

Theme Session on Cephalopod Stocks: Review, Analyses, Assessment, and Sustainable Management (CC)

ICES CM 2004/CC:01

Reproductive biology of *Octopus vulgaris* in an upwelling area (NE Atlantic)

J. Otero, A. F. González, A. Guerra, M. Regueira, and M.E. Garci

Monthly samplings of *Octopus vulgaris* were taken from the creel fishery in the Galician Rías (NE Atlantic) fishing ground to elucidate the reproductive cycle, the timing of spawning and the condition in 2003-04. A total of 340 individuals were studied. Sex ratio were neither annually nor seasonally significantly different from the 1:1 proportion. Specimens ranged from 10 to 31 cm DML and from 461.8 to 4972 g BW. The length-weight relationships found were $BW=0.924694 \cdot DML^{2.51256}$ ($n=173$; $r=0.924$), $BW=1.10295 \cdot DML^{2.45337}$ ($n=167$; $r=0.914$), $BW=1.02288 \cdot DML^{2.47871}$ ($n=340$; $r=0.918$), for females, males and the whole sampling, respectively. Maturity and reproductive indices showed that the spring was the most important spawning season, although mature females were present from December to August with a peak in May, and mature males appeared all year round. The dorsal mantle length and weight at first maturity were 20.2 cm and 1858.6 g for females. The absence of immature individuals did not permit to estimate size at first maturity for males. Potential fecundity ranged from 12,861 to 451,173 ($184,690 \pm 98,816$) oocytes. The number of fully developed spermatophores ranged from 12 to 374 (131 ± 77), with mean length ranging from 26.98 to 96.2 (47.2 ± 10.5) mm. Both number and mean length of spermatophores and oocytes were significantly correlated with the length and weight of the animals. Condition of females, based on the digestive gland, was higher in spring months and within mature specimens, although no significant differences were found among season and maturation.

Keywords: *Octopus vulgaris*, reproduction, spawning, condition, NE Atlantic.

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Stock assessment methods and management procedure of *Todarodes pacificus* in Japan

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In Japan, stocks of the Japanese common squid (*Todarodes pacificus*) have been managed since 1998 based on a total allowable catch (TAC) set by the government. The TAC is determined based on an allowable biological catch (ABC). The ABC aims to keep the stock biomass at the BMSY level, and is calculated from a biological reference point (BRP) and the forecasted stock biomass for the following year. Stock biomass is estimated using data obtained from research cruises conducted throughout the stock's distribution range at the beginning of the fishing season. The stock-recruitment relationship during the past 10 years is estimated from the spawning stock biomasses that are calculated from a mortality model and recruit abundances. The ABC is then calculated from the abundance of the following year and the BRP that are estimated from the stock-recruitment relationship. Stock assessment is now performed for two stocks: the 'autumn spawning stock' which is mainly caught in the Sea of Japan, and the 'winter spawning stock' which is mainly caught in the Pacific Ocean. Recent abundances of both stocks have been high.

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Progesterone and 17 β -estradiol involvement in the yolk protein synthesis in the ovary of *Octopus vulgaris*

Anna Di Cosmo, Marina Paolucci, and Carlo Di Cristo

Both 17 β -estradiol and progesterone have been detected in the reproductive system of the female of *Octopus vulgaris* and their levels fluctuate consistently with the hypothesis of their involvement in the reproductive cycle. Such hypothesis is also sustained by the presence of 17 β -estradiol and progesterone specific receptors in the reproductive system. In this frame, we have carried out a study demonstrating a direct involvement of the sex steroids 17 β -estradiol and progesterone in the yolk protein synthesis.

terone in the regulation of one of the most relevant reproductive functions in oviparous species characterized by telolecitic eggs, that is egg yolk protein synthesis. The possibility that sex steroids affect egg yolk protein synthesis is also reinforced by the observation that the electrophoretic profile of egg yolk proteins is ascribable to two clearly different patterns, corresponding to two periods of the reproductive cycle: the vitellogenic period (March-July), characterized by high levels of sex steroids and the non vitellogenic period (October-February), characterized by low levels of sex steroids. We also employed the 70 kDa band, which cross reacted with antibodies against one egg yolk protein of the crab *Potamon potamios* as a marker of 17 β -estradiol and progesterone activity on egg yolk protein synthesis in *Octopus vulgaris*, if any. Such a band appeared following the in vitro incubation of ovarian tissue with sex steroids, indicating for the first time in cephalopods that both hormones regulate the synthesis of egg yolk proteins.

Keywords: Sex steroids, vitellogenesis, reproduction, cephalopods, steroid

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Long-time conservation of biological structures as a possible solution for time-series preservation

A. M. Costa and J. Pereira

The recording of data for scientific purposes may require focused interest and technical expertise which does not always exist within a research institution. If the maintenance of time-series depends on adequately trained personnel, it may be impossible to sustain for long periods of time. One important set of data for fisheries assessment is that on fecundity, for which female ovaries are prepared and observed to produce counts of oocytes. The techniques involved require a series of procedures which are both time-consuming and depend on knowledge and facilities, not always available. In the present study, we report the results of an investigation into a technique which allows the adequate conservation for prolonged periods of time of female gonads, using low-cost equipment and materials, and employing non-skilled personnel. A case-study is presented demonstrating results obtained with gonads of the squid *Loligo vulgaris*, stored between 1991 and 2004. Several sections through gonads of 19 females collected in pre-mature condition (stage 3) at different times, demonstrate the quality of the material and the feasibility of a fecundity study.

Keywords: time-series, techniques, fecundity, gonads, conservation, *Loligo vulgaris*, assessment

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Abundance of the common octopus (*Octopus vulgaris*) and sea surface temperature off the Portuguese coast

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The aim of the present study is to estimate an abundance index for the common octopus (*Octopus vulgaris*) on the Portuguese continental shelf and to understand how this index correlates with environmental variables. Because of the high commercial value of the common octopus, all captured individuals are landed on commercial ports, so this information is considered a good abundance index. The rough data is organised in a central database at the Directorate General for Fisheries (DGPA), where, for each vessel and day of landing, port, weight and commercial value of sale are reported. All vessels that landed cephalopods at least once a year were selected. Second day landings only were extracted to ensure effort units of 24 hours. The series obtained is compared with sea surface temperature data. SST's time series are obtained from satellite data and organized by month. The analysis is carried out for four distinct areas of the Portuguese continental shelf. As a preliminary study, data starting in January 2002 were used for a total exceeding 3000 vessels.

Keywords: *Octopus vulgaris*, abundance index, environmental index, time series, landings, sea surface temperature.

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Estimation of biomass, production and fishery potential of ommastrephid squids in the World Ocean and problems of their fishery forecasting

Ch.M. Nigmatullin

21 species of the nektonic squids family Ommastrephidae inhabits almost the entire waters of the World Ocean. It is most commercial important group among cephalopods. Straight and expert evaluations of biomass were carried out for each species. In all ommastrephids the total instantaneous biomass is ~55 million t on average and total yearly production is ~ 400 million t (P/B = 5 in inshore species and 8 - in oceanic ones). Now there are 12 fished species, mainly 8 inshore ones. In 1984-2001 the yearly world catch of ommastrephids was about 1.5-2.2 million t (=50-65% of total cephalopod catch). The feasible ommastrephids fishery potential is ~ 6-9 million t including 4-7 million t of oceanic species. Thus ommastrephids are one of the most important resources for increasing high-quality food protein catch in the World Ocean. The same time there are serious economical and technical difficulties to develop oceanic resources fishery, especially for *Ommastrephes* and *Sthenoteuthis*. General obstacle in the real fishery operations for ommastrephids is their r-strategist ecological traits, related to monocyclia, short one year life cycle, pelagic egg masses, paralarvae and fries, and accordingly high mortality rate during two last ontogenetic stages. So, the stock size dynamics and distribution are associated with environmental variability. In this context the problem of fisheries forecasting has special significance. These problems of forecasting for short (within month), medium (1-11 months) and long (more than one year) terms are discussed on the examples of Soviet/Russian ommastrephid fishery, mainly on *Illex* and *Todarodes* species.

Keywords: biomass, ecological traits, fishery forecasting, ommastrephid squids, production, World Ocean.

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ICES CM 2004/CC:07 Poster

Studies of post-mortem evolution of cuttlefish viscera during their storage at two different temperatures

E. Le Bihan, N. Koueta, and A. Perrin

Cuttlefish viscera were placed at 4°C or 25°C during four month with regular sampling. Our results showed that rapidly (one to 2 hours) total acid proteases and cathepsins were released on extracellular medium due to the breakdown of lysosomes. The total alkaline proteases activity was already high at the dead of cuttlefish, nevertheless, that activity increased 24 hours after the death due to the breakdown of zymogene vesicle. The same observations were found with the trypsin and chymotrypsin activities. The lipases and -amylase activities were little affected by the cuttlefish death in the first time. After 29 days of incubation, no acid proteases activity was detected at 25°C due to an alkaline pH of 7.21. After 50 days of incubation, no endogen enzymatic activities were found. The TCA soluble proteins rate increased between 0' to 50 days to reach 70% and 80% in viscera at 4°C and 25°C respectively. After 50 days of storage, the TCA soluble protein rate decreased rapidly to be about at 30%. This decrease was due to a diminution of functional proteins because of a deterioration of native proteins and their aggregation. The molecular weight of protein and peptides contained in viscera was estimated by gel filtration. At the animal death, we observed two peaks: the first one corresponded to big proteins (>40 000 molecular weight), the second contained small proteins (30 000 < 15 000 molecular weight). After 29 days, we observed a decrease of the first peak and a loss of the second. Nevertheless, a third peak appeared, which contained small proteins and peptides (20 000 to 2000). Therefore, we observed a little hydrolysis of viscera proteins.

Keywords: Digestive enzymes, Post-mortem, *Sepia officinalis* L. (*Mollusca Cephalopoda*), Viscera.

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Behaviour of the common octopus (*Octopus vulgaris*) towards entrapment fishing gears: clay and plastic pots ("alcatruzes") and iron traps ("covos")

J. Sendão, P. Calixto, T. C. and Borges

The most efficient fishing gear takes into account the behaviour of the target species. Traps are devices designed to encourage the entry of animals, which are then prevented from escaping either by particular aspects of their behaviour or by the design of the trap itself. The traditional southern European octopus traps are made simply from clay pots ("alcatruzes") hung from a line set along the sea floor. More recently vinyl chloride has been used as material for octopus pots (plastic pots) replacing the traditional clay pots. As the animal entering such trap is territorial and prevents the entry of other individuals, a large number of small traps must be set in order to make a commercially viable catch.

The principle of baited traps is that animals, attracted to the bait, enter the trap through tapered openings from which it is difficult to escape. Traditional baited traps called "covos" (here called "iron traps") have been used to catch cuttlefish (and species of crustaceans) and more recently in Portugal have been used to also catch octopus.

Different behaviour aspects of the common octopus (*Octopus vulgaris*) have been observed towards the fishing gears pots ("alcatruzes") and iron traps ("covos"). Variables like different material (clay and plastic) shape and colour (black, white and red) have been introduced in the pots to understand possible preferences. Specific behavioural aspects towards the iron traps have also been registered by video camera, showing that octopus is entrapped due to the attraction by the bait, but he is also able to leave if wanted.

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Biogeography, biology and biochemistry of the deep-sea cirrate octopus *Opisthoteuthis* from the Portuguese continental slope

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We present the first analysis of the biogeography, biology and biochemistry of the genus *Opisthoteuthis* from the Portuguese continental slope, using 74 specimens obtained in 5 research cruises conducted by IPIMAR between 1996 and 2003 at depths ranging between 200 and 900m. Positions and depths of occurrence are reported. Catch rates and biomass, weights, lengths, sex and maturity stages and the first biochemical characterization of the genus at different stages of gonad development are detailed. Specimens have been found from 570 to 800m depth, south of 39°N, in approximately 1:1 sex-ratio. Females grow larger (80:65mm ML) and heavier (622:293g tBW) than males and both sexes have been caught in all stages of maturity in equal proportions ($p > 0.05$). Maturity records were only obtained in the second half of the year, between June and December, with a predominance of mature specimens in June and immature in December ($p < 0.05$). During sexual maturation, there was a significant increase in the protein, total amino acid (TAA), lipid and fatty acid (FA) contents ($p < 0.05$) in the gonad. In the digestive gland, the nitrogen and carbon compounds also revealed a significant increasing trend ($p < 0.05$). In the muscle, there was a decrease on the nitrogen compounds and an unclear pattern of variation in lipid and FA levels. In the three tissues analysed, the major FA were 16:0, 18:0, 18:1, 20:1, 20:4n-6, 20:5n-3 and 22:6n-3, the major essential amino acids (EAA) were lysine, leucine and arginine and the major non-essential (NEAA) were glutamic acid, aspartic acid and serine.

Keywords: Biochemical composition; Biogeography; Biology; Deep-sea; *Opisthoteuthis*

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The stock and fishery variability of the Argentine squid *Illex argentinus* in 1982–2004 related to environmental conditions

Ch. M. Nigmatullin, A. V. Zimin, and A. Z. Sundakov

Illex argentinus is the most important commercial squid species in South West Atlantic and in the world cephalopod fishery since beginning 1980-s. In 1991–2001 its yearly catch had varied from 505 to 1145 thousand t (15–32% of total world catch of cephalopods). Its total instantaneous biomass according to expert evaluation is 2–5 million t, but real interannual variability ranged probably more widely. Unfortunately we haven't actual ecological data for estimations of stock size long-term variability. So there is one possibility only – to use fishery statistics and especially data on CPUE. The mean monthly CPUE of Soviet/Russian trawler of BMRT type were recognized as indices of squid abundance. We use the Soviet/Russian fishery statistics on *Illex argentinus* for fishery seasons of 1982–1997 and 1999–2004. In addition to these data for description of stock condition, other countries fishery fleets and FAO capture statistics were used. During this period the years of good condition of stock prevailed. But in 1986, 1994–1995 and 2003–2004 there were observed the slump of stock size, especially in its slope-oceanic group. Most pronounced and system collapse of the Argentine squid stock was observed in 2004. Both shelf summer and autumn spawning group and winter spawning slope-oceanic group suffered sharp numbers decreases. There may be two factors that provoked this stock collapse: environmental change (mainly due to water dynamics of the Falkland-Brazil currents system and increase of paralarval stage mortality) and the overfishing. The influence of these factors on stock size variability is discussed.

Keywords: Argentine squid, environmental controlling factors, fishery, *Illex argentinus*, South-West Atlantic, stock dynamics.

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ICES CM 2004/CC:11

Effect of amino acid on isolated cells of digestive gland of cuttlefish *Sepia officinalis*

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The purpose of this study was to establish a bioassay from isolated digestive gland cells of the cuttlefish *Sepia officinalis* in order to observe the effect of amino acids on digestive enzyme activities. Lysosomal proteases can be used as markers of lysosome integrity. So, we characterized acid proteinase activity of the crude extract of cuttlefish digestive gland. Acid lysosomal proteases and alkaline secreted protease were dosed on extracellular medium and on cells from bioassay. These two enzyme groups are implied in digestion (intracellular and extracellular). Using the bioassay, on digestive studies showed that amino acids could have effects on cells survival and digestive enzyme activities after 24 hours of an incubation time. In fact, addition of cysteine 1 μ M or aspartic acid (1 mM or 1 μ M) permits an increase of cell viability. Nevertheless, tyrosine no have effects on cell viability. The cathepsin activity in extracellular medium was not affected by the addition of amino acids, which showed that the lysosome integrity was preserved. Excepted for the tyrosine (1 mM) addition, amino acids induced an increase of trypsin secretion. So, amino acids can regulated the extracellular protease secretion.

Keywords: Acid cysteine proteinase, Amino acids, Aspartic proteinase, Bioassay, Cathepsin, Characterisation, Digestive gland, *Sepia officinalis* L. (Mollusca Cephalopoda), Trypsin.

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Cuttlefish trammel net artisanal fishery in the Balearic Islands (Western Mediterranean)

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This study evaluates the cuttlefish fisheries in the Balearic Islands (Western Mediterranean) in terms of: a) the yield, size and sex structure of the cuttlefish catch, b) the efficiency of the fishery (ratio of commercialised and discarded overall and target species catch) and c) the physical ecosystem impact of the fishery. The spatial and temporal distribution of the fishery follows the annual reproductive migration of the target species, moving from shallow to deeper waters over sand and muddy bottoms of algae and *Posidonia oceanica* meadows during winter and spring. While yields increased through the winter, no seasonal differences in the size or sex-ratio of the cuttlefish catch were observed. While the overall efficiency of the fishery was high with commercialised species making up 78% of total catch in number, the efficiency of the target species was low (22 % in number). The most discarded species in number were: *Holothuria* spp (29.35%), *Thais haemastoma* (10.84%), *Sphaerechinus granularis* (7.80%) and *Mullus surmuletus* (2.74%). Cuttlefish made up 1.46 % of the discards in number. The threatened sea grass *Posidonia oceanica* is the main species affected by the physical impact of the fishery.

Keywords: Cuttlefish, trammel net, artisanal fisheries, discard, impact, Western Mediterranean.

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ICES CM 2004/CC:13

The spatio-temporal pattern of Argentine shortfin squid *Illex argentinus* abundance in the Spanish bottom-trawl fishery in the southwest Atlantic

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The Argentine shortfin squid (*Illex argentinus*) is a common neritic species occurring in waters off Brazil, Uruguay, Argentina, and the Falkland/Malvinas Islands in the southwest Atlantic, where it is the most important cephalopod species playing a significant role in the ecosystem. It is object of major fisheries using both trawlers (mostly from European countries) and jigging vessels (mainly from Asian countries) and the actual total annual catch could reach up to 700 thousand tons. Fishery and biological information collected by scientific observers aboard commercial trawlers between 1988 and 2003 was analysed in relation to physical and environmental factors to establish the spatio-temporal pattern of the species distribution. The data included 26 168 fishing haul records, of which 11 103 were positive. CPUE (Catch Per Unit Effort, kg-hr⁻¹) was used as abundance index. The analyses of the general spatio-temporal pattern of fish abundance, and the influence of environmental factors, such as SST, SBT and depth on squid abundance and distribution, was based on correlation, variograms, and time-series maps created using GIS. The areas of the highest densities were found in deep waters of the High Seas between 44.5° S - 47.0° S outside the Argentinean EEZ and to the northwest of the Islands in February-May. The correlations between squid abundance and cloud index at different moon phases were also analyzed.

Keywords: Argentine shortfin squid, *Illex argentinus*, GIS, environment, spatio-temporal pattern

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Coordination of ventilation and circulation in the cuttlefish *Sepia officinalis* (L.) in the light of an oxygen limitation of thermal tolerance

Frank Melzner, C. Bock, and H.-O. Pörtner

Laboratory raised *Sepia officinalis* were subjected to acute temperature change at a rate of 1°C *h⁻¹ from control temperature (15°C) to a lower and a higher critical temperature. Oxygen extraction (as measured with an oxygen microop-

tode in the funnel) from the ventilatory current (OE) is higher than previously thought (between 87% at 14°C and 96% at 8°C) and coincides with ventilatory stroke volumes (VSV) of 7,2 to 3,5 ml stroke⁻¹ * kg⁻¹ and ventilatory minute volumes (VMV) of 235 - 83 ml * min⁻¹ * kg⁻¹ in the same temperature range. High OE and resulting minute ventilation volumes are comparable to those obtained for flatfish that live in the same uniform environment and depend on minimizing movements in order to achieve good camouflage whilst lying on the sediment. Higher temperatures result in a drop in OER (down to 32% at 26°C) with VMV rising to 1736 ml * min⁻¹ * kg⁻¹, while stroke volume rises to 20 ml * stroke⁻¹ * kg⁻¹. High OE are supported by a tight coupling between ventilatory movements and Vena cephalica blood flow towards the gills. Ventilation rate matches Vena cephalica pulse rate (VCPR) between 8 and 23°C, with VCPR being elicited consistently at the maximum mantle pressure increase of each ventilatory cycle. A loss of the close phase relationship between both processes occurs at temperatures between 23 and 26 degrees and is in line with stagnating oxygen consumption rates. Advent of anaerobic metabolism in mantle muscle is witnessed in the same temperature range when investigated using in vivo ³¹P - NMR spectroscopy. Our findings further support the hypothesis of an oxygen limitation of thermal tolerance caused by limited capacity and a loss in coordination of the components of the oxygen delivery system.

Keywords: cuttlefish, oxygen extraction, thermal tolerance.

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ICES CM 2004 /CC:15

Advantages and limits of the direct approach for the octopus stock assessment, geostatistical approach

Abdelmalek Faraj and Nicolas Bez

The common octopus (*octopus vulgaris*) is an important fishery resource in Morocco. The most important stock of octopus in the Moroccan commercial fishing ground is the stock of Dakhla. Using two approaches for the stock assessment of octopus, Direct and Indirect approaches, the INRH have however concentrated many efforts to develop the first one which is based on the trawl-scientific surveys. According to the results of the surveys carried out from 1998 to now, we evaluate this approach and show some of its advantages and some of its limits. The geostatistical methods are the main tools used in this study. Among the advantages, we present the results of the spatial analyses, the mapping by kriging and the variance estimation of the abundance estimates. In the other hand, among the limits, using simulations, we show the level of fluctuation inherent to the sampling process. According to the sampling fluctuations, we show the difficulty to distinguish between the fluctuations intrinsic to the variable and those due to the sampling design. In particular, the year to year fluctuations observed at the beginning of the time series can be interpreted as sampling variations rather than changes in the fish population. This issue and other perspectives are discussed.

Keywords : Octopus vulgaris, stock of Dakhla, trawl-scientific surveys, geostatistical methods, sampling fluctuations.

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ICES CM 2004/CC:16

Detection of domoic acid, the amnesic shellfish toxin, in the digestive gland of *Eledone cirrhosa* and *E. moschata* (Cephalopoda, Octopoda) from the Portuguese coast

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Domoic acid (DA), the toxin responsible for the illness amnesic shellfish poisoning (ASP), is a food web transferred algal toxin produced naturally by some species of the diatom genus *Pseudo-nitzschia*, that has been detected in many marine organisms from copepods to whales. Cephalopods, which are important members of the food chain and active predators of known toxin vectors such as bivalves, crabs and some fishes, have just recently been implicated in DA transfer or accumulation. Here we present data showing relevant values of DA detected by HPLC-UV and also confirmed by HPLC-MS in two octopus species collected along the Portuguese continental coast: *Eledone cirrhosa* and *E. moschata*. Domoic acid was frequently detected in the digestive gland of *E. moschata* occasionally reaching concentrations exceeding 100 µg.g⁻¹, which reveals this species as a potential vector for higher predators in the Portuguese coastal marine food web. On the other hand *E. cirrhosa* showed lower concentrations of DA in the few times that it was de-

tected. These data, combined with known aspects of the life history of the species, are a necessary step towards achieving an understanding of the accumulation of phycotoxins in cephalopods.

Keywords: Domoic acid; *Eledone moschatta*; *Eledone cirrhosa*; Amnesic shellfish poisoning.

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Spatial pattern of the octopus life cycle in the South Atlantic of Morocco

Abdelmalek Faraj and Nicolas Bez

The common octopus (*octopus vulgaris*) is the main target species of the cephalopod fishery of the Moroccan waters in the south Atlantic. The octopus population is widely distributed throughout the continental shelf between Cap Boujdor (26°N) and Cap Blanc (21°N) and is made up of two stocks, the Dakhla and Cap Blanc stocks. The life cycle of the octopus is characterized, in this area, by a clear opposition between the recruitment and reproduction phases showing very different spatial patterns. The aim of this work is to describe the spatial pattern of the main phases of the octopus life, using the trawl-scientific surveys carried out by the INRH, twice a year from 1998 to 2003. Through a geostatistic approach, the most important demographic classes of octopus have been analyzed and mapped by kriging, especially the mature females' class to feature the spawning area and the juveniles' class to feature recruitment area. The results indicate that the spawning process occurs over the whole continental shelf and that there is no spawning migration for the Moroccan octopus. This was also reported for the Mauritanian octopus stock, but is contradictory to the Mediterranean case. This has very important implications in terms of resource management as it allows to re-evaluate the impact of the small-scale coastal fishery on the spawning stock biomass. Under the assumption that spawning octopus converge to the coast, these are often suspected to deplete the spawning stock.

Keywords: Octopus vulgaris, stocks of Dakhla and Cap Blanc, trawl-scientific surveys, spawning and recruitment areas.

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Intrannual trends in catches of squid (*Loligo spp.*) in the Bay of Biscay (ICES Div. VIIIa, b, d) during 2000 in relation to oceanographic features

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A first attempt to relate the environmental conditions in the Bay of Biscay to squid landings per unit effort (LPUEs) was carried out. The "Baka" Otter trawl fleet from just one Basque port fishing in Div. VIIIa, b, d during the year 2000 was chosen. Satellite images of Sea Surface Temperature (SST) and Chlorophyll a concentration ([Chl-a]) and LPUE squid data (abundance data) for the same year were used. As a preliminary result, squid catches appeared to be higher in months with cooler SST than in those with warmer SST. When SST is close to 12°C (January) squid catches remain the highest of the year. The spatial distribution of the catches for those cooler higher-catch months, production is associated to the coolest waters or to the frontal zones (between areas of very different temperatures). The assumed higher abundances of squid in oligotrophic areas is still a fact to be investigated in the Bay of Biscay waters.

Keywords: Intrannual trends, Catches, Squid, Bay of Biscay, Oceanographic features, SST, Chl-a.

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The cephalopods in the small-scale fishery in the eastern Thracian Sea (NE Mediterranean)

E. Lefkaditou, J. Haralabous, D. Sarikas, S. Karamelidou, and S. Kavadas

Landings data of the Fisheries Co-operative of Alexandroupolis "Evros" for the period 1998-2002 indicate that cuttlefish (*Sepia officinalis*) and octopus (*Octopus vulgaris*) consist an important resource for the small scale fishery in the coastal zone of the eastern Thracian Sea. Cuttlefish is targeted by specific trammel nets (32-36 mm mesh size) during late winter and spring, whereas it is fished as by-catch by trammel nets targeting shrimp (*Penaeus kerathurus*) and sole (*Solea vulgaris*) in summer and autumn. Octopus is the target species of pots used mainly in autumn and by catch of trammel nets. Variation of total landings and LPUE are examined considering vessel-day as the common unit of fishing effort for all fishing gears. LPUE for gears fishing octopus and cuttlefish as by-catches is generally very low. Octopus LPUE for pots shows a seasonal peak in June, whereas the cuttlefish LPUE for specific trammel nets in March-April, both reflecting the availability of the species in the coastal fishing grounds and probably depending on the size composition of the catches. Monthly variation of total landings by gear is clearly dependent on the fishing strategy followed, as well as, on the LPUE variation of the targeted species.

Keywords: Cephalopoda, small-scale fisheries, Mediterranean.

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The effect of time of hatching in age and size at maturity of *Loligo vulgaris*

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Loligo vulgaris shows a complex population structure in Portuguese waters, strongly influenced by continuous spawning. Squid were sampled in order to determine age and size at maturity. Differences in these parameters and reproductive investment in distinct cohorts as an indication of environmental influences in sexual maturity, were evaluated. Maturity ogives by age class were well fitted to the observed data indicating t50% of 7.6 months in males and 8.7 months in females and an ML50% of 17.6cm in the latter. A much higher complexity in size at maturity than in age at maturity was observed, especially in males. Significant differences in life cycle parameters were found between squid hatched under colder and warmer water regimes, the Cold and Warm Cohorts. The variability in age and size at maturity observed for the whole population, decreases when splitting squid by cohorts, but the variability in size at maturity in males is not as well explained by hatching cohort. An account of significant differences between the two cohorts of each sex in important life cycle parameters is fully exploited, providing a possible improvement to the utilization of biological data in assessment models.

Keywords: Biology; maturation; size; age; *Loligo vulgaris*; environmental influence.

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Distribution, abundance, biology and biochemical profile associated to sexual maturation of the Stout bobtail squid *Rossia macrosoma* from the Portuguese coast

Rui Rosa, João Pereira, Pedro R. Costa, and Maria L. Nunes

A study of *Rossia macrosoma* in Portuguese waters with emphasis on its biogeographical, biological and biochemical characteristics is presented. Approximately 1000 specimens collected in 33 cruises between 1990 and 2003 are used to determine the distribution and abundance of the species. Weight, length, sex and maturity information is analysed. The first biochemical characterization of the species at different stages of gonad development is made. The species occurs from the coast to 860m depth, concentrating between 300 and 600m. It is present along the whole Portuguese coast, but

most records are made south of 37°N, particularly in the Algarve. The sex-ratio is approximately 1:1 and it doesn't vary with depth or position along the coast ($p \gg 0.05$). Females grow larger (84:67mm ML) and heavier (161:100g tBW) than males. Mature specimens of both sexes constitute <1% of all records. Immature and maturing specimens are found year around, without significant differences between their monthly distributions ($p > 0.5$). No significant difference between sexes in the distribution of maturity stages with depth or position along the coast is noted ($p \gg 0.05$). During sexual maturation, there was a significant increase ($p < 0.05$) of total amino acid, protein, lipid and fatty acid contents in the gonad, but the allocation of these organic compounds from digestive gland and muscle was not evident. It seems that biochemical dynamics of these two tissues may be influenced by other biotic factors and the energy required for egg production may come directly from food, rather than from stored reserves.

Keywords: Biochemistry; Biogeography; Biology; Maturation; *Rossia macrosoma*

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Preliminary analysis of stock-recruitment relationships in the English Channel squid *Loligo forbesi*

L. Challier, J. Royer, G. J. Pierce, N. Bailey, B. A. Roel, and J. P. Robin

Updated stock assessments of the English Channel *Loligo forbesi* stock are based on cohort analysis developed at a monthly scale. Population numbers per monthly age-class are computed in a series of ten fishing seasons (1993–2002). Recruitment variations are analysed according to adult biomass prior to recruitment. Spawners in a semelparous species can be defined in various ways, considering for instance the terminal age-classes (in month) or using the proportion of animals above length-at-maturity. Parametric stock-recruitment curves show rather poor fits and an environmental variables like temperature when introduced do not increase significantly the part of recruitments variability explained by the model. Cohort strength seems to depend on a wide variety of factors and this preliminary study does not reveal obvious recruitment over fishing of the English Channel *Loligo forbesi* population.

Keywords: juvenile, cuttlefish, statolith, age, growth, model parameters.

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Spatial differences in biological characteristics of *Loligo forbesi* (Cephalopoda Loliginidae) in the Northeast Atlantic

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Biological data collected in *Loligo forbesi* during a series of EU funded programs were analysed using a common set of statistical tools to evaluate large scale variation in the Atlantic. Monthly samples collected in Scotland, English Channel, Portugal and Azores and analysed with similar protocols enabled to record a common set of basic biological variables (length, weight, sex, sexual maturity stage, gonad weight and reproductive system weight).

In each area, basic variables are used to compute compound variables which describe the relationship between biological variables (like parameters of the length-weight relationships, or length-at-maturity) the seasonal variation of indices (like sex-ratio, proportion of maturity stages or average gonado-somatic index) and the synchronicity of life history (like the number of months with a majority of mature -or immature- specimen in the population).

Differences in length-weight relationships were studied with ANCOVA-like methods. Length-at-maturity were estimated via GLM procedures fitting a logistic function with binomial errors. Seasonal variations in sex ratio and proportions of maturity stages were tested with Chi-square tests and other temporal aspects of life history were compared with non-parametric tests.

Significant geographical differences were discussed in the light of published population life-cycles, latitudinal gradients and genetic differences between Azores and continental shelf populations.

Keywords: *Loligo forbesi*, biological samples, statistical differences, geographical comparisons.

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Trends in age-at-recruitment and juvenile growth in the English Channel cuttlefish *Sepia officinalis*

L. Challier, M. R. Dunn, and J. P. Robin

The cuttlefish *Sepia officinalis* is a major fishery resource in the English Channel. This stock is among the largest cephalopod stocks in the Northeast Atlantic and cuttlefish landings represent a significant part of the earnings from mixed fisheries of the English Channel. Given the short life span of the species, fluctuations in landings depend on recruitment success which is favoured by high survival rates and rapid growth during the pre-recruitment stage.

Fishery statistics show two peaks of recruitment per fishing season (one in autumn and in one spring). In this study, evidence of differences between the early life of cohorts were sought by analysing age-at-recruitment and juvenile growth.

Biological samples of recruits were collected monthly during three fishing seasons (2000, 2001 and 2002) and additional pre-recruitment specimens were caught in 2000 and 2002 during experimental surveys carried out in coastal waters of the UK and France. Age in days was determined by statolith analysis.

Significant differences in age-at-recruitment were found between the autumn and spring recruitment peaks. Whatever the recruitment peak, inter-annual differences were also found between the three cohorts.

Juvenile growth models were fitted in both years when pre-recruitment specimens were available. Growth rate was significantly higher in 2002 than in 2000. Spatial differences observed in 2000 between UK and France samples indicates that pre-recruit growth may depend on coastal environmental conditions. This suggests that life-history may be heterogeneous within the English Channel stock.

Keywords: juvenile, cuttlefish, statolith, age, growth, model parameters.

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Factors affecting the encounter and feeding rates in squid paralarvae

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Motion and frame-by-frame analysis were combined to evaluate the role of predator-prey encounter rate in influencing the feeding rate in paralarvae of the squid *Loligo opalescens*, reared from 1-60 days. Simulated encounter rates from Gerritsen & Strickler's mathematical model were compared to observed encounter rates obtained by counting the number of encounters, attacks and captures between paralarvae and prey during filming sequences. Prey species supplied were mysids, copepods and *Artemia* nauplii, with speeds from 0.4-10mm s⁻¹. When mean swimming speeds of paralarvae and prey were different, the larger of the two had the greatest effect on the encounter rates. Observed and simulated

encounter rates overlapped for the 2-4 mm mantle length (ML). But, the math model overestimated the encounter rate in faster paralarvae (>4 mm ML), while image analysis underestimated it in the same size classes. In summary, the mathematical model did not take into consideration a maximal number of encounters per unit of time or space, and the time spent by paralarvae in activities like pursuit, attack, and ingestion. On the other hand, image analysis underestimated the encounter rate because an encounter was accounted for only after a positioning movement of a paralarva towards a prey, thus not all prey that entered the paralarva's field of vision were considered. Then, it is reasonable to suppose that the real encounter rates of paralarvae lay between the simulated (maximum, 0.20 enc. s⁻¹) and the observed (minimum, 0.03 enc. s⁻¹) in this study.

Keywords: squid, paralarvae, encounter rate, feeding rate

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ICES CM 2004/CC:26 Poster

Cephalopods in the trawl fisheries in the southeastern Brazil (1979–2000)

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The interest over cephalopods fisheries in southeastern Brazil increased after the middle of 80's when a crisis in shrimp trawl catches forced the fleet to find in the bycatch an aid to reduce operation costs, driving fishery effort to seasonal targets, including squids and octopus. This study evaluates the importance of the cephalopods exploited by trawl fisheries of the southeastern Brazil (23° to 27°S) composed by shrimps and fishes double-rigger trawlers. Data were provided by statistical database from 'Instituto de Pesca' and samples during the landings in São Paulo State between January 1993 and December 2000. Additional landing data from Rio de Janeiro and Santa Catarina States were also collected. Loliginid squid was the best cephalopod category represented (68% in average through the period, varying from 39 to 85%) with two species: *Loligo plei* and *Loligo sanpaulensis*. *Illex argentinus* occurred when boats operations were done deeper than 100 m during austral winter. Among the octopuses (32% of all cephalopods, varying from 15 to 61%), *Octopus cf. vulgaris* represented almost the entire catches (90%), followed by *Eledone massyae*. Other species were registered in the landings in small numbers. The species composition in the area do not differ, but abundance shown local differences possibly due to the oceanographic conditions, as a seasonal upwelling around 23°S amplifying the catches of *E. massyae* and *L. sanpaulensis*. Some yield peaks registered along the studied period may be related to earlier favourable conditions to recruitment. Those characteristics positioned the cephalopods not more as accessories catches, but as important fisheries resources with potential market to be explored, not only driven to the domestic market.

Key-words: cephalopods, trawl fisheries, Brazil.

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ICES CM 2004/CC:27 Poster

Pot fishery for octopus, an alternative for trawling in São Paulo State coast, southeastern Brazil

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Octopus cf. vulgaris has great commercial value and occurs along the Brazilian southeastern coast (23° and 29°S) up to 150 m deep. It's usually caught by the trawling fleet as the fifth main landed category representing in near 80% of trawler's landings between 2000 and 2003. An adapted shrimp trawler started octopus pot fisheries in December 2002, using a longline with PVC pipe pieces. Since then, the catches and effort targeted to octopus experienced a considerable increase due to the high efficiency of this fishing method. From 2000 to 2003, the average annual yield of São Paulo State was of 207 ton (93 ton in 2002 to 316 ton in 2003). In the last year, 37% of the landed octopus in main fishing port came from eight boats using pot longlines, while the remaining catch came from 95 trawlers. Longlines consist of a main cable of 6 to 8 mm wide twisted Nylon and pots are mostly plastic made with cement base around 2.0 kg. Each pot is tied to a polyethylene branch line attached to the main line by a steel snap. A boat may set up to 15,000 pots, divided into longlines of 500 to 5,000 pots, which stay immerse by 3 days. Specimens lighter than 1 kg are returned alive to sea. With technical advice from Instituto de Pesca, some fishermen also started to return brooding females. Due to high selectivity and low impact to the sea bottom, comparing to trawling, this fishery may allow a healthier management. Nevertheless an uncontrolled increment may lead to collapse the stock. In order to keep high yields some assessment meas-

measurements ought to be applied. It's suggested the control of fisheries licenses to limit the fleet size; the introduction of daily fishing log (catch and effort data); a program of dockside data collection and embarking technical observers to carry tag-and-release experiments and to obtain detailed data of the species distribution and life cycle.

Key-words: octopus, pot fisheries, trawl fisheries, Brazil.

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Ontogenetic changes in the diet of *L. forbesi*: insights from fatty acid and stable isotope analysis

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The diet of *L. forbesi* in Scottish waters was subject to ontogenetic changes as shown by fatty acid and stable isotope analysis. Crustaceans were more frequently found in stomachs of immature squid smaller than 150 mm mantle length. With increasing size (> 150 mm) and maturity fish became more prominent in the diet. Seasonal differences in the diet were also found but seemed to be linked to seasonal changes in squid size. Prey type and species composition also varied slightly between different regions. Differences between size and region were reflected in fatty acid profiles of mainly the digestive gland tissue. High levels of saturated fatty acids 16:0 and polyunsaturated fatty acids 20:5n-3 and 22:6n-3, which are typical for fatty acid signatures of crustacean species, were found in tissues of smaller immature squid. Higher levels of monounsaturated fatty acids 16:1n-7, 20:1* and polyunsaturated fatty acids of the linoleic family (C18), which are typical for fish prey species, were found in squid of larger sizes and higher maturity stages. Regional differences found for fatty acid profiles of the digestive gland suggested a significant difference in origin of fatty acids thus indicating different diets. In comparing the fatty acid profiles of squid to those of putative prey species of *L. forbesi*, analysis indicated that gadid species *Trisopterus minutus*, *Micromesistius poutassou* and *Gadus morhua*, overall played an important part in the diet of *L. forbesi*. With increasing size of the predator however the composition of fish species in the diet shifted more towards species *Gadiculus argenteus*, *Trachurus trachurus* and *Sebastes marinus*. Results of quantitative fatty acid analysis on the estimate of the contribution of each prey species to the diet also reflected this shift in the importance of different prey species with increasing predator size.

Due to slower turnover rates in muscle, changes in carbon and nitrogen stable isotope ratios with diet were more pronounced in this tissue. Smaller squid showed the lowest $\delta^{15}\text{N}$ ratios thus feeding on the lowest trophic level of all squid examined. $\delta^{13}\text{C}$ ratios were the most depleted for small squid indicating small squid to feed on prey closer to the carbon source in the food chain. Stable isotope analysis also showed that squid with fish remains in their stomachs showed higher ratios of nitrogen and less depleted carbon ratios than squid feeding on crustaceans. Comparisons of isotope levels of squid and putative prey species identified blue whiting and silvery pout as putative prey species of bigger sized squid. Small squid seemed to feed on the same trophic level and all other prey species examined were always similar or higher in isotope ratios than squid of any size.

ICES CM 2004/CC:29

A review of records of giant squid in the north-eastern Atlantic and severe injuries in *Architeuthis dux* stranded after acoustic exploration

A. Guerra, A. F. González, and F. Rocha

A review of the verified reports to date of *Architeuthis dux* showed that 43 % (146 specimens) of worldwide reports were derived from the north-eastern Atlantic. Biological data are presented on fifteen females and two males from Asturian waters (Northern Spain). Both males represent the two first records captured off the Iberian Peninsula. Immature and maturing females ranged from 60 to 140 Kg total weight, whilst mature males weights were 42 and 66 Kg. The peculiar observation of spermatophores embedded in the skin of one of the males near the proximal part of the ventral, ventro-lateral and dorso-lateral arms is discussed. A comparison was undertaken of several morphometric measurements between both sexes and between these two males and five other north-eastern Atlantic males from which data were available. Two incidents of multiple strandings affecting nine specimens in 2001 and 2003 appear to be linked spatially and temporally to geophysical prospecting using air-gun arrays in the Bay of Biscay. Here we present evidence of acute tissue damage in the stranded and surface-floating giant squids. The incidence of such cases during two research cruises contemporary with integrated geological and geophysical studies of the continental margin of the Cantabrian Sea indicate that acoustic factors could have caused or contributed to the organ and tissue lesions that probably caused the deaths of these animals. Thus, further environmental regulation of such activity may be warranted to protect animals of the continental slope.

Keywords: Giant squid, *Architeuthis*, life history, acoustic explorations

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Patterns of investment in reproductive and somatic growth in *Loligo forbesi*

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Most previous studies on reproductive investment in squid have relied on use of indices such as the gonado-somatic index (GSI); however, use of such indices may obscure real trends in the underlying data. The availability of non-parametric analytical techniques such as GAMs and regression trees allows analysis and modeling of inherently non-linear relationships between multiple variables. In the present analysis we use an extensive existing data set on biological characteristics of *Loligo forbesi* based on market samples mainly collected during the period 1990-2001. Data available include body length, body weight, gonad weight, mantle weight, digestive gland weight, sex, maturity stage, and capture date. We ask (a) what controls the onset of maturation – season, size, nutritional state, external conditions or some combination of these factors; (b) does somatic investment continue, stop or is energy stored in the mantle mobilised to grow gonads; (c) how do the sexes differ in terms of the time course and cost of reproductive investment?

Keywords: life history, squid, reproduction

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Interannual variation in life-cycle characteristics of *Loligo forbesi*

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The loliginid squid *Loligo forbesi* has a flexible life-cycle, involving variable size and age at maturity, presence of summer and winter breeding populations, and extended periods of breeding and recruitment. This paper reviews life history data collected since 1985 from the commercial fishery in Scottish (UK) waters and examines (a) the relationship between hatching month and age, size and timing of maturation, (b) shifts in the relative abundance of the summer and winter breeding populations, and (c) the role of environmental signals in determining the timing of breeding. Results indicate that length-weight relationships differ in 1980s and 1990s and that the timing of breeding varies between years. Evidence from fishery data suggests that, since the 1970s, the summer breeding population has declined, winter breeding population now dominates and breeds later than was previously the case. Size at maturity varies between years. Timing of breeding and size at maturity may be related to environmental variation (NAO index) but relationships were only marginally significant.

Keywords: life history, time series, environmental factors

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Review of variation in the life-cycle of *Loligo forbesi* across its range

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This paper draws together data collected under a series of European projects, to summarise variation in the life-cycle biology of *Loligo forbesi* across the range and compare it with the biology of the closely related *L. vulgaris*. The review covers reproductive characters, length-weight equations, recruitment, size-frequency, trophic interactions, geographical distribution and fishery abundance. In particular, we consider variation between areas in the timing of reproduction and recruitment, and variation through time.

Keywords: life history, geographic variation, *Loligo*

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The Moray Firth directed squid fishery

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In 2003, the previously small directed fishery for *Loligo forbesi* off the northeast coast of Scotland in autumn involved over 100 boats. The present papers reviews the history of this fishery, which targets recruits appearing close inshore and examines trends over the last 35 years.

Keywords: *Loligo*, fishery, Moray Firth

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The disappearance of *Loligo forbesi* from the south of its range in the 1990s

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Since the early 1990s, *Loligo forbesi* has apparently disappeared from much of the southern part of its former range, with catches off the Iberian Peninsula, for example, declining dramatically during the 1990s. The present paper assembles data from fishery and research cruise databases to examine the evidence for a shift in distribution and identify possible environmental correlates.

Keywords: *Loligo*, fishery, Moray Firth

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Interannual patterns of variation in concentrations of trace elements in arms of *Octopus vulgaris* in two localities on the Portuguese coast

S. Seixas, P. Bustamante, and G. J. Pierce

Concentrations of metals (manganese, iron, copper, zinc, arsenic, selenium, cadmium, lead and mercury) were measured in arms of *Octopus vulgaris* sampled from commercial fishery landings at two sites on the Portuguese coast in spring 2002 and 2003. Mercury was determined using an Advanced Mercury Analyser Spectrophotometer (AMAS) and other metals were measured using Inductively Coupled Plasma - Atomic Emission Spectrometry (ICP-AES). Since high levels of arsenic were detected, identification of the forms present was carried out using High Performance Liquid Chromatography (HPLC) followed by ICP-MS.

Concentrations of metals were in the following order: Zn, As, Cu, Fe, Cd, Pb, Se, Mn, Hg. Despite high As concentrations, this element was mainly under arsenobetaine form whatever the origin. Compared with the other samples, and with literature values, the concentrations of several metals were generally high in samples from Viana in 2002. Cadmium concentrations were above the legal limit for human consumption in samples from Viana in 2002 and two of these animals also had lead concentrations that exceeded legal limits. Mercury appeared in all samples but levels were within legally defined safe limits. No relationship was detected between trace element concentrations and size or maturity of octopus.

Keywords: cephalopods, trace elements, metals, speciation, contamination,

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Approaches to Short-term and Long-term Stock Assessment of *Loligo gahi* around the Falkland Islands

Rubén Roa and Alexander Arkhipkin

We define short-term, or in-season assessment, as the use of fisheries data from the on-going season to provide both immediate stock assessment estimates and management advice. Conversely, long-term assessment involves the use of the whole available history of the fishery to estimate the status of the stock and the exploitation rate at the end of the current season or at the beginning of the next season. Since 1987 the only approach to stock assessment in the *Loligo gahi* trawling fishery on the continental shelf off the Falkland Islands has been in-season analysis of catch and effort data using a generalized version of Delury depletion method. The generalized Delury method was aimed at accounting for natural deaths and the existence of four fleets with potentially different catchabilities, but it only treated as free parameter the numbers of squid at the start of each season, while it treated the four catchabilities as nuisance parameters. A new (ADMB) implementation of the Delury method in which all 5 parameters were treated as free indicated its inability to provide statistically reliable estimates (variances tending to infinity). A modification of the method (also in ADMB) in which the four fleets are treated as one and thus there are only two free parameters to be estimated, does provide statistically reliable estimates and is introduced as a new alternative for short-term assessment. We also implemented (ADMB) two long-term models, namely a dynamic biomass and a daily-based delay-difference model to harvest the long-term trends from the historical database. Usage of both in-season and long-term assessments appears to be the best way to manage the stocks of short-lived animals such as the squid *L. gahi*.

Keywords: *Loligo*, Delury, biomass dynamic model, delay-difference model, long-term assessment, short-term assessment.

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New data on the biology of the Lesser Flying Squid, *Todaropsis eblanae* (Cephalopoda, Ommastrephidae) in the North Sea

Karsten Zumholz and Uwe Piatkowski

A total of 326 specimens of the ommastrephid squid *Todaropsis eblanae*, collected from bottom trawl surveys in the North Sea were examined. New information on seasonal length frequency distributions, reproductive biology, beak size- mass relationships and diet of the squid from a hitherto not very well studied area is supplied. An overall male: female ratio of 1: 0,78 was observed. Males (mean ML=100mm, range 30-160mm, N=175) were smaller on average than females (mean ML= 116mm, range 33-190mm, N=137). Maturing males and females were found in winter and summer, while fully mature animals were observed only in summer. Sexual maturity in females occurred in bigger sizes than in males. Prey consisted mainly of fish. Fish bones and otoliths identified from stomach contents suggest that Gadidae and Clupeidae were the most common prey.

Keywords: *Todaropsis eblanae*, North Sea, reproductive biology, diet, beak size

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Statolith trace element distributions in response to a manipulated environment in cuttlefish (*Sepia officinalis*)

Karsten Zumholz , Uwe Piatkowski, and Thor H. Hansteen

Synchrotron X-ray Fluorescence (SYXRF) and electron-microprobe analysis were used to determine the distribution of minor and trace elements in statoliths of cuttlefish (*Sepia officinalis*) reared in the laboratory. We show that statolith elemental composition is strongly related to salinity in ambient waters. A migration through diverse water bodies was simulated by manipulating salinity and temperature, and resulted in a distinctive microchemical pattern in the statoliths. The excellent micro-scale resolution and the precise analysis of elements from Calcium (Ca) to Lead (Pb) makes SYXRF a very accurate tool to gather life history information of individual cuttlefish from statoliths. The electron microprobe proved to be a useful and relatively inexpensive tool for analysing more abundant elements in statoliths.

Keywords: statoliths, trace elements, Sr/Ca- ratio, SYXRF, electron microprobe

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Rearing, yolk absorption and growth in *Loligo vulgaris reynaudii* paralarvae

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The chokka squid, *Loligo vulgaris reynaudii* is a fished species off South Africa with high variability in biomass and catches that is thought to be environmentally driven. To investigate this variability, knowledge of the early life cycles is required. In this paper, an experiment was undertaken in which eggs were incubated and the paralarvae reared at 16 °C for the first time. Simultaneous rearing of two groups of paralarvae took place (n=1000-2500). In order to determine the survival time of unfed hatchlings, food was supplied to one group (fed) while no food was supplied to the other (starved). Mantle length (ML), wet and dry weights (WW and DW) and yolk weight (YW) were obtained daily from samples of 20-60 paralarvae from each group. Measurements of the yolk sac made by image analysis were converted into volume and later into weights. Mean ML, WW, DW and YW at hatching were 2.3 mm, 1.85 mg, 0.45 mg and 0.16 mg, respectively. Daily exponential yolk utilization rates were found to be about 80% d⁻¹, indicating that the yolk reserve was almost exhausted 4 days after hatching. Nevertheless, starved paralarvae survived 6-7 days, while fed paralarvae attained a growth rate of 7.2% body WW d⁻¹, 6.9% body DW d⁻¹ in the first 22 days after hatching, reaching 42 days when the experiment was terminated. Standard metabolic rates were calculated using daily mean WW and temperature, and were approximately 0.07 cal d⁻¹. Results were interpreted in relation to environmental conditions and life cycles.

Keywords: squid, paralarvae, yolk, growth, temperature

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