimate and overfishing status would be based on the 2009 catch divided by the 2008-2009 annual biomass estimate.
[5] Min., max. and mean values are for the time period of the domestic fishery, 1987-2009, with the exception of the biomass estimates which include 1976-2009.

Landings

The U.S. squid fishery began in the late 1800s as a source of bait, and from 1928 to 1967, annual squid landings (including Northern shortfin squid, *Illex illecebrosus* landings) from Maine to North Carolina ranged from 500 to 2,000 mt (Lange and Sissenwine 1980). During 1967-1984, total landings of *Loligo* were predominately from an offshore, foreign fishery and averaged 20,130 mt, with a peak of 37,613 mt in 1973 (Figure B3). A small, seasonal domestic fishery operated inshore prior to 1987 and a domestic offshore fishery developed thereafter when the foreign fishery was eliminated. There is substantial uncertainty in the landings data prior to 1987 (Cadrin and Hatfield 1999). The onset and duration of the fisheries reflect the timing of squid migrations; generally offshore during October-March and inshore during April-September. Landings are highest in the offshore winter fishery and lowest in the inshore summer fishery. During 1987-2009, landings averaged 16,610 mt with a peak of 23,738 mt in 1989. Landings have been lower since in-season quotas were implemented in 2000, averaging 14,214 mt during 2000-2009. Landings declined between 2005 and 2009, from 16,720 mt to 9,307 mt.

Catches

Discards represented a small percentage of the annual catches during 1989-2009, averaging 3.4% of the landings, but were variable (0.4-11.2% of the landings during the same period). Discard estimates were imprecise (CVs ranged between 0.02 and 1.14 and averaged 0.53 during 1989-2009). Most of the discards occurred in the small-mesh (codend mesh size ≤ 64 mm) bottom trawl fisheries conducted in the Mid-Atlantic region (i.e., Statistical Areas > 600). Due to a lack of quantitative discard data prior to 1989, discards were assumed to be 3.4% of the landings during 1963-1988.

Total catches during the period of dominance by the foreign fleets (1967-1984) averaged 20,814 mt with a peak of 38,892 mt in 1973 (Figure B3). During the period of dominance by the domestic fishery, (1987-2009), catches averaged 17,181 mt with a peak of 24,566 mt in 1994. During 1988-1995, catches were generally at or above the 1987-2008 median (17,328 mt), but have generally been below the median since 2000, when in-season quotas were implemented and fishery closures occurred at least once per year. Catches declined after 2005 and reached their minimum since 1968 in 2009 (9,560 mt). During 1987-2009, catches in the January-June fishery were 1.4 times higher than the July-December catches on average.

Data and Assessment

A method used during the previous assessment (NEFSC 2002) was refined to assess the stock based on catchability-adjusted swept-area biomass, computed from NEFSC spring (March-April) and fall (September-October) bottom trawl surveys, and seasonal and annual exploitation indices. Catches were updated with new discard estimates for 1989-2009 and assumed discards of 3.4% (1989-2009 average discards) prior to 1989. In order to annualize the biomass estimates for the seasonal cohorts tracked by these surveys, annual averages of the fall and spring bottom biomass estimates were computed for 1976-2009.

Only daytime catches were used to compute the biomass estimates because the capture efficiency of bottom trawls is highest for *Loligo* during the day (Sissenwine and Bowman 1976; Brodziak and Hendrickson 1999). Daytime was defined based on the solar zenith (43-80º during fall surveys and 29-84º during spring surveys). Catchability (q) was determined using the median of composite "q-priors" computed using upper and lower bounds on effective tow distance, width of the area swept by the gear, capture efficiency and a defined stock area.

The spring and fall biomass estimates represent mean biomass estimates of seasonal cohorts that are available to the January-June and July-December fisheries, respectively. Exploitation indices for the two fisheries were computed for 1987-2009 as January-June catch/March-April biomass and July-December catch/September-October biomass. Annual exploitation indices were also computed as the annual catch divided by the annual average of NEFSC spring and fall survey biomass estimates. Because of the rapid growth rates and overlapping cohorts, exploitation indices were calculated using all sizes of squid rather than just the recruited sizes (> 8 cm dorsal mantle length).

The NEFSC bottom trawl survey switched from the FRV *Albatross IV* to the FSV *Bigelow* in spring 2009. Survey data given here are in "*Albatross IV"* units.

Estimates of minimum consumption of *Loligo* by a subset of finfish predators (15 species) were computed seasonally and annually using data from NEFSC spring and fall surveys conducted during 1977-2009.

Estimates of spawning and non-spawning mortality were computed following Hendrickson and Hart (2006) and Caddy (1996).

Biological Reference Points

There are no existing biomass reference points for *L. pealeii* (NEFSC 2002; MAFMC 2009). The median of the annual averages of the spring and fall survey biomass during 1976-2008 is 76,329 mt. The stock appears to be lightly exploited, so assuming that the 1976-2008 median biomass estimate represents 90% of the stock's carrying capacity (K, see Special Comments), a new B_{MSY} target of 50% of K ($0.50*(76,329/0.90) = 42,405$ mt) is recommended. An appropriate biomass threshold is 50% of B_{MSY} (= 21,203 mt).

The current F_{MSY} proxy (0.31 per quarter or 1.24 per year) was calculated in the last assessment as the 75th percentile of quarterly exploitation indices during 1987-2000. The current fishing mortality reference point approach is not appropriate for the lightly exploited *Loligo* stock. New fishing mortality reference points are not recommended in this assessment due to the lack of evidence for the impacts of fishing on subsequent annual biomass estimates during 1975-2009. In addition, annual catches were low relative to annual estimates of minimum consumption by a subset of fish predators. The perception is that the stock is lightly exploited.

Exploitation indices

Annual exploitation indices were generally higher during 1987-1998 than during 1999-2009. Exploitation indices were higher during January–June than during July-December (Figure B4). The values of the exploitation indices depend directly on the value of "q". Other values of "q" would provide different absolute values but the same trends. The 2009 exploitation index (catch in 2009 divided by the average of the spring and fall survey biomass during 2008-2009 = 0.176, 80% CI = 0.124-0.232) is shown in Figure B2.

Recruitment

Given the complex life history characteristics of the species (see Forecasts and Special Comments sections) and lack of a suitable assessment model, recruitment could not be estimated.

Biomass

Squid species exhibit large inter-annual fluctuations in biomass (Boyle and Rodhouse 2005). Annual biomass (i.e., annual average of spring and fall survey biomass estimates) ranged between 25,806 mt and 175,894 mt during 1976-2009 (Figure B5A). In 2009, annual biomass was slightly below the median. Estimates of annual biomass relative to the proposed B_{MSY} threshold are shown in Figure B6.

During 1976-2008, spring biomass (median = 27,578 mt) levels were only one fifth of the fall biomass levels (median = 124,730 mt), suggesting that the productivity of the spring survey cohort may be much lower than the fall survey cohort (Figure B5B and C).

Ecosystem considerations

Natural mortality of this semelparous, subannual species (multiple cohorts per year with life spans shorter than one year), which is consumed by a wide range of cetacean, pinniped, avian, invertebrate and finfish predators, is very high; especially for spawners. Estimates of non-spawning mortality, 0.11 per week and spawning mortality, 0.19-0.48 per week, are very high. Minimum estimates of *Loligo* consumption by finfish showed high inter-annual variability, but were 0.8 to 11 times the annual catches during 1977-2009 (Figure B7). During 1987-2008, minimum consumption was much higher during the fall (median = 34,089 mt) than during the spring (median = 14,643 mt, Figure B6).

ABC considerations

Differences in productivity among cohorts could be considered when setting the annual Acceptable Biological Catch (ABC). The summer-hatched cohort has a faster growth rate than the winter-hatched cohort (Brodziak and Macy 1996) and the cohorts caught in the spring and fall surveys appear to have very different productivity and biomass. Exploitation indices for the January-June fishery (median = 0.315) are much higher on the less productive, spring survey cohort compared with the July-December fishery (median = 0.064) on the more productive fall survey cohort. The perceived differences in productivity could be due to different catchabilities in the spring and autumn surveys, as well as due to other factors.

The ecological importance of *Loligo* as prey for a wide range of species could also be considered. Alternatively, knowledge about consumption by selected predators could be used as a basis to “allocate” squid production between humans and other predators (e.g., fish).

During 1987-2009, when there was no foreign fishery, catches ranged between 9,560 mt in 2009 and 24,544 mt in 1989 and minimum consumption estimates ranged between 15,762 mt and 125,400 mt. for minimum estimates of total removals between 25,322 mt and 149,944 mt. These removals do not appear to have impaired productivity and higher catches may be sustainable.

Special Comments

Recruitment occurs throughout the year with seasonal peaks in overlapping “microcohorts” which have rapid and different growth rates (Brodziak and Macy 1996; Macy and Brodziak 2001) As a result, seasonally stable biomass estimates may mask substantial population turnover rates (Guerra *et al*. 2010).

Annual biomass estimates exceed annual carrying annual carrying capacity in multiple years, which is to be expected for a species with highly variable seasonal population dynamics that are linked to variability in environmental conditions.

The duration of each seasonal cohort is about six months. Age data indicate that squid caught in the offshore, winter fishery (October-March) were hatched about six months prior, during the previous summer, and squid caught in the inshore, summer fishery (April-September) were also hatched, about six months prior, during the previous winter (Macy and Brodziak 2001). The NEFSC spring (March) and fall (September) surveys are conducted six months apart. Within a year, the relative abundance of the seasonal cohorts caught in these two surveys are correlated ($r = 0.53$). However, there is no correlation ($r < 0.10$) between relative abundance estimates in year t and year t+1, for either the spring or fall surveys, or between the fall surveys in year t and spring surveys in year t+1.

Loligo pealei attaches its egg masses to the substrate and fixed objects (MAFMC 2009). Fishing and spawning mortality occur concurrently during late spring through fall, when spawning *Loligo* and an unknown proportion of their egg masses are taken inshore, in weir and bottom trawl fisheries (Hatfield and Cadrin 2002). The locations of spawning sites at other times of the year are unknown.

The current approach to management with reference points, annual ABC, OFL, etc. is unlikely to be optimal for *Loligo* which live less than one year. It is likely to result in foregone yield in period of high productivity and may not protect the resource in periods of low productivity. For such a species adequate spawner escapement from each seasonal fishery is required to ensure sufficient recruitment in subsequent seasons, and in–season assessment and management is necessary to extract optimum yield.

Previous squid assessments (Pacific Fishery Management Council, 2002; NEFSC, 2003) have considered $F_{40\%}$ as a possible biological reference point. This approach has been used in other managed squid fisheries.

Survey biomass estimated in different years and in the spring and the autumn of the same year, largely correspond to different cohorts. Nonetheless, overfished status is determined using 2 year averages of annualized spring and autumn survey biomass estimates recognizing that a portion of the annual variability is due to factors other than changes in squid abundance, including estimation error. It is not clear if the spring and autumn biomass estimates should be averaged to obtain an annual estimate of if they should be summed.

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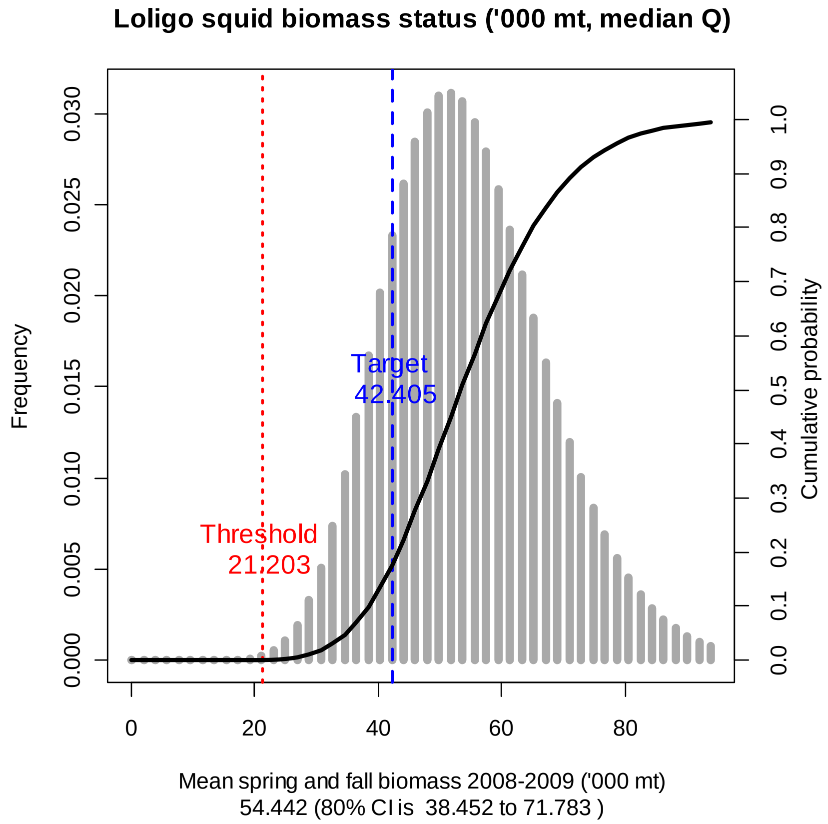
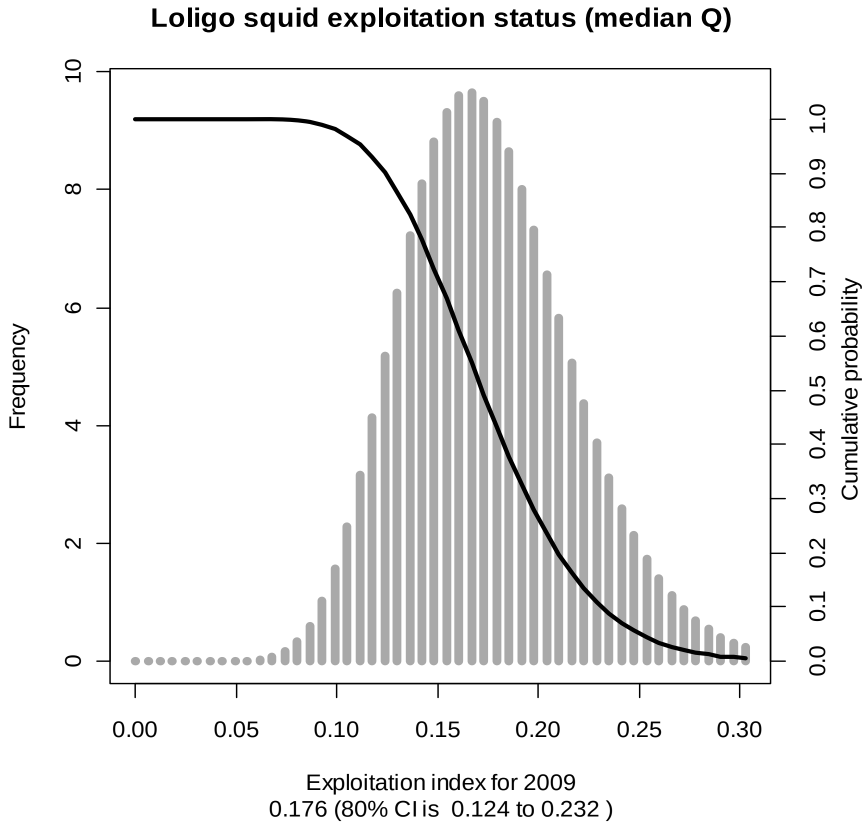
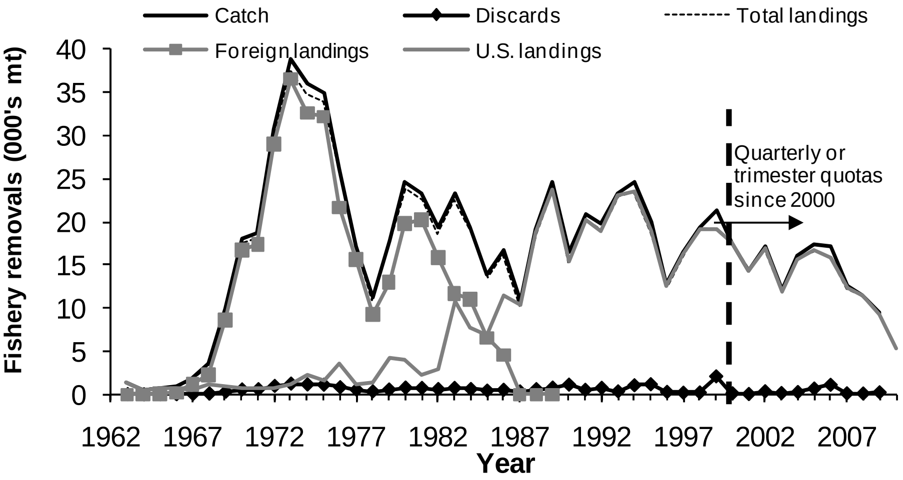


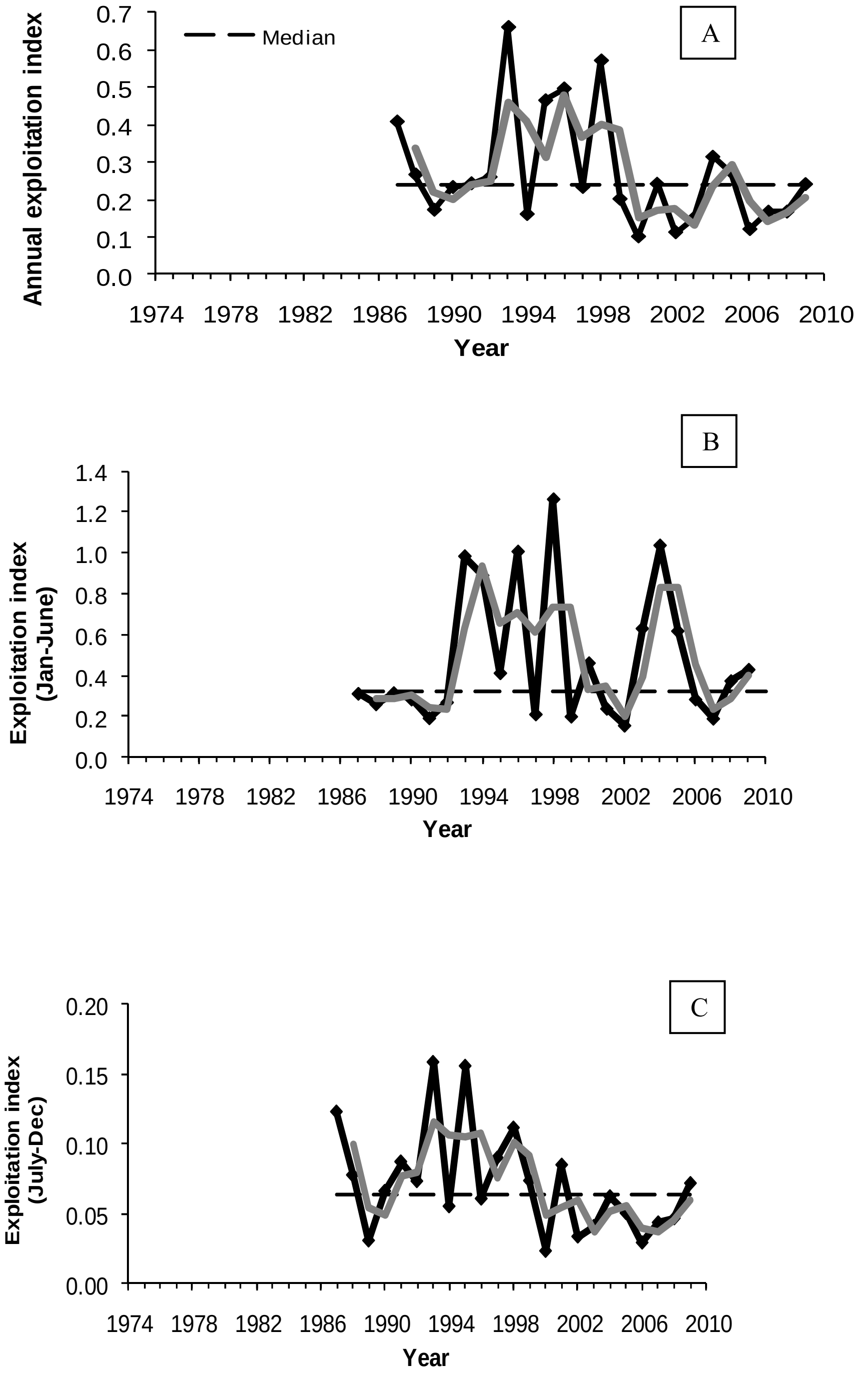
B1. *Loligo pealeii* biomass estimate (000s mt), spring and fall survey average for 2008-2009, shown as a probability distribution. Also shown are proposed biomass reference points.



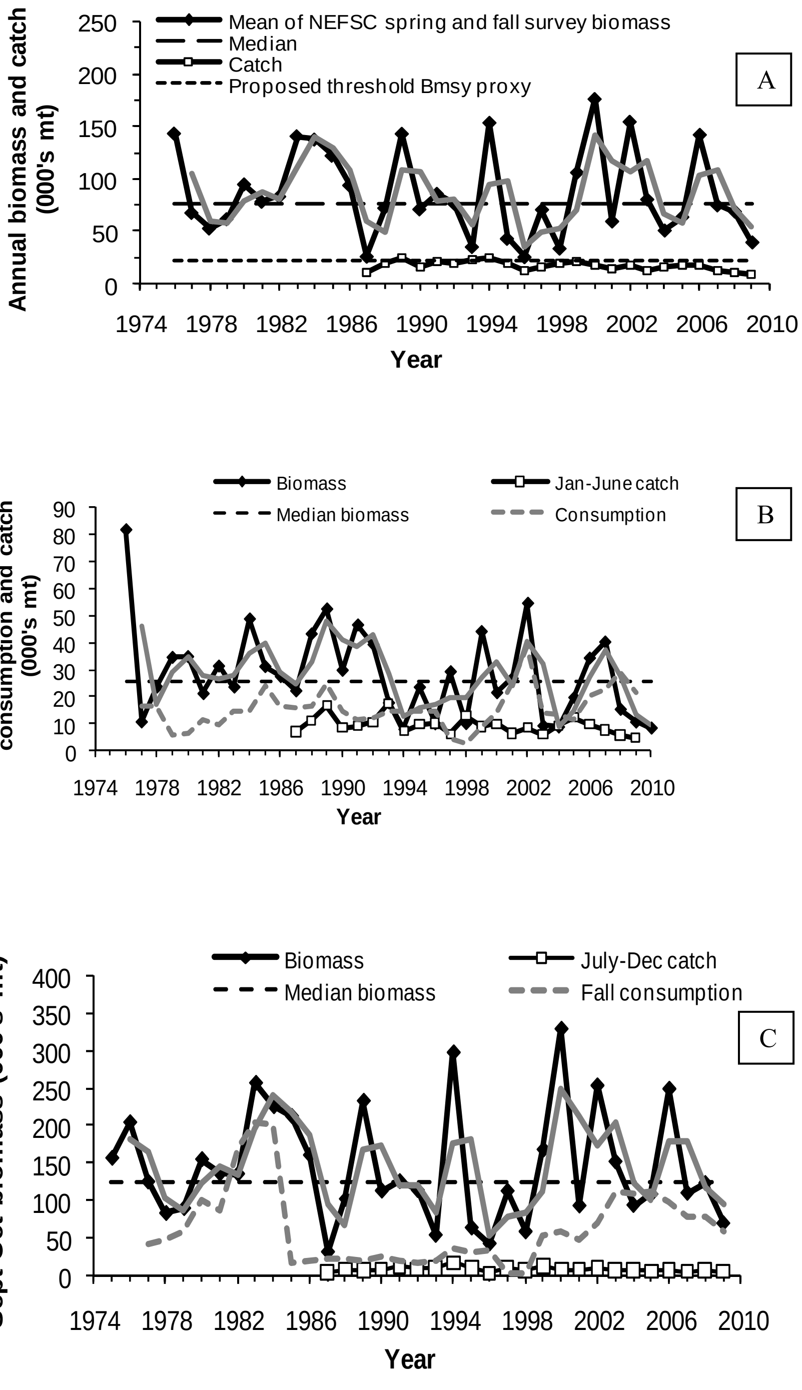
B2. *Loligo pealeii* exploitation index for 2009 shown as a probability distribution.



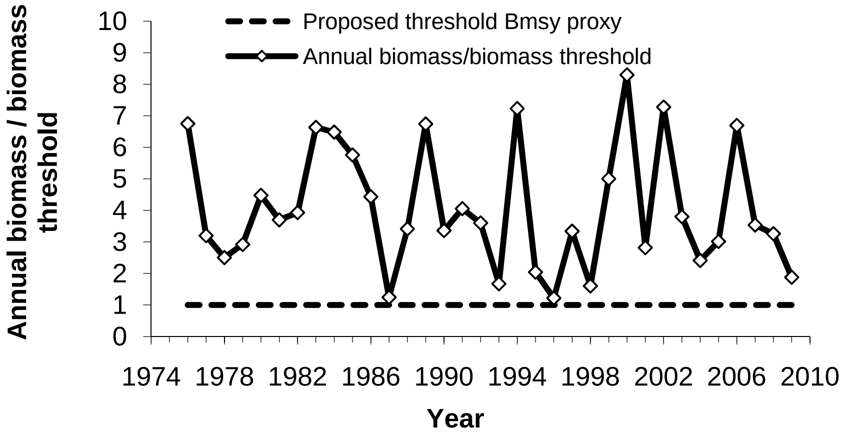
B3. Fishery removals of *Loligo pealeii*.



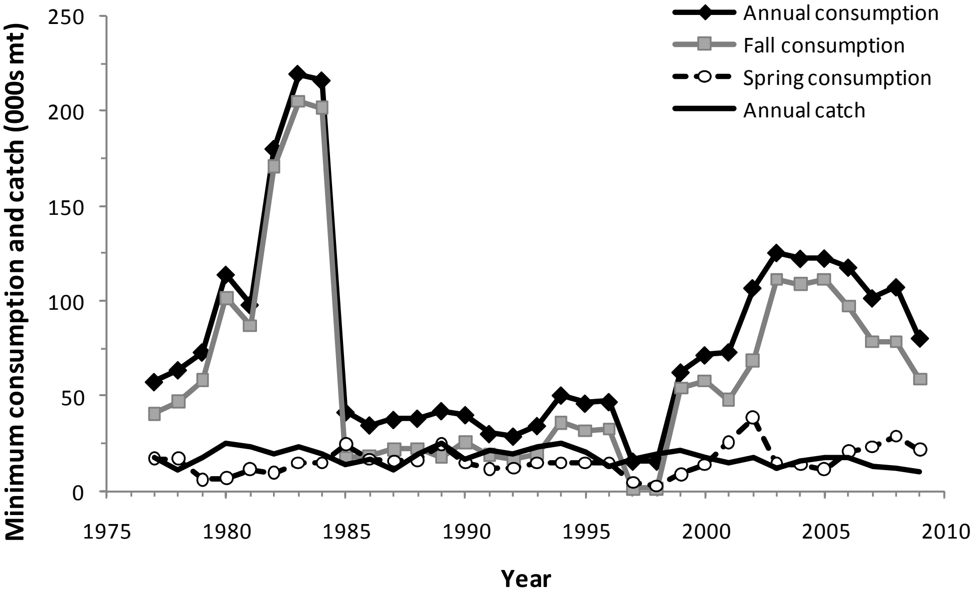
B4. Annual exploitation indices (annual catch / average of spring and fall biomass) of *Loligo pealeii* (A) and exploitation indices for the January-June fishery (January-June catch / March biomass) (B) and the July-December fishery (July-December catch / September biomass) (C). The grey lines represent the two-year moving averages which, in the top figure, indicates the 2009 value that would have been used for overfishing status determination if an $F_{THRESHOLD}$ had been defined.



B5. Annual estimates of *Loligo pealeii* biomass (annual averages of NEFSC spring and fall survey biomass) (A), March-April biomass and consumption in relation to January-June catch, (B), and September-October biomass and consumption in relation to July-December catch (C). The grey lines represent the two-year moving averages which, in the top figure, indicates the 2009 value used for stock status determination.



B6. Annual biomass (average of annual spring and fall biomass / B_{MSY} threshold) in relation to the proposed biomass threshold (shown here as a relative value).



B7. Annual, spring and fall minimum consumption estimates of *Loligo pealeii*, for a subset of 15 finfish predators, in relation to annual catches of *L. pealeii.*