

ABSTRACTS

RAPT VIEWING: A DAY IN THE ENERGETIC LIFE OF THE GIANT CUTTLEFISH (*SEPIA APAMA*) by J. P. Aitken¹, R. K. O'Dor¹ and G. D. Jackson².—The giant cuttlefish *Sepia apama*, lives in the shallow temperate waters of South Australia. Few detailed studies have been undertaken into the biology, behavior and reproduction of this cephalopod. With surgically attached acoustic transmitters cuttles were physiologically monitored using a radio acoustic positioning and telemetry system (RAPT). Diurnal activity cycles were observed with individualistic behavior. *S. apama* live in dens, similar to octopus, or hover under rocks and emerge during daylight for short food excursions. The cuttlefish enhances this conservative lifestyle with efficient foraging while exposure to predation is minimized. Daily activity was tied with the reef environment of wind, tide and storm patterns. Position and mantle jet pressure transmitters were attached telemetering jet pressure/swimming speed and daily activity levels. Activity monitoring on their native reef was ground-truthed with swimtunnel respirometry. Daily energy budgets were obtained as well as insight into their diurnal lifestyle.—¹Biology Dept., Dalhousie University, Halifax, N. S., Canada, B3H 4J1. ²Institute of Antarctic and Southern Ocean Studies, University of Tasmania, GPO Box 252-77 Hobart, Tasmania 7001, Australia.

A REVIEW OF THE MONOTYPIC GENUS *MEGALELEDONE*: TAXONOMY, BIOLOGY AND BIOGEOGRAPHY by A. L. Allcock¹, F. G. Hochberg² and T. N. Stranks³.—The holotype of *Graneledone setebos* Robson, 1932 was re-examined. An additional male specimen collected near the type locality in Antarctica was compared to the type. Both specimens were determined to belong in the genus *Megaleledone* based on similarities in size, and configuration of the radula, beak and suckers. It was further determined that *M. senoi* Taki, 1961 represents a junior synonym of *M. setebos* (Robson, 1932). During extensive trawling in the Antarctic over several seasons nearly one hundred new specimens of this species were obtained with sizes ranging from 23–230 mm ML. *Megaleledone setebos* has a circumpolar distribution but does not appear to extend its range to sub-Antarctic islands such as South Georgia. It occurs in depths from 130 to 792 metres.—¹National Museums of Scotland, Chambers Street, Edinburgh EH1 1JF, U.K. ²Department of Invertebrate Zoology, Santa Barbara Museum of Natural History, 2559 Puesta del Sol Road, Santa Barbara, California 93105. ³Department of Invertebrate Zoology, Museum of Victoria, 285-321 Russell Street, Melbourne, Victoria 3000, Australia.

THE EMBRYONIC DEVELOPMENT OF *LOLIGO SANPAULENSIS* by Pedro J. Barón.—The embryology of several *Loligo* species has already been reported. However, this aspect has not been covered for most southwestern Atlantic species. The embryonic stages of *Loligo gahi* were first described in a previous CIAC meeting. This is the first report on the embryology of *Loligo sanpaulensis*. Egg masses were obtained by scuba diving in Nuevo Gulf (Argentina, 42°46'S, 65°20'W) from March to May 1998. Eggs were incubated in aquaria at 12°C and 19°C (salinity range = 33.7–34.5‰) to determine the chronology of embryonic development at different temperatures. At first observation, embryos were at the beginning of the blastulation process. A particular scale for the embryonic development of *L. sanpaulensis* was developed based on incubation at 19°C starting from stage 13, and using Arnold's scale (Arnold 1965: Biol. Bull. (Wood's Hole) 128: 24–32) as a framework. Egg sizes of *L. sanpaulensis* (1.2–1.3 mm) are similar to

those reported for *L. pealii* (1.1–1.6 mm). Pre-organogenic stages are the same as those of Arnold's scale. Some features particular to *L. sanpaulensis* embryonic stages are the formation of: an equatorial waist at stage 19, primordia of gills and posterior funnel folds at stage 20, first tentacle sucker at stage 21, 1st sucker primordia on arms 2, 3 and 4 at stage 23, Hoyle's organ primordium at stage 26, first orange chromatophores on the ventral mantle and olfactory organs primordia at stage 27 and yellow chromatophores on the dorsal mantle at stage 30. Development from stage 13 to hatching took 14 d (266°C of daily accumulated temperature) and a total of 300°C of daily accumulated temperature is estimated for the complete embryonic development of *L. sanpaulensis*. At 12°C incubation, the embryos showed abnormal characteristics related to a slower chorion growth from stage 23.—*Centro Nacional Patagónico—Consejo Nacional de Investigaciones Científicas y Técnicas, Chubut, Argentina.*

INVESTIGATIONS ON THE WINTER POPULATION OF *LOLIGO FORBESI* (CEPHALOPODA: LOLIGINIDAE) FROM THE NORTH SEA by *Marco D. Biemann and Uwe Piatkowski.*—Samples of *Loligo forbesi* were obtained from the by-catch of two ICES bottom-trawl surveys of FRV WALTHER HERWIG III in the North Sea during January/February 1998 and 1999. The sea areas sampled covered the ICES fishery statistical sub-divisions IVa northern North Sea and IVb central North Sea. A total of 262 specimens of the loliginid squid *L. forbesi* were collected from which we provide information on geographical distribution, sex ratio, mantle length frequency, wet weight and maturity stage. Relationships between mantle length and wet weight as well as relationships between mantle length/wet weight and maturity stage are illustrated. The sample included 42% females, 53% males and 5% juveniles. Mantle lengths varied between 37–356 mm in females, and between 32–339 mm in males. Wet weight ranged between 3–481 g in females and 2–599 g in males. Differences of morphometric relationships between the two sexes are discussed.—*Institut für Meereskunde, Universität Kiel, Düsternbrooker Weg 20, D-24105 Kiel, Germany.*

FUNCTIONAL MORPHOLOGY AND EVOLUTION OF THE SHELL IN COLEOID CEPHALOPODS by *Vjacheslav A. Bizikov.*—The evolution of structure and morphology of the cephalopod shell is determined largely by the evolution of its function. The external cephalopod shell served mainly for providing buoyancy and protection of the body. Development of the internal shell was the crucial event in cephalopod evolution that gave origin to the diversity of their recent forms. It was induced by the development of a muscular mantle, fins and a mantle-funnel complex that reflected an increasing activity of the animals. The internal shell became the main supporting structure of the soft body. Its buoyancy and protective functions gradually reduced in most coleoid lineages. The earliest undoubtedly coleoid cephalopods are aulacoceratids and phragmoteuthids (Jeletzky, 1966). Their primitive shell with well-developed living chamber, phragmocone and rostrum may be treated as a 'starting point' in the evolution of the coleoid shell. From this point, the evolution of the shell proceeded in the following directions: (1) Reduction of ventral and lateral walls of the living chamber, preservation of phragmocone as floatation mechanism and development of bulky rostrum as a counterweight (Belemnitida). (2) Reduction of ventral walls of the living chamber and phragmocone, change in orientation and structure of phragmocone septa, reduction of rostrum, widening of the shell, enhancement of supporting functions of proostracum that were correlated with the develop-

ment of nekto-benthic forms (Sepiida). (3) Complete reduction of septal phragmocone and partial or complete reduction of rostrum were the most advantageous solutions of coleoids on their way to the colonization of the pelagic realm. Apparently in Lower Jurassic, this lineage resulted in the appearance of some vampyromorph forms that later gave origin to loligosepiids, ancestors of octopods, ancient squids (geoteuthids, plesiotheuthids, teudopsiids) and extant *Vampyroteuthis*.—VNIRO, 17 Verkhne-Krasnoselskaya str., Moscow 107140, Russia.

EVOLUTION OF THE SHELL IN OCTOPODA (CIRRATA AND INCIRRATA) by Vjacheslav A. Bizikov.— Functional morphology of the shell and its relationship with the soft body were analyzed in vampyroteuthids, cirrate and incirrate octopods to reveal possible evolution of the shell in this clade. Apparently, a common ancestor of octopods and vampyroteuthids had a vampyromorph-like decalcified shell with a broad dorsal plate, wide short conus, thick cartilage-like hypostracum and small rostrum. The phragmocone was absent. The shell lay near the surface of the mantle. The mantle was attached to the ventral edges of the shell; the head and funnel retractors were attached to its ventral side. Well-developed oar-like fins were attached to the dorsal side of the shell in the region of its wings. The crucial event in the octopod evolution was the systemic reduction of the shell that occurred when the fins became the main organ of locomotion. The conus and rostrum totally disappeared; only the wings remained from the dorsal plate. The wings provided a support for fins (by their dorsal side) and for the funnel retractors (by their ventral side). The ostracum also reduced and the shell was composed from concentric layers of the hypostracum. As a result, the shell became V-shaped, like in extant *Grimpoteuthis*. A similar reduction of the shell occurred recently in planktonic squid *Bathothauma* (Cranchiidae) indirectly testifying that first stages of octopod evolution occurred in the open ocean. The ancestor forms were pelagic and were not fossilized. Two evolutionary lines may be traced within cirrates. The first led to near-bottom forms (*Cirrothauma*, *Cirroteuthis*, *Stauroteuthis*) and the second line, to mainly benthic forms (*Opisthoteuthis*). Further evolution of octopods was determined by transition to benthic life by some near-bottom cirrate forms with a U-shaped shell. Evolution of benthic forms required enhancement of plasticity of the body in order to hide from predators into even narrow cracks on the bottom. In this case the fins became an obstacle and were reduced. The shell lost its function of fin support and reduced into lateral stylets supporting funnel retractors, mantle and visceral sac. Some incirrates secondarily re-entered the pelagic realm. However, they inherited from their ancestral benthic forms the basic 'octopodid' pattern of soft body structure.—VNIRO, 17 Verkhne-Krasnoselskaya str., Moscow 107140, Russia.

RELATIVE BIOMASS AND PRODUCTION OF LONGFIN INSHORE SQUID, *LOLIGO PEALEII* by Steve X. Cadrin¹ and Emma M. C. Hatfield².—A non-equilibrium production model (ASPIC) of the 1987–1998 *Loligo pealeii* fishery was developed to assess stock status and provide advice on managing the fishery. An analysis of quarterly yield and biomass indices from seasonal surveys indicated that the stock was at approximately half the biomass that can support maximum sustainable yield (Bmsy) in 1999, and there is high probability that fishing mortality exceeded Fmsy (predicted level of fishing mortality when maximum sustainable yield is taken) in 1998. Temporal patterns of relative biomass and fishing mortality were similar to those from length-based analyses. How-

ever, survey catchability estimates from the production model were unrealistically high, and therefore estimates of absolute biomass were considered to be unreliable. A more complicated model with seasonally specific production parameters was developed, but results were similar to the simpler model, and adding parameters did not significantly improve the goodness of fit. Stochastic projection of relative biomass from the simple quarterly model was used set seasonal limits on catch in 2000 with the goal of rebuilding the stock to Bmsy.—¹NOAA/NMFS/NEFSC, 166 Water Street, Woods Hole, Massachusetts 02543. ²FRS Marine Laboratory Aberdeen, PO Box 101, Victoria Road, Aberdeen, AB11 9DB, Scotland, U.K.

EXPLOITATION OF OCTOPUS IN THE AZORES (NE ATLANTIC): CURRENT STATUS AND EXPERIMENTAL FISHERY by G. P. Carreira¹, J. M. A. Gonçalves^{1,2} and R. D. M. Nash².—An analysis of the octopus fishery (*Octopus vulgaris*) in the Azores was undertaken based on the official landing statistics for the last 7 yrs. Experimental fishing surveys were also carried out during 1998–99. Three different types of traps (clay pots, iron framework traps and Japanese mechanical traps) were used on soft substrata at 3 depths; 25, 75 and 150 m. There were inter-annual fluctuations in landings, however, there was general increase throughout the 90s, reaching a maximum of 63 t in 1997. This increase could reflect species abundance and availability and/or a shift in fishing methods, from diving-based to traps. The majority of the landings came from S. Miguel Island (95%). The weight per landing (kg per landing) was used as an approximate measure of CPUE. The experimental fishing survey showed that the Japanese mechanical traps were the most efficient and specific for octopuses. The maximum CPUE with these traps was 15 ind 100 traps⁻¹ d⁻¹, or 7.0 kg 100 traps⁻¹ d⁻¹, at the shallowest depth (25 m). The abundance decreased with depth. Iron frame traps also caught octopus, but the majority of the catches were composed of other marketable species. The mechanic traps could be particularly useful in further stock assessments once some methodological problems, e.g., attraction area, best soaking time, etc., have been sorted out. The shift from the more traditional diving-based octopus fishery to a trap fishery in the Azores should be encouraged. This could reduce the fishing pressure on the coastal fringe (10–15 m), distributing the fishing effort over wider areas. However, the development of such a fishery should be implemented gradually, accompanied by management measures, improved collection of landing and fishing effort data, stock assessment and ecological studies.—¹Departamento de Oceanografia e Pescas, Universidade dos Açores, Cais de Sta Cruz, PT9901-862 HORTA, Açores, Portugal. ²Port Erin Marine Laboratory, University of Liverpool, Port Erin, Isle of Man IM9 6JA, U.K.

DISTRIBUTION OF DEEP WATER BENTHIC AND BENTHO-PELAGIC CEPHALOPODS FROM THE NE ATLANTIC by Martin A. Collins¹, Cynthia Yau¹, Louise Allcock² and Michael Thurston³.—The distribution of deep-water (>200m) benthic and bentho-pelagic cephalopods is described, based on specimens collected from commercial and research trawling in the NE Atlantic. Thirty-three species of cephalopod belonging to 11 families were identified, though problems remain with the taxonomy of some of the octopus genera. At the shallower depths (200–500 m) sepiolids were the most abundant group with five species identified. *Sepiolo atlantica*, *Sepietta owenianna* and *Rondeletiola minor* were restricted to the shallow depths (<300 m), but *Neorossia caroli* (400–1535 m) and *Rossia macrosoma* (205–515 m) extended into deeper water. Among the incirrate

octopods, *Eledone cirrhosa* was found to depths of 208–490m. Three putative species of *Benthoctopus* and three of *Bathypolypus* were identified occupying depths of 500–1500 m. *Graneledone verrucosa* was found at depths of 1700–2100 m. The cirrate octopods were the dominant cephalopods from the deeper areas, with *Opisthoteuthis* (2 species) occurring from 800–1500 m, *Stauroteuthis syrtensis* from 1400–2100 m, *Cirrotheuthis* from 500–4000 m, *Cirrothauma* from 2500–4850 and *Grimpoteuthis* (6 putative species) from 1600–4850.—¹Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ. ²National Museums of Scotland, Chambers St, Edinburgh EH1 1JF. ³Southampton Oceanography Centre, Empress Dock, European Way, Southampton, Southampton, SO14 3ZH.

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CLOSING THE LIFECYCLE AND DEVELOPMENTAL PLASTICITY IN SQUID by S. Craig¹, P. R. Boyle², K. D. Black¹ and J. Overnell¹.—The squid *Loligo forbesi* is a fast growing and short-lived (1–2 yrs) species. The short life span and semelparous nature means that populations are determined by the success of the previous years' recruitment. Embryogenesis occupies a considerable proportion of this short life cycle and is, therefore, a critical period of the life of this animal. It is hypothesized that incubation temperature, yolk quality and genotype determine the fitness of the hatchling. Females of this neritic squid spawn eggs in finger-like strings and attach them to rocks and other objects on the sea floor. Temperature is a crucial factor in determining the developmental timing of many squid. In *L. forbesi* the incubation period (egg to hatchling) ranged from a mean of 32 d at 16°C to 130 d at 8°C. There was significant inter-string variation with mean incubation period of egg strings ranging between 45–64 d at 12°C. Within-string variation in development was also observed in the majority of egg strings, with about 20 d existing between the first and last hatchling emergence. Such observed developmental variability may assure a spread of squid recruitment. The principal component of the egg yolk is protein but lipid reserves are also present. Both of the fatty acids eicosapentaenoic and docosahexaenoic acid, deemed essential in membrane phospholipids, are present in eggs of *L. forbesi* in similar proportions to those found in the eggs of cod and herring. These fatty acids are also associated with vision, clearly important in a predator. There is some evidence that fatty acid profiles are related to the geographic area of origin, which may have important implications for fitness. Larval animals also require trace metals, invariably the most important stores are those of zinc and copper. Zinc is abundant in eggs of *L. forbesi* and the binding protein is presently being isolated and characterized. This work is contributing to a greater understanding of the environmental and biochemical factors affecting the variability in recruitment in loliginid populations and the plasticity of life cycles.—¹Dunstaffnage Marine Laboratory, P.O. Box 3, Oban, Argyll, PA34 4AD. ²Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, U.K.

AN EMPIRICAL MODEL FOR THE RELATIONSHIP BETWEEN SQUID ABUNDANCE AND ENVIRONMENTAL CONDITIONS IN FRENCH TRAWLERS NORTH ATLANTIC FISHING GROUNDS by Vincent Denis and Jean-Paul Robin .—In this study, Generalised Additive Models (GAM) fitting techniques were applied to analyse the relationship between loliginid spatial distribution, in the English Channel & Celtic Sea area, and environmental variables. Historical series (1989–1998) of monthly abun-

dance indexes (CPUE) were derived from French commercial trawler data by statistical rectangle. Hydroclimatic conditions are described with a data set (SST, solar flux, atmospheric pressure, wind) extracted from the Météo-France marine database. GAM predicted values were compared with original data and displayed with a G.I.S. The influence of the explanatory variables on loliginid abundance was clearly shown. Climatic variable effects change with time scale. They vary during the year and are mainly important during the pre-recruitment month. GAMs allow explanation of the main part of seasonal abundance variation in time and space in these species. GAMs also provide the first means of predicting the main recruitment peak area by using previous month climatic variables. This work demonstrates the advantages of using commercial fisheries data for ecological studies.—*Laboratoire de Biologie et Biotechnologies Marine de l'Université de Caen.*

SPECIES COMPOSITION AND DISTRIBUTION OF PARALARVAL CEPHALOPODS IN THE SUBTROPICAL NORTH ATLANTIC OCEAN WITH AN EMPHASIS ON SEAMOUNTS by R. Diekmann and U. Piatkowski.—Species composition and distribution of paralarval cephalopods were investigated in two different areas of the subtropical North Atlantic, i.e., on the eastern and western side of the Middle Atlantic Ridge. Specimens were collected during two research cruises (POS 200/1 1993, Sargasso-Sea; M 42/3 1998, Great Meteor Seamount) with different nekton- and macroplankton sampling devices between 300 m depth and the surface. Sampling was carried out on 36 stations in the Sargasso-Sea and 22 stations in the area of the Great Meteor Seamount. In total 2120 individuals were caught representing 20 families and 37 species. A typical subtropical oceanic community was revealed in both areas. Families of significance with corresponding abundances in either location were the Eupoloteuthidae (19.4% of total cephalopods in the Sargasso Sea; 19.1% at the Great Meteor Seamount), the Onychoteuthidae (13.9%; 18.1%) and the Pyroteuthidae (7.6%; 8.7%). Apart from this the oceanic Cranchiidae were less frequent around the Great Meteor Seamount (5.4%) but were dominating in the catches of the Sargasso Sea (26.5%). In the latter the endemic cranchiid *Leachia lemur* was the most abundant species altogether (14.6%). Furthermore, a higher diversity consisting of 34 different species was revealed around the Great Meteor Seamount in contrast to an impoverished fauna of 24 species in the Sargasso Sea. This was caused by the frequent occurrence of varying species of the order Octopodina, Incirrina and some seamount-specific species such as *Spirula spirula* around the bank. In order to resolve the significance of the Great Meteor Seamount for the species composition a non metric multi-dimensional scaling analysis was performed. Besides a divergent composition in several deep-sea stations, no clear pattern concerning the water depth or the geographical proximity of the stations was observed. The analysis of the general cephalopod abundances around the seamount showed higher catches on the leeward side of the seamount, where the pycnocline was sharp and intensified upwelling was described. In addition to the faunal description the vertical distribution of the paralarval cephalopods was investigated in the area of the Great Meteor Seamount. Distinct diurnal vertical migrations were recognised for representatives of the families Eupoloteuthidae and Pyroteuthidae and the species *Onychoteuthis banksii* and *Chtenopteryx sicula*.—*Institut für Meereskunde, Universität Kiel, Düsternbrooker Weg 20, Kiel 24105, Germany.*

SQUID FAMILY VALUES: MULTIPLE PATERNITY OF *LOLIGO FORBESI* EGG STRINGS EXAMINED by *A. M. Emery, L. R. Noble and P. R. Boyle*.—The encapsulated egg strings of *Loligo forbesi* provide a record of the reproductive history of a female. Each embryo within an egg string shares the same mother, but multiple mating can lead to multiple paternity, creating a full-/half-sibling progeny array. Genetic analysis using microsatellite markers has allowed us to reconstruct the relationships between individuals from single egg strings without requirement for parental genotyping. We found patterns of paternity within strings to be diverse; both single and multiple paternity with up to five fathers were observed. In multiple paternity strings, progeny were not evenly distributed among paternity groups and comparisons of several strings from a putative single female indicated that the same fathers were associated with a similar proportion of offspring in each string. Identification of full-/half-sibling relationships also allows investigation into whether multiple paternity contributes to phenotypic as well as genotypic diversity in egg strings.—*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, U.K.*

THE PECULIARITIES OF MORPHOGENESIS OF THE ANTARCTIC SQUID *ALLUROTEUTHIS ANTARCTICUS* ODHNER, 1923 (NEOTEUTHIDAE; OEGOPSIDA) by *Julia A. Filippova*.—The squid *Alluroteuthis antarcticus* is known to be one of the most common species of the Antarctic squid fauna. Although there are numerous records of this squid in Antarctic waters, its morphology, to date, has received little attention. Analysis of 82 specimens with mantle length (ML) ranging from 12 mm to 270 mm allowed us, for the first time, to study ontogenetic changes in morphology from paralarva to adult. The examination of the microanatomy of different parts of the body revealed the presence of a remarkable amount of reticulated connective tissue with large vacuoles in both arms and mantle. This tissue first appeared in paralarvae and juveniles and achieved its greatest development in adults. Apparently it serves as a place for accumulation of ammoniacal liquid allowing the animal to be neutrally buoyant. The following ontogenetic changes of the soft body morphology were found in *A. antarcticus*: the fins become relatively smaller, the arms, larger and the mantle wall becomes thicker. On the whole, these morphological changes indicate the weakening of locomotion abilities and activity of the squids during the growth. Apparently, the weakening of swimming ability is partly compensated for by the development of arms and tentacles. During ontogeny, the suckers of the 1st–3rd pairs of arms gradually transform into hooks. The transformation of suckers into hooks occurs rather late in ontogenesis, at ML > 50 mm (about 1/5 of the adult size) while in other hook-bearing squid families development of hooks occurs already at the paralarval stage. The presence of ammonium-bearing tissue and development of hooks puts *A. antarcticus* apart from two other genera in the family Neoteuthidae: *Neoteuthis* and *Nototeuthis*. The question of possible polyphyly within the Neoteuthidae is discussed.—*VNIRO, 17 Verkhne-Krasnoselskaya Str., Moscow 107140, Russia.*

FIRST RECORDS OF TRAWL COD-END SELECTIVITY FOR CEPHALOPODS IN PORTUGUESE WATERS (ICES DIVISION IXA) by *P. Fonseca and A. Campos*.—In Portuguese continental waters, cephalopod landings represent about 5.8% in weight of the total landings, but that figure triples if the price of first sale is considered. The catches are made by different segments of the fleet, the majority of the octopuses and cuttlefishes are caught by the polyvalent fleet, while squids are caught primarily as a by-catch of the

finfish bottom trawl métier. The economical importance of these species justifies the studies that have been carried out in European waters during the last decade. However, with the exception of the work by Hastie [L. C. Hastie. 1996. Estimation of trawl cod-end selectivity for squid (*Loligo forbesi*), based on Scottish research vessels survey data ICES J. Mar. Sci. 53: 741–744], there are no other references concerning the selectivity of this group of species in EU waters. Recently, a research project (TRASEL), funded by the EU, was carried out with the aim of obtaining selectivity data for different bottom trawl métiers in Region 3. Three surveys were performed on board a commercial trawler on the Portuguese northwest coast (November 1998, June 1999 and August 1999), where 65, 80 and 90 mm cod-end mesh sizes were used. Although fish species were the main objective, it was possible to obtain selectivity data and derive selection parameters for octopus, *Octopus vulgaris*, the European squid, *Loligo vulgaris*, and the broadtail shortfin squid, *Illex coindetii*, in some of the cruises and mesh sizes.—*Department of Fishing Technology, Portuguese Institute for Fisheries and Sea Research, Avenida de Brasilia, 1449-006, Lisbon, Portugal.*

CLINAL VARIATION IN THE GROWTH RATE VERSUS TEMPERATURE RELATIONSHIP OF THE REEF SQUID, *SEPIOTEUTHIS LESSONIANA*, FROM JAPAN, OKINAWA AND THAILAND by *J. W. Forsythe*.—The Pacific reef squid, *Sepioteuthis lessoniana* occurs over a broad geographic range in the Indo-Pacific. From the Red Sea in the east to Hawaii in the west and from North-central Japan in the north to the Central coast of Australia in the south, this species is fished commercially in shallow coastal waters throughout its range. *S. lessoniana* is known to grow quickly reaching sizes of 1–2 kg in less than 1 yr and it is found in waters ranging in temperature from 16°C to 34°C. Over the past several years it has been possible to obtain field collected eggs of this species from the temperate/subtropical area of Tokyo Bay in Japan, the sub-tropical/tropical waters of Okinawa and the tropical waters of the Gulf of Thailand. Growth rate data were collected for each geographic group by culturing two groups of hatchlings concurrently at two different temperatures and comparing growth rates. These findings were then compared to other geographic groups. In growing these different groups through the life cycle, it became apparent that this species did not respond to temperature variation in a uniform manner when comparing results across this geographic cline. There was great consistency within groups with growth rate at a given temperature being very predictable. The slope of the relationship between growth rate and water temperature was almost identical between groups but the relative elevation of the relationship differed significantly. At a common seawater temperature *S. lessoniana* hatchlings from Japan grow faster than their congeners from Okinawa or Thailand. What does this tell us about how *S. lessoniana* adapts to different geographic environments and acute (El Niño/La Niña) temperature anomalies as well as possible responses to chronic (global warming) temperature change?.—*University of Texas, Marine Biomedical Institute, 301 University Boulevard, Galveston, Texas 77555-1163.*

THE EFFECTS OF *AGGREGATA* INFECTION ON CEPHALOPOD PRODUCTIVITY: ULTRASTRUCTURAL, BIOCHEMICAL AND CONDITION ANALYSIS by *C. Gestal¹, A. Guerra², E. Abollo¹ and S. Pascual¹*.—Although the pathogenicity of the intracellular coccidian parasite *Aggregata* in cephalopods is still inconclusive, this parasite is believed to be an important factor in reducing host condition in massive infections. Ultrastructural

techniques were applied to the study of parasitised sections of the caecum of cephalopods, revealing that invaded host cells undergo considerable nuclear and cytoplasmic hypertrophy, and the nuclei became displaced to one side. The submucosa was sometimes ulcerated, and fibrosis and necrosis were observed. In heavy infections, the host tissue was almost completely replaced by parasites. Nucleic acid ratio and RNA to protein ratio were measured in the mantle muscle of wild *Octopus vulgaris* to evaluate sources of variation and growth indices in relation to the infection levels by *Aggregata*. Additionally, variations in the enzymatic activity of maltase, acid phosphatase, alkaline phosphatase and leucinaminopeptidase have been monitored in the caecum of parasitised specimens and those free of infection. Finally, the Fulton-K index was also calculated to sampled octopus to check the existence of significant correlation between cephalopod condition and infection levels. Results showed that RNA-DNA and RNA-protein ratios were all higher in unparasitised octopus than in the parasitised ones. Similarly, the condition index was also higher in unparasitised octopus than in parasitised ones. Lower absorption activity with increasing infection stages was noted as indicated by low peptidase and carbohydrate activity levels in heavily infected cephalopods. Acid phosphatase activity clearly increased with increasing infection values, suggesting a higher lysosomic activity as a consequence of macrophage increasing due to harmful effect of *Aggregata* infection. This overview highlights that coccidian infection by *Aggregata* reduces the condition of exploited octopus. This problem should be considered as an important economic loss at the time of management of infected stocks which are common in nature.—¹*Area de Parasitologia, Fepmar-PB2, Facultad de Ciencias, Universidad de Vigo, Apto. 874, 36200 Vigo, Spain.* ²*ECOBIMAR, Instituto de Investigaciones Marinas, IIM-CSIC, Eduardo Cabello no.6, 36208, Vigo, Spain.*

MICROSCOPIC CELLULAR CHARACTERIZATION OF THE EUROPEAN COCCIDIAN PARASITES OF CEPHALOPODS by C. Gestal¹, A. Guerra², E. Abollo¹ and S. Pascual¹.—In European waters, the type-species of the genus *Aggregata* (*Aggregata eberthi* Labbé, 1895) infects the cuttlefish *Sepia officinalis* in the Mediterranean Sea, North Sea, English Channel, Cantabric Sea and the Atlantic coast of the Iberian Peninsula. Another *Aggregata* species, *A. octopiana* infects the common octopus *Octopus vulgaris* with the same geographical distribution. Scanning electron microscopy (SEM), transmission electron microscopy (TEM) and atomic forces microscopy (AFM) techniques were used to study different topographic and cytological aspects of the architecture of the sporogonial stages of the eimeriorin coccidian *Aggregata octopiana* and compared with the previously studied sporogonial stages of *A. eberthi*. Ultrastructural studies concerning the formation of sporoblasts, sporocysts and number of sporozoites were presented for *A. octopiana*. The surface of the sporocyst, completely smooth in *A. eberthi*, and rough (spiny cover) in *A. octopiana*, seems to be the most distinctive ultrastructure character sufficiently developed, represented, and important enough to be used to distinguish both European *Aggregata* species. The microscopic analysis of the spiny sporocysts cover in *A. octopiana*, a very important diagnostic character for the taxon, makes it possible to clear up the diagnoses of the species, allowing the taxonomic reappraisal of *A. spinosa* Moroff, 1908, as a synonymy of *A. octopiana* Schneider, 1875.—¹*Area de Parasitologia, Fepmar-PB2, Facultad de Ciencias, Universidad de Vigo, Apto. 874, 36200 Vigo, Spain.* ²*ECOBIMAR, Instituto de Investigaciones Marinas, IIM-CSIC, Eduardo Cabello no.6, 36208, Vigo, Spain.*

NOTES ON THE LIFE CYCLE OF *AGGREGATA EBERTHI* AND *A. OCTOPIANA*: EXPERIMENTAL INFECTIONS ON REARED *SEPIA OFFICINALIS* by C. Gestal¹, A. Guerra², E. Abollo¹ and S. Pascual¹.—Mature cuttlefish of both sexes were collected from the Ria of Vigo, and reared in tanks on a recirculating sea-water system. The water was subjected continuously to UV irradiation. Laboratory specimens of *Sepia officinalis* were hatched from eggs laid in the laboratory. Immediately after egg eclosion, specimens were separated into five groups of six individuals, each in different tanks. Cuttlefish were fed ad libitum on free-parasitised live mysid shrimps that were collected daily in the Ria of Vigo. After 50 d feeding, the cuttlefish are ready to be fed on live crustaceans with a known 95% infection prevalence by an unidentified *Aggregata* species. The first group of cuttlefish was fed on *Palaemon elegans*, the second one on *P. adpersus*, the third one on *P. serratus* and the fourth one on *Portunus arcuatus*. After 2 mo, the caecum and intestine of each cuttlefish were fixed in 10% formalin and histologically processed. In the first four groups, 4–6 specimens were found alive at the end of the experiment. Feeding on *P. adpersus*, five specimens were infected with *A. eberthi*. *P. elegans* also infected six specimens, while *P. serratus* did not infect any specimens. Cuttlefish feeding on *Portunus arcuatus* did not survive, all dying within a month. No infection was detected in the group feeding on mysid shrimps. *P. elegans* and *P. adpersus* can therefore be considered to be the intermediate hosts of *A. eberthi*, while *P. serratus*, even though infected with *Aggregata*, does not infect cuttlefish.—¹Area de Parasitologia, Fepmar-PB2, Facultad de Ciencias, Universidad de Vigo, Aptdo. 874, 36200 Vigo, Spain. ²ECOBIOMAR, Instituto de Investigaciones Marinas, IIM-CSIC, Eduardo Cabello no.6, 36208, Vigo, Spain.

ALLOZYME VARIATION IN *OCTOPUS VULGARIS* (CEPHALOPODA: OCTOPODIDA) IN NE ATLANTIC: PRELIMINARY RESULTS by J. M. A. Gonçalves^{1,2}; J. P. Thorpe¹ and R. D. M. Nash¹.—*Octopus vulgaris* is the most well known and best studied of all octopus species. It is an important model for basic research in behavior and physiology. This species is also economically important in the NE Atlantic, supporting large artisanal and industrial fisheries, particularly in Latin countries and NW Africa. Despite its importance, the taxonomic status and geographical distribution are still not well established. Samples of *Octopus* (*O. vulgaris* Cuvier, 1797) were taken from four locations on the Iberian Peninsula and from two Atlantic islands (Azores and Madeira) and were compared by isozyme electrophoresis on starch gels (n = 21–50). In preliminary runs 31 enzymes from the mantle muscle tissue were screened on five buffer solutions. Fourteen of these enzymes (AAT, G3PDH, G6PDH, GPI, IDH, IDDH, ME, MDH, MPI, OPDH, PEP-C, PEP-D, PGD, PGM) showed activity and were resolved in only two buffers (*c*-Tris-Citrate pH7.0, and *c*-Tris-Borate-EDTA pH8.7). Sixteen loci were scored from the zymograms and five of them were shown to be polymorphic (*AAT**, *MDH1**, *MDH2**, *ME2**, *OPDH**). Although smaller differences in allelic frequencies were recorded from the populations studied, the levels of genetic variability were low. The most significant difference was from the island of Madeira, suggesting that it is at least a different population. Heterozygosity was very low, as has been shown for other cephalopod species. The genetic information gathered from this and other studies, plus morphometric and biological data, will help to clarify the geographic distribution and taxonomic status of this species.—¹Port Erin Marine Laboratory, University of Liverpool, Port Erin IM9 6JA, Isle of Man, U.K. ²Departamento de Oceanografia e Pescas, Universidade dos Açores, Cais Santa Cruz, PT-9901-862 HORTA, Açores, Portugal.

BIOLOGY OF *OCTOPUS VULGARIS* CUVIER, 1797 (CEPHALOPODA: OCTOPODIDA) IN THE AZORES (NE ATLANTIC) by J. M. A. Gonçalves^{1,2}, G. P. Carreira¹, H. R. Martins¹ and R. D. M. Nash².—In order to study the general biology of *Octopus vulgaris* in the Azores (NE Atlantic), an annual study, based on monthly samples, from the islands of Faial and Pico was undertaken between February 1998 and March 1999. Biometry, reproduction and condition data were obtained and analyzed from 904 individuals. Arm mutilation was quantified for the first time (82.6% of individuals). Half of the individuals had three or more arms mutilated and larger individuals were more affected than smaller ones. The 2nd and 3rd arm pairs were more mutilated than the others, with the exception of the hectocotylus in males (3rd right arm) which is commonly unamputated. This sexual arm was significantly less mutilated than the corresponding one in females, suggesting a distinct inter-sexual behaviour in the utilization of this arm. The overall length-weight relationship calculated were: $W = 0.241DML^{3.12}$ ($r^2 = 0.88$) for males; $W = 0.326DML^{2.99}$ ($r^2 = 0.89$) for females. The sex ratio was in favor of females (1:0.87), although complementary data suggest a 1:1 sex ratio. Mean size at maturity was larger for females (DML = 16.2 cm, Weight = 1327.0 g) than for males (DML = 9.74 cm, W = 312.8 g). Spawning occurred mainly in Spring (March–July). Two main recruitment periods were recorded: late Summer/Autumn, resulting from individuals hatched in early Spring; and Winter/Spring, corresponding to individuals hatched in late Summer. In immature animals, there was a positive allometric relationship ($b > 3$) between gonad weight and DML, indicating a high investment in genital development. During the final stages of maturity, the digestive gland index (condition) decreased in both sexes, suggesting the use of the reserves from this organ. Somatic loss in brooding females was estimated as 19–29 % of the eviscerated body weight. The overall results from this study indicates that the octopus population of the Azores has similar biological characteristics to the populations in the Mediterranean and on the North West African coast, which may reflect similar ecological conditions.—¹Departamento de Oceanografia e Pescas, Universidade dos Açores, Cais Santa Cruz, PT-9901-862 HORTA, Açores, Portugal. ²Port Erin Marine Laboratory, University of Liverpool, Port Erin, Isle of Man IM9 6JA, U.K.

DEVELOPMENT OF SOFTWARE TO ESTIMATE UNREPORTED OR MISREPORTED CATCH AND EFFORT DATA by J. Gracia¹, A. Guerra¹, F. Rocha¹, A. F. González¹, H. I. Daly² and G. J. Pierce².—The aim of this study is to develop software for the estimation of unreported or misreported catch and effort data using the approach developed by Gómez Muñoz (1990). The target species were hake, megrim, monkfish and commercially exploited cephalopods from areas VI, VII and VIII of ICES. A total of 82 fishing ports along the Galician coast (NW Spain) and four ports in Scotland were studied from January 1998 to December 1999. Data on fleet and catches of these ports were obtained for 1997 and 1998. A total of 38 Galician ports with catches of the target species were selected. Monthly catches of the target species from landings in these ports were obtained. Sampling at the ports with the highest target species landings (8) was carried out in order to obtain direct catch data. An interview protocol was created. In total, 508 and 26 interviews were carried out in Galicia and Scotland, respectively. The whole set of data (fleet, landings, direct catch data and interviews) was analysed, classified and introduced in a database created for this purpose. Software was developed, which allowed the input of fleet and interview data for each port, and the acquisition of: (1) Categorisation of the ports by fishing ground and fishing gear to select the model port; (2)

Total catch by species, fishing ground and gear in the model ports; (3) Total catches in the remaining ports from results obtained in each model port, considering the number of vessels of the same characteristics in each port; (4) Catch per unit effort for each gear, fishing ground and species in each model port; (5) Catch per unit effort in the remaining fishing ports. Accuracy of the catches obtained from interviews processed by the software was assessed by comparison with direct catch data. Bias between landings and data from the model is discussed.—¹*Instituto de Investigaciones Marinas (CSIC), Eduardo Cabello 6, 36208 Vigo, Spain.* ²*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, U.K.*

ACCESSORY NIDAMENTAL GLANDS SYMBIOTIC ASSOCIATIONS IN SEPIOIDS AND MYOPSIDS by *S. Grigioni, D. Pichon and R. Boucher-Rodini*.—Female cuttlefish harbour a dense bacterial community in their Accessory Nidamental Glands (ANG), as is also the case for the myopsid squids. Molecular approaches have been applied to explore this symbiotic association in sepoids (*Sepia elegans*, *S. esculenta*, *S. recurvirostra*, *S. pharaonis*, *Sepietta neglecta*, *Sepiolo intermedia*) and myopsids (*Loligo vulgaris*, *Photololigo chinensis*, *P. edulis*, *Sepioteuthis lessoniana*). In situ localization by bacteria specific probes in tissue sections of the ANG revealed the presence of a dense bacterial population in the lumina of the organ tubules. Bacterial morphology and the use of specific probes, allowed to point out differences in the composition of each bacterial population. Restriction fragment length polymorphism analysis was carried out on the strains associated with the different species. The phylogenetic identification of some bacterial strains was realised by 16S rRNA gene sequencing analysis in the various sepoid and myopsid species. Some bacteria seem to be ubiquitous (*Agrobacterium* bacterial group and *Rhodobium-Xanthobacter* bacterial group) and other more specific (Gram positive strains and *Roseobacter* bacteria group). The investigation of a larger sample of bacterial symbionts of the ANG is currently underway.—*Muséum National d'Histoire Naturelle, Biologie des Invertébrés Marins et Malacologie, 55 Rue Buffon, Paris 75005, France.*

SYMBIOTIC ASSOCIATIONS IN *SEPIA OFFICINALIS* by *S. Grigioni and R. Boucher-Rodini*.—Bacteria populations associated with *Sepia officinalis* have been localized in various organs and characterized phylogenetically by means of molecular biology techniques. Various bacteria strains are present in the accessory nidamental glands, the renal appendages and the shell epithelium. Bacteria 16SrDNA sequencing identifies five symbiotic taxa in the accessory nidamental glands (*Agrobacterium*, *Roseobacter*, *Rhodobium-Xanthobacter*, *Sporichthya*, *Clostridium*). Only the *Roseobacter* group is already known from the ANG of another cephalopod, the myopsid squid *Loligo*, the other strains are probably specific to *Sepia officinalis*. In situ hybridization confirms that the various bacteria strains are located in the tubules of the glands. In the renal appendages and the shell epithelium three taxa belonging to the family Pseudomonaceae are identified. This family is characterized by its activity in nitrogenous products recycling. In the symbiotic association, these bacteria strains may participate to the reactions involved in the transformation of ammonia into gaseous nitrogen, which accumulates in the cuttlebone chambers. All the bacteria strains described from *Sepia officinalis* organs, except Gram positive bacteria, are also present in the embryos before hatching, which suggests vertical transmission, i.e., maternal transmission at egg stage, for these symbiotic associations.—*Muséum national d'Histoire naturelle, Biologie des Invertébrés Marins et Malacologie, 55 Rue Buffon, Paris 75005, France.*

THE ARTISANAL FISHERIES FOR *OCTOPUS CYANEA* IN TANZANIA by *Martin Guard*¹, *Saleh Yahya*² and *Peter Boyle*¹.—Artisanal fishing for *Octopus cyanea* is an important economic and subsistence activity for local coastal communities in East Africa. Yet, little information is available on the life cycle and ecology of *O. cyanea* in East African tropical waters and the impacts of fishing on local octopus stocks. To address these issues a collaborative study of the artisanal fisheries of *O. cyanea* in Tanzania was initiated between the University of Dar es Salaam, Tanzania and the University of Aberdeen, Scotland with financial support provided by WWF, Tanzania. The study is being conducted over a 2 yr period at four locations along the coast: Mafia Island Marine Park, Men Bay Conservation Area, Mnazi Bay, Mtwara and Tanga district. The main objectives of the study are: (1) to train and utilize local community research assistants to collect octopus catch and effort data from sites undergoing different fishing intensities, (2) determine ecology and life history characteristics for *O. cyanea* at comparable sites, (3) determine the impact and effects of fishing on local octopus stocks through analysis of catch and life history data and applied experiments (4) develop a database of octopus catch and research data and (5) provide recommendations for the effective management of artisanal octopus fisheries.—¹*Department of Zoology, University of Aberdeen, Scotland, U.K./University of Dar es Salaam, Tanzania.* ²*Institute of Marine Sciences, Zanzibar, Tanzania.*

DYNAMICS OF THE MATING SYSTEM OF THE GIANT AUSTRALIAN CUTTLEFISH *SEPIA APAMA*, GRAY by *Karina C. Hall*¹ and *Roger T. Hanlon*².—Mating systems are not well characterized in cuttlefish, particularly from field studies. A sizeable aggregation of reproductively active *S. apama* is the basis of a small fishery in northern Spencer Gulf, South Australia. Thousands of cuttlefish aggregate to spawn over a small area of rock reef during the austral winter. Our goal is to behaviorally sample this mating system in a quantitative manner to sort out mechanisms of sexual selection, sperm competition, mating and egg production. During the 1999 spawning season, 26 h of behavior sampling was undertaken using underwater video techniques. Analysis revealed a complex mating system with multiple reproductive tactics used by both sexes. The sex ratio was an average of four males to each female, resulting in intense male-male competition for females. Large males formed pairs with females and exhibited strong mate guarding (both pre- and post-copulation), which is a key feature of sperm competition. Lone large males searched out pairs and challenged paired males for females through dramatic agonistic displays. Small males spent most of their time searching for lone females and opportunities for extra-pair copulations; they used open stealth, hidden stealth and female mimicry to achieve sneak matings. Males of all sizes and tactics gained copulations, but they varied in mating success. Females accepted multiple mates, showed rare signs of direct mate choice, and successfully rejected unwanted matings. They spent most of their time laying eggs and searching for appropriate egg laying sites under rocks.—¹*University of Adelaide, Adelaide, South Australia.* ²*Marine Biological Laboratory, 7 MBL Street, Woods Hole, Massachusetts 02543.*

DEMONSTRATION OF MULTIPLE PATERNITY WITHIN INDIVIDUAL EGG CAPSULES OF *LOLIGO PEALEII*: GENETIC AND BEHAVIORAL EVIDENCE FROM FIELD AND LABORATORY STUDIES by *R. T. Hanlon*, *M. R. Maxwell*, *K. M. Buresch*, *S. Ring*, *N. Shashar* and *R. B. Sussman*.—We examined the possibility that most egg capsules (each containing about 200 eggs) are fathered by multiple males. We used three

approaches: extensive video behavioral recordings from natural spawning congregations, controlled mating experiments in the laboratory, and random collection of egg capsules from the field. Field video revealed that multiple mates are common for both sexes, sometimes even within an hour's time. Males of different sizes showed up to five tactics to obtain copulations with females. Controlled laboratory trials provided egg capsules with known mating history and parentage. DNA fingerprinting (using microsatellite polymorphisms) confirmed multiple paternity both in the laboratory trials and in field-collected egg capsules. Initial genetic data show that among large consort males paired with a female, the last to copulate in the male-parallel position usually showed precedence in paternity. Smaller, non-consort 'sneaker' males obtained extra-pair copulations and succeeded in fertilizing eggs in lower percentages than large paired consort males. We discuss the significance of these findings with respect to management of the fishery, which partly targets spawning squids.—*Marine Biological Laboratory, 7 MBL Street, Woods Hole, Massachusetts 02543.*

GEOGRAPHIC AND TEMPORAL PATTERNS IN *LOLIGO PEALEII* SIZE AND MATURITY OFF THE NORTHEASTERN UNITED STATES by *Emma M. C. Hatfield¹ and Steve X. Cadrin²*.—Analysis of 31 yrs of survey catches indicate significant patterns in the distribution of *Loligo pealeii* over the northwest Atlantic US continental shelf, by geographic region, depth, season and time of day. Catches were greatest in the mid-Atlantic Bight, with significantly greater catches in deep water during winter and spring, and in shallow water during autumn. Body size generally increases with depth in all seasons. Large portions of juveniles in shallow waters off southern New England during autumn result from observed inshore spawning during late spring and summer; large portions of juveniles in the mid-Atlantic bight during spring suggest that substantial winter spawning also occurs. Dissection of survey sub-samples indicates that few mature squid are caught in surveys. A large portion of observed mature squid were captured south of Cape Hatteras during spring. These analyses confirm that spawning occurs inshore from late spring to summer and suggest that winter spawning occurs primarily south of Cape Hatteras.—¹*FRS Marine Laboratory Aberdeen, P.O. Box 101, Victoria Road, Aberdeen, AB11 9DB, Scotland, U.K.* ²*NOAA/NMFS/NEFSC, 166 Water Street, Woods Hole, Massachusetts 02543.*

LABORATORY TESTING OF A GROWTH HYPOTHESIS FOR JUVENILE SQUID, *LOLIGO PEALEII* (CEPHALOPODA: LOLIGINIDAE) by *Emma M. C. Hatfield¹, Roger Hanlon², John Forsythe³ and Eric Grist⁴*.—Growth modelling in squid has been hampered by a paucity of raw growth data on live individuals. We grew wild-caught juvenile *Loligo pealeii*, from the north-eastern United States, for up to 97 d post-capture, to determine the form of growth and to test the hypothesis that a 5°C difference in temperature would produce a significant growth rate increase. Using statolith increment analysis it was possible to estimate the age of seven squid on the day of capture. From these data, pre-capture growth rates (IRGR — the instantaneous relative growth rate or percent increase in body mass per day) of 8–11% were estimated. Laboratory growth rates over a maximum of 97 experimental days fell into two phases. In phase 1, 6 of 9 squid grew exponentially; in phase 2, 5 of 6 squid also grew exponentially, albeit at a slower rate. In both phases, the values of IRGR were significantly higher for squid reared at 20°C than at 15°C: phase 1 rates were 4.36 vs 2.69; phase 2 rates were 2.57 vs 1.63. The IRGR values

obtained experimentally were used to simulate growth of squid hatched in nature from May to September. The growth simulations indicated that, by the end of Phase 1 growth, the squid hatched in June and July were 2 and 3 times the weight, respectively, at the same age, as squid hatched in May. Although the younger cohorts did not actually surpass older ones in size in the simplified climatic scenario simulated here, the potential for them to do so was self evident. This illustrates why length frequency analyses, not calibrated with statolith ageing data (which would compensate for temperature), can grossly miscalculate cohort age and growth rates.—¹FRS Marine Laboratory Aberdeen, P.O. Box 101, Victoria Road, Aberdeen, AB11 9DB, Scotland, U.K. ²Marine Biological Laboratory, 7 MBL Street, Woods Hole, Massachusetts 02543. ³University of Texas, Marine Biomedical Institute/NRCC, 301 University Boulevard, Galveston, Texas 77555-1163. ⁴School of Biological Sciences, Royal Holloway, University of London, Egham TW20 0EX, U.K.

DO MORPHOLOGICAL AND MOLECULAR PHYLOGENIES SHOW CONGRUENCE IN THE SHALLOW-WATER OCTOPUS FAUNA OF FIJI? by Heather A. Herb.—Despite the more than 200 named species, few *Octopus* (Cephalopoda: Octopodidae) species have been described in detail. The poor taxonomy of these *Octopus* species is particularly evident in the Indo-West Pacific region, where many undescribed species and several unresolved species complexes are found. Because of the status of the systematics of the Indo-West Pacific fauna, more comprehensive studies of areas, such as Fiji, are needed. As with other areas in the region, the octopus fauna of Fiji is important because of the diversity of the fauna, the exploitation by subsistence fishing, and the particular species found in the area. In an effort to begin to resolve the problems associated with shallow-water octopus systematics in the Indo-West Pacific, the objectives of this study are to identify the shallow-water octopus fauna of the Fiji islands, using morphological characters, behavioral and body patterning characters, and genetic analyses. In addition, two alternative methods, morphology and molecular analysis, will be used to develop phylogenetic trees describing these species. The phylogenies developed for the Fiji shallow-water octopus fauna will be used to test for congruence in percent variation between species using morphological characters and molecular characters.—Department of Fisheries and Aquatic Sciences, University of Florida, 7922 NW 71st Street, Gainesville, Florida 32653.

BEAKS OF *ILLEX COINDETII*: GROWTH AND DARKENING PROCESS IN RELATION TO SEXUAL DIMORPHISM AND REPRODUCTIVE ASPECTS by V. Hernández-García.—The beaks of 200 specimens of *Illex coindetii* caught as by-catch by the fishing trawl fleet operating off northwest Africa were studied in order to determine possible sexual dimorphism and ontogenetic morphological changes. The development of the darkening process was also studied and a species-specific scale was constructed. Differences in growth rate between sexes were observed (an overall difference of 0.2 in the slope of the regressions) and differences between sexes within the life cycle were also found. Growth inflection points were estimated to be at around 150 and 200 mm mantle length (ML) for males and females respectively. The darkening process started earlier in males (at a smaller ML). The changes observed coincide with the maturation process in both sexes.—Sea Fisheries Institute, Gdynia, Poland.

ANALYSIS OF MITOCHONDRIAL DNA CYTOCHROME OXIDASE I DIVERGENCE SUGGESTS THE CRYPTIC STATUS IN *OCTOPUS MARGINATUS* (CEPHALOPODA: OCTOPODIDAE) by ^{1,3}Chuan Wen Ho, ²Chung Cheng Lu, ³Chang Feng Dai and ¹Chaolun Allen Chen.—DNA sequences of the mitochondrial cytochrome oxidase I (mtCOI) gene was obtained from fresh or frozen gill tissue of specimens belonging to *Octopus marginatus* and *Octopus aegina* from the coastal waters of Taiwan. A 509 bp fragment of the mtCOI gene was sequenced and aligned to the orthologous sequences available from *Octopus* species in the database. The mtCOI gene phylogeny revealed that *O. marginatus* was segregated into two distinct clades. The distinctness of these two clades is supported by a high nucleotide divergence of 8.8%, suggesting that cryptic species exist in *O. marginatus* around the water of Taiwan.—¹R131, Institute of Zoology, Academia Sinica, Nankang, Taipei, Taiwan 115-29. ²Department of Zoology, National Chung Hsing University, Taichung, Taiwan 402-27. ³Institute of Oceanography, National Taiwan University, Taipei, Taiwan 106-17.

MOLECULAR TECHNIQUES AND PHYLOGENY OF OCTOPODS by Cendrine Hudelot.—Genetic techniques were used to construct a phylogeny of octopods. The study focused on the genus *Octopus* but considered all the octopuses. Different experimentations were pursued but only two genes give interesting results and were intensively sequenced. The 3' end of the LrRNA gene (or 16S) produced a portion of around 500 bp was analyzed for ca forty species. Its infraspecific variations were examined in several species. This gene is mostly conserved and is present in different variable regions. Because of important saturation phenomenon, it only allows discrimination of Octopoda genera but seems to be more powerful for Cirroctopoda. The 16S shows a difference of evolution rate between groups, mainly based on the variation of nucleotides which are subject to mutations. The third sub-unit of the cytochrome oxydase (or COIII) gave a longer fragment (660 bp) and was sequenced only for 20 species. This gene seems to be informative when amino-acid sequences were analyzed. The third position in the codon is too variable and the other positions are too constant for studies at a nucleotide level. The main conclusion is the different evolution rate of these two molecular markers between decapods and octopods. The last ones present a faster rate of evolution. The different classification levels are really different between the two groups. Another important result is that the search of more specific mitochondrial and nuclear primers at all level of the classification is urgently needed to continue.—*Museum National d'Histoire Naturelle, Biologie des Invertebrates Marins at Malacologie, 55 Rue Buffon, 75231 Paris, Cedex 05, France.*

INITIAL TRIALS ON SQUID REARING, MAINTENANCE AND EXPERIMENTATION AT THE BRAIN SCIENCE INSTITUTE OF RIKEN by Yuzuru Ikeda¹, Ikuko Sakurazawa¹, Keiko Ohkawa¹, Hitoshi Yamada¹, Michinori Ichikawa¹, Yasunori Sakurai² and Gen Matsumoto¹.—The Brain Science Institute was established to understand the brain using cephalopod models using both ethological and molecular approaches. A special facility, the Center for Squid Culture and Behavioral Research, was opened in January 1999. The initial work dealt with technical problems such as methods of squid transfer, type of aquaria used, and type of diet. Several types of closed-system aquaria are used: a large circular tank (10,000 L); a small circular tank (1700 L); cylindrical tanks (eight of 20 L and eight of 50 L). Two species of squid (*Loligo bleekeri*, *Sepioteuthis*

lessoniana) and a cuttlefish (*Sepiella japonica*) were hatched and cultured from eggs, while wild-caught adult *L. bleekeri*, *S. lessoniana*, and *Todarodes pacificus*, were maintained. Hatchlings of *S. lessoniana* and *S. japonica* were successfully cultured in cylindrical tank for 5 mo and 10 mo, respectively. *L. bleekeri* hatchlings survived nearly 2 mo in cylindrical tank. Adult squids were successfully maintained in the large tank for the following durations: *L. bleekeri*, 78 d; *T. pacificus*, 21 d; *S. lessoniana*, 5 mo. A wide variety experiments can now be undertaken using live squid and cuttlefish at this facility, but some modifications are still needed for culturing more delicate species such as *L. bleekeri*.—¹Brain Science Institute, RIKEN, Wako, Saitama 351-0198 Japan. ²Graduate School of Fisheries Science, Hokkaido University, Hakodate, Hokkaido 041-8611 Japan.

DEVELOPMENT OF REPRODUCTIVE ORGANS AND CHANGES IN NUTRITIONAL STATE DURING THE SPAWNING MIGRATION OF THE JAPANESE COMMON SQUID (*TODARODES PACIFICUS*) by H. Kidokoro.—Development of the reproductive organs and changes in the nutritional state of Japanese common squid (*Todarodes pacificus*) were examined during its spawning migration in the southwest Sea of Japan and East China Sea. Analyses were made based on maturity and nutritional indices calculated from measurements of mantle length (ML), body weight (BW), mantle weight (MW), digestive gland weight (DGW), testis weight (TW), accessory gland weight (AGW), ovary weight (OW) and oviduct weight (ODW). The maturity indices included TSI (= TW/BW), AGSI (= AGW/BW), OSI (= OW/BW), and ODSI (= ODW/BW). The nutritional indices included the hepatosomatic index (HSI = DGW/BW) and the mantle thickness index (MTI; = MW/ML³). The relationships between the indices and sea surface temperature (SST) were examined to observe how the reproduction organs and nutritional state changed during the southeastward migration to warmer waters. Most males were mature, with numerous spermatophores present in their accessory glands. Average TSI and AGSI values at SST < 20°C were high (ca 3.0%), but at SST > 20°C, the average TSI was lower (2.0–2.5%). Most females collected at SST < 15°C were immature, with low average OSI and ODSI values (1.5 and 0.2%, respectively), while most collected at SST > 15°C were mature, with high average OSI and ODSI values (3.5 and 3.0%, respectively). At SST > 20°C, the average OSI was high (5.0%), but the average ODSI was relatively low (2.0%). The HSI and MTI decreased for both sexes as SST increased, and most individuals collected at SST > 20°C were spent.—Japan Sea National Fisheries Research Institute, 1-5939-22, Niigata-shi, 951-8121, Japan.

CEPHALOPOD FAUNA IN JAPANESE WATERS by Tsunemi Kubodera¹ and Takashi Okutani².—Many studies have listed the cephalopod species that occur around the Japanese Archipelago. 169 species of cephalopod from Japanese and adjacent waters have been listed. However, many of them have been recorded only once from a single locality and many of the type specimens from the early 20th century have been lost. Systematic confusions still exist in some genera and families. This study documents the cephalopod species collected around Japan by the National Science Museum (Tokyo) during several surveys conducted off Ayukawa, the Sea of Japan (1986), off Cape Erimo, Hokkaido (1993), off Sanriku and Joban, northeastern Japan (1996), Suruga Bay, central Japan (1997), the East China Sea (1998) and research continues in Tosa Bay, western Japan and the Seto Inland Sea. A total of 121 species were identified, including several previously undescribed. Additional data from registered specimens at the museum and other recent

reports bring the total number of cephalopod species that occur around Japan to 169. This group comprises a single species from nautilid, 115 species from the Decapodiformes (including 1 spirulid, 22 sepiids, 1 sepiadariid, 10 sepiolids, 1 idiosepiids, 9 loliginids, 12 enoploteuthids, 1 pyroteuthid, 1 ancistrocheiid, 3 octopoteuthids, 5 onychoteuthids, 12 gonatids, 1 cycloteuthid, 2 architeuthids, 1 lepidoteuthid, 1 pholidoteuthid, 5 histioteuthids, 1 chtenopterygid, 1 thysanoteuthid, 7 ommastrephids, 3 mastigoteuthids, 3 chiroteuthids, 1 promachoteuthid, 1 joubiniteuthid, 1 grimalditeuthid, and 9 cranchiids) and 53 species from the Octopodiformes (including 1 vampyroteuthid, 1 cirroteuthid, 1 stauroteuthid, 4 opisthoteuthids, 1 bolitaenid, 1 amphitretid, 38 octopodids, 1 tremoctopodid, 1 ocythoid, 3 argonautids, and 1 alloposid). The Japanese Archipelago is located at the eastern periphery of the Asian continent with more than 6800 islands, extending north to south from 45°31'N (Cape Soya) to 24°02'N (Hateruma Island) for about 2600 km. It is surrounded by the relatively shallow and narrow Sea of Japan to the west and the deep and vast North Pacific to the east. The warm Kuroshio Current flows from the south and washes along the western coasts, while cold Oyasho waters come down from the north and reach the northern coasts. They meet and mix off middle Honshu, Main Island, forming a large-scale oceanographic front. Such complicated geographical and oceanographic conditions of Japanese waters may provide a considerably rich cephalopod fauna. They can be roughly divided into subtropical, temperate and subarctic components. The species listed from the Ryukyu Islands and the East China Sea are considered to be the subtropical component and the species listed from Suruga Bay, Tosa Bay and the Seto Inland Sea, the temperate component; those listed from the Northeastern Pacific are a mixture of subarctic and temperate components. Although there are data from more than 10 yrs of surveys on cephalopod fauna around Japanese waters, several species, especially octopodids described by Sasaki (1929 Journal of the Faculty of Agriculture, Hokkaido Imperial University, 20(suppl.): 1-357+pls. 1-30.), have not yet been recovered. Further extensive research is required.—¹National Science Museum Tokyo, Department of Zoology. ²Nihon University, College of Bioresource Sciences.

COMPARISON OF LM - AND SEM - DERIVED AGES OF *LOLIGO PEALEII* by Marek R. Lipinski¹, William K. Macy², and Deon M. Durholz¹.—Ages of *Loligo pealeii* from the NW Atlantic were estimated using two light microscopy preparations for one statolith from the pair, and SEM preparations for the other statolith. While presumptive daily increment counts from statoliths ground in the oblique frontal plane agreed well with those of transverse sections, they differed greatly from the SEM data. At this time the reason(s) for this discrepancy is not known. It is possible that the much higher resolution SEM method reveals sub-daily micro-increments or that some feature of the crystalline structure not related to temporal differences in statolith deposition was counted.—¹DEAT, Private Bag X2, Roggebaai 8012, South Africa. ²University of Rhode Island, Narragansett, Rhode Island 02882.

LIFE HISTORY PARAMETERS OF SQUID by William K. Macy, III¹ and Jon K. T. Brodziak².—The main objectives of this research program were to learn how basic life history parameters, such as size, age and maturity, vary between seasonal cohorts and to learn if heavy offshore winter fishing pressure could be related to the recent decline of summer inshore catches. Samples of squid, taken from inshore and offshore fisheries from 1993–1997, were measured and their sexual maturity state determined. Representa-

tive size-stratified sub-samples were aged using statolith microstructure. The population structure was found to be quite variable with regards to season, size distribution, and sexual maturity. In general, size and age were not highly correlated, but highly significant relationships were found for sexually undifferentiated juveniles. The age structure of the samples was remarkably stable throughout the year except fall, with modal ages at capture of only 150–180 d. Spawning was shown to occur throughout the year. Since both offshore and inshore samples were about the same age it is evident that the two respective fisheries do interact.—¹*Graduate School of Oceanography, University of Rhode Island, Narragansett.* ²*National Marine Fisheries Service, NEFSC, Woods Hole, Massachusetts.*

FEMALE REPRODUCTIVE OUTPUT IN THE SQUID *LOLIGO PEALEII*: MULTIPLE EGG CLUTCHES AND IMPLICATIONS FOR A SPAWNING STRATEGY by *Michael R. Maxwell and Roger T. Hanlon.*—We examined female reproductive output by recording the egg-laying histories of individuals in addition to measuring gametes that remained in their reproductive tracts. Combining the results of two summer spawning seasons (1997 and 1998), 28 of 47 wild-caught females that laid eggs in captivity produced substantial clutches (i.e., five or more egg capsules per clutch) at least twice. The ages of the 47 females spanned 4–6 mo. Multiply-ovipositing females exhibited a variety of patterns of oviposition, ranging from relatively small clutches at short intervals to large clutches several weeks apart. Actual reproductive output varied greatly between females. In both years, the number of egg capsules and ova laid showed a negative relationship with the combined mass of the ovary and oviduct at death. Importantly, the number of ova laid in captivity (mean = 11,800 in 1997 and mean = 15,293 in 1998) exceeded the combined number of ova and oocytes remaining in the females' bodies at death (mean ca 4500 in both years) by roughly 3x, providing an indication of the extent to which counting remaining oocyte and ova can underestimate fecundity. Neither age nor mantle length consistently affected reproductive output, i.e., short young females could be just as fecund as longer older females. The females of 1 yr (1998) were maintained in isolation without access to males and laid fertile eggs, demonstrating the use of stored sperm. For females that had oviposited in both years, the oocytes remaining in the ovary always ranged greatly in size and structure. Thus, the 'spawning strategy' of *Loligo pealeii* appears to involve multiple ovipositions over weeks or months, with oocytes possibly being developed continually. In a larger context, reproduction by females in this species most likely entails copulation with multiple males and the laying of multiple clutches of eggs, possibly in different locations.—*Marine Biological Laboratory, Woods Hole, Massachusetts 02543.*

DISTRIBUTION AND COMMUNITY STRUCTURE OF EPIPELAGIC SQUIDS IN THE KUROSHIO-OYASHIO TRANSITION ZONE, WESTERN NORTH PACIFIC by *Ken Mori,¹ Kotaro Tsuchiya,² and Kinoshita Takaaki¹.*—The Kuroshio-Oyashio Transition Zone of the western North Pacific is recognized as an important nursery ground for both pelagic fishes of fisheries importance, such as mackerel, sardine and Pacific saury, and the large pelagic squids such as *Todarodes pacificus* and *Ommastrephes bartrami*. The present study aims to clarify the distribution of epipelagic cephalopods in the Kuroshio-Oyashio transition zone, and discuss the cephalopod community structure. Materials were collected with a large pelagic trawl net by the RV KAIYO-MARU in 1987, and the RV TANSHU-MARU during May–June of 1995 and 1996 in the water east of Honshu, Japan (32–40°N, 141–170°E) at depths of 0–200 m (mainly 0–25 m). Based on the three cruises,

it was recognized that the community mainly consisted of three families, Enoploteuthidae (e.g., *Watasenia scintillans*), Ommastrephidae (e.g., *Todarodes pacificus*) and Onychoteuthidae (e.g., *Onychoteuthis borealijaponica*), which accounted for 92–99% of the population, and 99% of the total volume of cephalopods. With the exception of some large mature *W. scintillans* and *Eucleoteuthis luminosa*, most of the sampled squid were young and immature. The survey area was divided into two major areas bounded by the 160°E line. Western water had abundant populations of distant-neritic species such as *T. pacificus* or *W. scintillans*, in contrast to the eastern water with the open water species such as *Abraliopsis felis*. The north-south distribution pattern of each species corresponded with the position of Kuroshio or Oyashio water front at 200 m depth. The distribution pattern was classified into six categories related to distribution area and size. The majority of distributed species only used the transition zone occasionally or temporarily in their life cycle. Few species completed their entire life cycle within the transition zone.—¹Hokkaido National Fisheries Research Institute, Kushiro, Hokkaido 085-0802. ²Tokyo University of Fisheries, Konan, Minato, Tokyo 108-8477, Japan.

BIOMASS OF THE JUMBO SQUID *DOSIDICUS GIGAS* IN THE EEZ OF NICARAGUA AND ADJACENT OPEN WATERS by Ch. M. Nigmatullin., Yu. M. Froerman and Yu. N. Zheronkin.—There are no biomass estimations for *Dosidicus gigas* in the Central East Pacific. The abundance of *D. gigas* was assessed at 221 light night drifting stations during eight seasonal surveys in the Nicaraguan EEZ in 1984–1986. Squid were distributed throughout the EEZ to the west of the shelf break (32,500 km²). Its size structure and distribution varied during these surveys. The total biomass of *D. gigas* fluctuated significantly: 107,000 mt (October 1984), 150,000 (November 1984), 190,000 (March 1985), 275,000 (August 1985), 100,000 (March 1986), 20,000 (June 1986) to 12,000 (May 1986) and 163,000 t (June 1990). In the open waters outside the EEZ (8–13°N), ecological investigations of *D. gigas* and the active Soviet pelagic trawl fishery were carried out in 1989–1991. The total catch was 2447 t in 1989 and 9800 t in 1990. The biomass of *D. gigas* in a high productive zone of the Costa Rica Dome (9°20'–10°12'N, 89°20'–90°46'W) was estimated by two methods in 1990. The June trawl survey over an area of 36,442 km² revealed a biomass of 1,001,000 t. Most of these squids (675,000 t) occurred in the dense aggregations in the Dome water mass throughout an area of 1518 km². The second assessment based on the trawl fishery data showed similar values: 1,114,000 t in June, and 825,000 t in July throughout an area of 58900 km², and 681,000 t in August (area of 69,600 km²). In the areas of fishery concentrations with catches greater than 0.3 t h⁻¹ the squid biomass was 975,000 t (area of 35,600 km²) in June, 648,000 t (29,500 km²) in July, and 477,000 t (35,300 km²) in August. Due to the relatively stable CPUE, the habitual round-the-year biomass of *D. gigas* in the Dome area may be assessed to be approximately 0.5–1.0 million t.—Atlantic Research Institute of Fisheries and Oceanography (AtlantNIRO), 5 Dmitry Donskoj Str., Kaliningrad 236000 Russia.

DISTRIBUTION AND BIOMASS OF THE OMMASTREPHID SQUIDS IN THE SOUTH-EASTERN PACIFIC IN THE EARLY 1980S by Ch. M. Nigmatullin¹, A. V. Parfenjuk¹ and R. M. Sabirov^{1,2}.—The ecological investigations of ommastrephid squids were carried out in the open waters of the Southeast Pacific both outside the EEZ (3°N, 25°S) and inside the EEZ in 1979–1984 at 1460 light night drifting stations. Abundance and biomass (BS) of squid were estimated by the method of visual counting at light

stations. The two dominant species *Dosidicus gigas* and *Sthenoteuthis oualaniensis* were present. In the Western Equatorial area (1°N–1°S, 95–106°W, 123,000 km²) the BS in April–May 1981 was 940,000 metric t. The stock consisted of *S. oualaniensis* (75%) and *D. gigas* (25%). In the Eastern Equatorial area (a narrow zone between the boundaries of the EEZ, 3°N, 5°S, 280,000 km²) the BS in same period was 300,000 t of *D. gigas* (83%) and *S. oualaniensis* (17%). In the open waters of the Peruvian region (5–25°S, from the EEZ boundary to 95°W, 1,020,000–1,630,000 km²) squid distribution and BS were studied in different seasons during 1982. In April–June the BS was 1,770,000 t. In July–September the BS increased to 2,190,000 t and in October–December it was 2,020,000 t. *D. gigas* dominated in all seasons, its proportion of the total BS being 57%, 76% and 80% respectively. The biomass of *D. gigas* changed during the year in the opposite way to *S. oualaniensis* abundance fluctuations, therefore the total BS was relatively stable. *D. gigas* was particularly abundant in eastern and southeastern parts of the investigated area, but *S. oualaniensis* dominated in the western part. The latter formed no monospecific dense aggregations (>2500 kg km⁻²). The dense aggregations of *D. gigas* were assessed as 175,000; 1,250,000; and 550,000 t in the mentioned seasons. The respective total BS (together with *S. oualaniensis*) in aggregations was 750,000; 1,550,000; and 1,100,000 t. These aggregations were located in the zone of divergence of the Peruvian Oceanic Current (17–22°S), and in the areas of meanders on the western periphery of this current.—¹AtlantNIRO, 5 Dmitry Donskoj Str., Kaliningrad, 236000 Russia. ²Kazan State University, 18 Kremlevskaya Str., Kazan 420008 Russia.

BIOLOGY OF THE CIRRATE OCTOPOD *OPISTHOTEUTHIS CALIFORNIANA* IN THE NORTH-WESTERN PART OF THE BERING SEA by Ch. M. Nigmatullin.—The north-western part of the Bering Sea is the most northern periphery of the range of *Opisthoteuthis californiana*. The samples were collected by bottom trawls in the Russian EEZ from 168°E to 179°W at depths of 100–700 m in 1995–1997. The catches of 200 trawls and 1360 specimens of *O. californiana* were analysed. *O. californiana* occurred relatively uniformly at depths between 300–700 m. Its number and biomass in the 5399 nm² area were 319,000 specimens and 366 mt in September 1997 and 58,000 specimens and 67 t in November 1997. Body diameter (with arms - BD) in males was 80–580 mm (mode 200–360 mm) and in females 100–505 mm (mode 220–320 mm). BD of mature males was 220–580 mm (mode 280–380 mm) and in females 230–505 mm (mode 300–380 mm). Maximal BD of maturing males was 310 mm and of females 360 mm. Two spent females had a BD of 500–505 mm and males near spent condition had a BD of 560 mm. The ratio of males/females was 1.3:1 in the total sample and 2:1 among mature *O. californiana*. Egg size was 8–8.5 × 5–5.5 mm. Egg number in the oviducal tube was 1–30 (mean 8). The development of oocyte stock is asynchronous. Potential fecundity was 3500–4000 in prespawning and 2000–2500 in spawning females. Mature *O. californiana* were caught at depths of 300–700 m. Spawning is continuous and very prolonged as the females laid single eggs in different localities. Food items identified from the stomachs of *O. californiana* were juvenile shrimp *Pandalus borealis* (48.5% by frequency) and crab *Chionoecetes* (45.5%); adult amphipods (38.6%), cumaceans (5%), polychaetes (20%), euphausiids (5%), and very rarely (<1%) fish fry and small bivalve shells. Transit (secondary) food included copepods, isopods and embryonic shells of gastropods. There were also small pebbles in some stomachs. All prey items were small-sized near-bottom animals.—Atlantic Research Institute of Fisheries and Oceanography (AtlantNIRO), 5 Dmitry Donskoj Str., Kaliningrad 236000 Russia.

PRELIMINARY ESTIMATION OF TOTAL STOCK SIZE AND PRODUCTION OF OMMASTREPHID SQUIDS IN THE WORLD OCEAN by *Ch. M. Nigmatullin*.—There are two main ecological groups among squids of the family Ommastrephidae: inshore (nerito-oceanic) and oceanic. By expert evaluation, the instantaneous biomass of inshore ommastrephids (five genera) is between 12–22 million t, including: *Illex* 4–8, *Todaropsis* 1–2, *Todarodes* 4–6, *Nototodarus* 2–3 and *Martialia* 1–3 million t. The assessments for oceanic ommastrephids (3 genera, 5 spp.) are based mainly on the field estimations and their extrapolations and are evaluated at about 30–40 million t, including: *Dosidicus gigas* 8–10, *Ommastrephes bartramii* 10–13, *Sthenoteuthis pteropus* 4–6, and *S. oualaniensis* 8–11 million t. Assuming the production/biomass (P/B) coefficient for oceanic ommastrephids is 8, as it was estimated for *S. pteropus* by Laptikhovsky (1995), the yearly production of oceanic ommastrephids may be assessed to be 240–320 million t and the total instantaneous biomass to be about 40–60 million t. Assuming P/B = 5 for inshore ommastrephids (the average P/B value for 1-yr-living molluscs, Nesis, 1985), their yearly production may be estimated at 60–110 million t. Then, total yearly production for all ommastrephids may be about 300–440 million t. Total daily food consumption for all ommastrephid stocks (using minimal value of individual daily feeding rate 5%BW) is 2–3 million t and yearly food consumption is 730–1100 million t. Ommastrephid squids transform matter and energy very rapidly in the food webs of the world's oceans. These animals increase the rates of energy transformation in the oceanic ecosystems. In the 1990's the yearly world catch of ommastrephids was about 1.5–2 million t. The feasible potential catch of only oceanic ommastrephids may be 4–7 million t. These squids are the only abundant reserve in the World Ocean for the increase in world commercial catch of high-quality food protein.—*Atlantic Research Institute of Fisheries and Oceanography (AtlantNIRO), 5 Dmitry Donskoj Str., Kaliningrad 236000 Russia.*

ASPECTS OF BIOLOGY, ECOLOGY AND FISHERY POTENTIAL OF OCTOPUS IN THE EASTERN CAPE, SOUTH AFRICA by *Ané Oostuizen^{1,2}, M. J. Smale¹ and W. H. H. Sauer²*.—Finfish stocks are on the decline world-wide and fisheries are shifting their focus to cephalopods, resulting in an increased value of cephalopod fisheries. Squid is currently the only directly commercially exploited cephalopod resource in South Africa. There are nine species of octopus that have potential commercial value. Smaller octopus species are exploited by recreational and subsistence fishermen in the intertidal area, while the larger *O. magnificus* is caught as a bycatch in the rock lobster fishery and trawling industry. No fishery targets octopus at present, although their experimental development has been planned. Octopus as an alternate resource could augment local fishers and their communities in the Eastern Cape province of South Africa. The exploitation of an alternate resource such as octopus could lessen fishing pressure on already depleted fish stocks, more specifically reef fish and sharks. The present study was initiated to provide a scientific basis for the management of the fishery. The population structure, abundance and distribution of both the intertidal and subtidal populations of *Octopus vulgaris* in the Eastern Cape was assessed. Results from the intertidal study show a size range of 2–4000 g with a mean mass of 650 g, and a sex ratio of 2:1 female: male. No mature females were found intertidally, all the stages of maturity were found in intertidal males. No distinct cohorts were present. Subtidal investigations are still ongoing, however a few brooding females have been found from 7–26 m depth. This suggests a migration of maturing females from the intertidal to the subtidal areas to spawn. Accurate age

determination is important in the assessment and management of cephalopod resources. Tetracycline is currently being used in the assessment of age and growth of *O. vulgaris*. *O. vulgaris* are injected with tetracycline which is deposited into the beak. Preliminary results show that the tetracycline is incorporated into the growth rings, but also into strengthening layers deposited on top of the daily? rings. Various patterns of tetracycline deposition were evident. The one ring—one day hypothesis have not been validated for *O. vulgaris*, but field validation is currently underway.—¹Port Elizabeth Museum, P.O. Box 13147, Humewood, Port Elizabeth, 6013, South Africa. ²Dept. Ichthyology & Fisheries Science, Rhodes University, Grahamstown, 6140, South Africa.

EFFECTS OF HATCHING SEASON ON THE GROWTH RATE, REPRODUCTIVE-SOMATIC INVESTMENT AND SPAWNING BIOLOGY OF *SEPIOTEUTHIS AUSTRALIS* IN THE TEMPERATE WATERS OF SOUTHERN AUSTRALIA by *Gretta Pecl.*—This paper is a synthesis of several studies examining the influence of hatching season on growth rates, patterns of reproductive-somatic investment and the spawning biology of the temperate water squid, *Sepioteuthis australis*, from the east coast of Tasmania, Australia. Hatching season was determined for 400 squid using back-calculated dates of hatching derived from validated statolith age estimations. Growth rate of *S. australis* was strongly influenced by hatching season, with individuals hatched in warmer seasons having a final size that could surpass that of earlier hatched (and therefore older) individuals. There was also evidence that the effect of temperature was not limited to initial growth stages, instead temperature continued to influence growth patterns throughout the adult life cycle. These seasonal differences in growth translate into substantial variations in size-at-age, for example, the mean total weight of summer hatched squid at 170–190 d of age was 1002g (\pm 98 g SE), compared to 632 g (\pm 27 g SE) in winter hatched squid. Fast growing summer-hatched females caught during winter had relatively heavy mantles but low gonado-somatic indices and appeared to be laying relatively small batches of eggs. Slower growing winter-hatched females had lighter mantles, gonado-somatic indices almost double that of summer-hatched females and were laying much larger batches of eggs. The waters off the east coast of Tasmania are derived from a mixture of nutrient-rich subantarctic and nutrient-poor subtropical water masses with considerable intra- and inter-annual variability in the broad patterns of oceanic circulation and productivity. Given that the growth, patterns of repro-somatic investment and spawning biology, and potentially life span of *Sepioteuthis australis* are responsive to environmental factors, the dynamic nature of oceanographic conditions on the east coast of Tasmania are likely to result in high variability in both the population structure and stock-recruitment relationship.—*Tasmanian Aquaculture and Fisheries Institute, P.O. Box 252-49, Hobart, Tasmania 7001.*

SOME BIOLOGICAL ASPECTS OF *ILLEX COINDETII* (VÉRANY, 1839) IN THE SOUTH OF PORTUGAL by *P. A. Pereira and T. C. Borges.*—Squids of the genus *Illex* are one of the most important cephalopods to be commercially exploited, representing about 30% of the world cephalopod catch and yielding up to 500,000–700,000 t yr⁻¹, mainly of the species *I. argentinus* (Laptikhovsky and Nigmatullin, 1993). In Portugal, the catch of Ommastrephidae started to increase in 1996, with about 382 tonnes landed in 1998, with a value of 1.6 million Euro. In the Algarve (south Portugal) 93 tonnes were landed in 1998, with a value of 94 thousand Euro. Although these species are a by-catch of the

trawl fishery (mainly in crustacean trawls) most of the catches are discarded, due mostly to the low price. *Illex coindetii* is a common species in the Algarvian waters, but as little is known about the biology of this species, this work will provide information of great importance for fisheries. Several morphometric relationships were established, which can explain different growth rates in different seasons, and can successfully be used as a secondary sexual character (DML/head length). A gonadosomatic index, spermatophoric complex index, ovarian index and a digestive gland index were applied, which led to the conclusion that although the recruitment period of this species occurs during the entire year, two major peaks are observed: one during summer time, and another during winter time.—*Centre of Marine Sciences, University of Algarve, Campus de Gambelas, 8000 Faro, Portugal.*

LIPIDS AS DIETARY TRACERS IN SOUTHERN OCEAN SQUID by *Katrina Phillips¹, George Jackson¹ and Peter Nichols^{2,3}*.—Squid comprise a major component of the diets of many vertebrate predators foraging in the Southern Ocean. Despite their ecological importance, the trophic interactions between squid and their prey are largely undescribed. Conventional stomach content analyses are restricted as squid finely macerate food and often do not consume hard body parts. An alternative method is to use signature lipid biomarkers to identify prey species consumed by squid in the Southern Ocean. Dietary lipids have shown potential as trophic markers, particularly if passed unmodified from prey to predator. We have used Thin Layer Chromatography-Flame Ionisation Detection and Gas Chromatography-Mass Spectrometry to construct the lipid profiles of several squid species and a range of potential prey items. The identification of lipid biomarkers, used in conjunction with conventional dietary analysis, will provide a clearer understanding of the trophic interactions of Southern Ocean squid.—¹*Institute of Antarctic and Southern Ocean Studies, University of Tasmania, Hobart 7001.* ²*CSIRO Marine Research, Hobart 7001,* ³*Antarctic CRC, Hobart 7001.*

THE CEPHALOPOD PREY OF SOUTHERN ELEPHANT SEALS (*MIROUNGA LEONINA*) FROM STRANGER POINT, KING GEORGE ISLAND, ANTARCTICA by *Uwe Piatkowski¹, Daniel F. Vergani²*.—In the austral summers of 1992 and 1993 stomach contents were lavaged from 59 anaesthetized southern elephant seals (*Mirounga leonina*) at Stranger Point, King George Island, Antarctica. Thirty-six (61%) stomachs contained a total of 224 lower cephalopod beaks, which were identified and measured. Allometric equations were used to relate lower rostral beak length with cephalopod body size and mass. The cephalopod prey represented a total wet mass of 35.8 kg. Six species of squid and 2 octopod species occurred in the elephant seals' diet. The glacial squid *Psychroteuthis glacialis* was most abundant numerically (83.9%) as well as in terms of biomass (77.4%). All other species were much lower in abundance with *Alluroteuthis antarcticus* being the second most important cephalopod prey (9.7% estimated biomass), followed by *Kondakovia longimana* (6.0%) and *Grimptoteuthis glacialis* (5.0%). The remaining four species, *Galiteuthis glacialis*, *Gonatus antarcticus*, *Brachioteuthis picta* and *Pareledone charcoti* accounted for less than 2% of the total cephalopod biomass estimated from the seals' diet. Relative abundance and species number of cephalopods in the diet increased with the size of the seals, but did not differ between their sexes. The present study gives first information on the cephalopod diet of southern elephant seals of the Antarctic Peninsula region. The data suggest that the seals are preying upon a cephalopod community

which is typical for the high-Antarctic seas south of the Antarctic Polar Front.—¹*Institut für Meereskunde, Universität Kiel, Düsternbrooker Weg 20, D-24105 Kiel, Germany.*²*Centro Nacional Patagónico (CENPAT), Boulevard Almirante Brown s/n, 9120 Puerto Madryn, Chubut, Argentina.*

CEPHALOPOD FISHERY PATTERNS IN THE UK AND ADJACENT WATERS by G. J. Pierce, J. Wang and P. R. Boyle.—Cephalopod fishery patterns in UK and French waters were studied using Geographical Information System (GIS) technology and statistical methods. French and UK fishery data extracted from official national fishery statistical databases were used. French landings and fishing effort data are from 1989 to 1997. UK landings and effort data are from 1980 to 1997 and include data from UK-registered fishing boats landing at ports in England, Wales, Scotland, and Northern Ireland. For these fleets, landings (kg) and fishing effort (hours fishing) data were available by month and by capture location. The spatial resolution is the International Council for the Exploration of the Sea (ICES) statistical rectangle (0.5° latitude × 1° longitude). Data from other nations fishing in these waters (notably Ireland) were not available with the same spatial and temporal resolution and could not be included. Monthly abundance indices were derived using landings per unit effort (LPUE, kg h⁻¹) data for various types of fishing gear. The data were integrated into a GIS based on UNIX ARC/INFO, PC ARCVIEW, and an ACCESS database. Visualization and visual analysis were carried out using GIS techniques. Statistical analysis was carried out using the statistical software package S-PLUS. Spatial and temporal patterns of cephalopod abundance were analysed by species. The English Channel, French and Scottish west coasts are the major areas for cephalopod fishing. In the southern part of the study area, the major cephalopod resource categories are cuttlefish (*Sepia* spp.), loliginid and ommastrephid squid. Further north, the veined squid *Loligo forbesi* is the dominant cephalopod species in landings. Catches are taken mainly within the shelf area with sea depth <200 m, with high abundance at the shelf edge on the Scottish and French West Coasts and the offshore Rockall Bank. The different species show distinct spatial and temporal patterns in the distribution of abundance. The areas of high abundance show intra- and inter-annual shifts. Mapping of the spatial and temporal distribution of fishing hours shows that fishing activities of French and UK fleets are concentrated in different areas, and fishing effort is generally quite consistent from month to month. Thus the seasonal shifts in catch distribution are largely due to changes in cephalopod distribution and abundance.—*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen AB24 2TZ, U.K.*

A REVIEW OF THE REPRODUCTIVE STRATEGIES IN CEPHALOPODS by Francisco Rocha and Angel Guerra.—Cephalopod reproductive strategies were reviewed in order to clarify their current, confusing status. Based on the type of ovulation, spawning pattern and growth between egg batches or spawning periods, five comprehensive and flexible cephalopod reproductive strategies are defined. Accordingly, with these three factors the following classification is proposed: A) Spawning once (formerly semelparity) consisting of *Simultaneous Terminal Spawning*, with synchronous ovulation, monocyclic spawning and absence of growth between egg batches. B) Spawning more than once (formerly iteroparity) including: i) *Polycyclic Spawning* with egg-laying occurring in separate batches during the spawning season and growth occurring between production of egg batches and spawning seasons; ii) *Multiple Spawning*, with group-synchronous

ovulation, monocyclic spawning and growth between egg batches; iii) *Intermittent Terminal Spawning*, with group-synchronous ovulation, monocyclic spawning and no growth between egg batches; iv) *Continuous Spawning*, with asynchronous ovulation, monocyclic spawning and growth between egg batches. Examples of species exhibiting each one of these reproductive strategies are given. The large amount of inter-species variation in selected life-history traits related with reproductive events is discussed.— *Instituto de Investigaciones Marinas (CSIC), Eduardo Cabello 6, 36208 Vigo, Spain.*

ONTOGENETIC AND EVOLUTIONARY PATTERNS OF THE MALE REPRODUCTIVE SYSTEM FUNCTION IN THE SQUID FAMILY OMMASTREPHIDAE by R. M. Sabirov¹ and V. P. Zalygalin².—Ontogenetic trends in morphology and morphometry of spermatophores (SP) and the spermatophoric gland (SG) were studied in 17 species of Ommastrephidae. Seven stages were revealed. 1. Embryonal: separation of the non-differentiated gonadal primordia from mesodermal tissue. 2. Larval: gonad autodifferentiation and appearance of SG as a coelomoduct with involvement of the ectoderm. 3. Fry: proliferation of spermatogonia and spermatocytes I, morphogenesis of SG. 4. Juvenile: formation of the spermatocytes II and spermatids, growth of SG and its trial functioning with production and evacuation of tentative SP without spermatozoa. 5. Adult maturation: physiologically mature, normal SP accumulate in the spermatophoric sac: the proper spermatophorogenesis goes on but males at yet not ready to copulate. 6. Adult, functionally mature, copulating males. 7. Full exhaustion and death. The 6th stage has two sub-stages: 6.1. Active spermatophorogenesis, 6.2. Residual spermatophorogenesis and its breakdown. Physiological exhaustion (testis degeneration, degradation of SG, decreasing of SP length), but there are still enough SP in the spermatophoric sac to copulate. Three types of allometric growth of the SG were revealed during substage 6.1. A) growth isometric or with a weak tendency to negative allometry, length of SP insignificantly increases during the ontogenesis (*Todaropsis*, *Illex*); B) weak positive allometry present, length of SP and sperm volume per one SP increase insignificantly (*Todarodinae*, *Ornithoteuthis*, *Eucleoteuthis*, *Hyaloteuthis*); C) well expressed positive allometry, length of SP and sperm volume per one SP increase remarkably (*Dosidicus*, *Ommastrephes*, *Sthenoteuthis*). Changes in the length of SPs and of the 4th section of SG are correlated with mantle length during all the spermatophorogenesis and are species specific.—¹Kazan State University, 18 Kremlevskaya Str., Kazan 420008 Russia; ²Atlantic Research Institute of Fisheries and Oceanography (AtlantNIRO), 5 Dmitry Donskoj Str., Kaliningrad 236000 Russia.

EFFECTS OF LOW TEMPERATURE AND COLD SHOCK ON THE EMBRYONIC DEVELOPMENT OF *LOLIGO BLEEKERI* (CEPHALOPODA: LOLIGINIDAE) by Yasunori Sakurai¹, Gyanne Lima¹, Jun Yamamoto¹, Hiromi Nakao² and Kengo Itoh³.—*Loligo bleekeri* is the target of a major fishery near its spawning grounds in northern Japan. Annual catches in this region tend to be high when local sea temperatures are high and low when temperatures are low. The present study was conducted to determine if these fluctuations in adult stock size might be due to the effect of changing seawater temperatures near the spawning grounds on the developing embryos. In captive experiments, we first examined the effect of constant temperature on embryonic development at temperatures between 5 and 11°C. The results suggest that 7°C is the lowest temperature at which embryos develop normally. We then exposed developing embryos to tem-

porary drops in temperature ('cold shocks') below this temperature minimum to examine the effect on embryonic development. When the shocks were small, embryos developed normally when exposed to temperatures below 6°C. However, large shocks caused many embryos to develop abnormally or to die. These and other observations on the importance of seawater temperatures near the spawning grounds on the stock size of *L. bleekeri* were discussed.—¹Graduate School of Fisheries Sciences, Hokkaido University, Hakodate, Hokkaido, Japan. ²Hokkaido Fisheries Expansion Office, Nemuro, Hokkaido, Japan. ³Aomori Prefectural Fisheries Experimental Station, Ajigasawa, Aomori, Japan.

BY-CATCH AND DISCARDS OF CEPHALOPODS IN THE FISHERIES OF THE SOUTH PORTUGUESE COAST by *S. J. Sendão, I. Gonçalves and T. C. Borges*.—The quantity and composition of by-catch and corresponding discard catch varies considerably with fishery, gear type, area, and season. Some gears such as octopus pots are highly selective. However, other gears such as trawls capture a wide variety of fish, and other organisms. By-catches in their various forms can have significant consequences for populations, food webs, and ecosystems. The problem of by-catch is when it has to be discarded. By-catch fish can also have a very high commercial value, but if they cannot be marketed, then they are discarded. A major problem is when the discards are ignored, not only at the level of their quantification, but also at the species level (which species, biological information). In Portugal, coastal fisheries employ a great variety of techniques ranging from trawls to artisanal gears. The discards in Algarve of some of the fishing gears have been studied since 1996: crustacean trawl, fish trawl, demersal purse seine, and pelagic purse seine. The results presented here are concerned with cephalopods, an ecologically and economically important group of species. Some of these species are poorly known in Portuguese waters, with little information on their biology, distribution and abundance. During the sampling period of the study (winter 1997 to the spring of 1999), a total of 25 fishing vessels were sampled (5 crustacean trawls, 4 fish trawls, 7 demersal purse seine and 9 pelagic purse seine) with a total of 74 fishing trips and 350 hauls/sets. A total of 6 families and 20 species of cephalopods were identified, classified by the frequency of rejection (occasional, frequent and regular) and their occurrence (number of trips in which the species has occurred) registered. The most abundant species in the fisheries discards were *Illex coindetii*, *Eledone moschata*, *Eledone cirrhosa*, *Alloteuthis subulata* and *Sepia elegans*. The reasons for discards are presented and discussed. Biological aspects of some of the species are presented, including size distribution, sex ratio, maturation and length-weight relationship.— *Centre of Marine Sciences, University of Algarve, Campus de Gambelas, 8000 Faro, Portugal.*

THE FISHERIES OF THE COMMON OCTOPUS (*OCTOPUS VULGARIS* CUVIER, 1797) IN THE SOUTHERN PORTUGUESE COAST by *J. Sendão, I. Gonçalves and T. C. Borges*.—The main objective of fisheries management is the conservation of stocks, and to achieve this it is essential to have information on the population dynamics of the species. In spite of the great importance of octopus, very little is known concerning the fisheries and biology of the species, in southern Portuguese waters. Therefore, important aspects of the biology of the most important octopus species (*O. vulgaris*) in Algarve have been studied during the period 1997–1999 and is here presented and discussed. The most efficient fishing gear takes into account the behaviour of the target species. The traditional Algarvian common octopus traps are made simply from clay pots ('alcatruzes')

hung from a line set along the sea floor. 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. Pots are typically made of clay with openings of about 15cm diameter and are not baited. More recently plastic pots have been introduced in Portugal very successfully. However, the use of these pots is, for the moment, restricted to the north of Portugal, with not much success in the south. Traditional baited traps called 'covos' have been used to catch cuttlefish (and species of crustaceans) and more recently in Portugal have been used to also catch octopus. This type of trap can have a variety of different shapes and be made of different materials. In Algarve, it was observed that in the last few years an increase of popularity has occurred in the use of this type of trap in comparison to the clay pots. The possible reasons are presented and discussed. Due to their life history strategies and specific characteristics, the assessment of cephalopod stocks is particularly challenging. Special attention has to be given also to aspects like fishing effort. In the present study, an assessment exercise was made for the common octopus fisheries in Algarve.— *Centre of Marine Sciences, University of Algarve, Campus de Gambelas, 8000 Faro, Portugal.*

QUANTIFICATION OF ONTOGENETIC DISCONTINUITIES IN CEPHALOPODS by *Elizabeth K. Shea*¹ and *Michael Vecchione*².—In cephalopods, the existence of a larval stage during the life cycle has been hotly debated because of variation in the amount of morphological differences between newly-hatched animals and adults of the same species. The term "paralarva" was introduced by Young and Harman (1988, *Malacologia* 29(1): 201–207) to describe post-hatching, planktonic cephalopods, emphasizing the importance of behavioral and ecological criteria to discriminate between newly-hatched and older conspecifics. Although this term has been widely adopted, the endpoints of the paralarval phase have not been assessed on a species by species basis. We use an iterative, Model II, piecewise linear regression technique to quantify discontinuities in growth trajectories of *Ctenopteryx sicula* (Verrill, 1881), *Idioteuthis magna* (Joubin, 1913) and *Brachioteuthis* sp. 3. This method is statistically sound, simple, repeatable, and broadly applicable to all taxa. Breakpoints in growth trajectories are compared to day and night vertical depth distributions, to assess whether there are concomitant changes in morphology and ecology. Our results indicate that the present definition of a "paralarva", with its reliance on diel vertical migration, is not uniformly applicable to our three selected oegopsid cephalopods.—¹*Dept. of Biology, Bryn Mawr College, Bryn Mawr, Pennsylvania 19010.* ²*National Systematics Laboratory, National Marine Fisheries Service, 10th and Constitution, N.W., Washington, D.C. 20560.*

ULTRASTRUCTURE OF THE OMMASTREPHID PROBOSCIS by *Elizabeth K. Shea*.—The ultrastructure of loliginid squid tentacles and arms has been well characterized, and each appendage is known to function as a muscular hydrostat. The tentacles of ommastrephid squids are different from all other families because they are joined into a 'proboscis' in developing and newly-hatched specimens. The proboscis separates during ontogeny to become two, fully functional tentacles in late juvenile and adult specimens. Understanding the functional morphology of the tentacles before, during and after the fusion phase is critical to understanding how the proboscis is used in feeding. The proboscis of a 4.1 mm DML specimen of *Ommastrephes bartramii* (LeSueur, 1821) was examined using light and electron microscopy. The two tentacles share transverse muscle

(TM) tissue at the center of the proboscis, with some muscle fibers apparently starting in one tentacle and ending in the other. The extent of the fusion changes along the length of the proboscis. Longitudinal muscle (LM) is not present along the fused (internal) edge of the proboscis, but is present along the external edge of the two tentacles. Developing LM bundles are evident at the juncture of the external and internal edges. These results indicate that the two tentacles that make up the proboscis may be used as a single appendage.—*Dept. of Biology, Bryn Mawr College. Bryn Mawr, Pennsylvania 19010.*

INVESTIGATING THE DIET OF TWO SQUID SPECIES *LOLIGO FORBESI* AND *ILLEX COINDETII*: APPLICATION OF FATTY ACID AND STOMACH CONTENT ANALYSES by *G. Stowasser¹, G. J. Pierce¹, C. Moffat² and M. A. Collins¹*.—Fatty acids are transferred in a conservative way from prey to predator tissue with certain fatty acid classes operating as indicative biomarkers for species of different trophic levels. In the present study, to provide new information on the feeding ecology of the squid species *Loligo forbesi* and *Illex coindetii* and improve understanding of their role in food webs, fatty acid analysis, in conjunction with stomach content analysis, was used to examine the diet. To obtain information on average diet integrated over different lengths of time, lipid content and fatty acid composition were studied in two tissues, digestive gland and mantle, representative of tissues used for short-term and long-term storage respectively. Intra-specific and inter-specific comparisons were made to relate variation in lipid content and fatty acid profiles to results on stomach contents. Lipid content of mantle tissue showed little variation either within or between species. In contrast, lipid content of digestive gland tissue showed high intra-specific variation, although this appeared to be unrelated to individual stomach contents or the sampling area. However, certain biomarkers, characteristic of fish or crustacean prey respectively, could be identified. Significant differences in lipid content of digestive gland were found between squid species and there was also significant inter-specific variation in concentrations of individual fatty acids. Differences in fat content and individual fatty acids between species are likely to reflect different habitats and different prey species. Future work will include establishing the fatty acid signatures of different prey species and quantitative analysis of individual squid fatty acid profiles to identify average diet composition in different areas.—¹*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen AB24 2TZ, U.K.* ²*FRS Marine Laboratory, Victoria Road, Aberdeen AB9 8DB, U.K.*

SIZE SELECTIVITY OF SQUID JIG FOR OVAL SQUID *SEPIOTEUTHIS LESSONIANA*, AND ITS RELATIONSHIP TO PREY-SIZE SELECTIVITY by *Tadashi Tokai¹ and Yukio Ueta²*.—Squid jigging and small sized set net fisheries catch the oval squid *Sepioteuthis lessoniana* in the coastal waters along the Pacific Ocean coast of Tokushima Prefecture, Japan. Most squid jigs used there are ready-made, colored, and prawn-shaped lures with a double ring of barbless hooks, and their body lengths (length of shrimp-shaped part of the jig, apart from the hooks) are about 12 cm. In this study, the set nets were regarded as a non-selective fishing gear due to the small enough mesh of the net, and their catch as a representative of the size frequency of the squid population in the fishing area. Size selectivity curve of squid-jig fisheries was estimated with the extended SELECT (Share Each Length's Catch Total) analysis model by comparing the size distributions of catches by squid-jigs and by set-nets carried out simultaneously in the same fishing area. As a result, size-selectivity $r(l)$ in the squid jig size was expressed as a

logistic function of mantle length l , $r(l) = \exp(-10.0 + 0.485 l) / [1 + \exp(-10.0 + 0.485 l)]$. From these logistic-parameter estimates, retention probability of the oval squid of 12cm mantle length was calculated to be 1.5 %. This implies that oval squid of smaller size than the jig of 12cm body length were not caught by the squid jig. In general, before squid seizes prey with its tentacles and arms the squid judges with their high visual acuity whether the prey size is appropriate or not. In rearing experiments, oval squid were most likely to attack a prey smaller than their body size, and when the squid seized a little larger prey they often discarded parts of the prey. In contrast, oval squid of a small size were often preyed on by rudder-fish *Girella punctata* of a size larger than the squid. Thus, oval squid appeared to feed on prey of a size smaller or a size relative to their own body size and may be unable, or select not, to attack prey larger than their own body size. These mean that oval squid have prey-size selectivity. For squid jigging to succeed, the squid must attack the jig as it would a prey; therefore a likely explanation of the squid jig size-selectivity found here is that it is a type of prey-size selectivity by the oval squid.—¹ Tokyo University of Fisheries, 4-5-7 Konan, Minato, Tokyo 108-8477, Japan. ² Tokushima Prefectural Fisheries Experimental Station, Hiwasa, Kaifu, Tokushima 779-2304, Japan

WHEN OCTOPUS ABUNDANCE DOES NOT REFLECT PREY AVAILABILITY: IMPLICATIONS FOR GENE FLOW by Janet R. Voight.—Submersible-based observations document a large number of octopuses at Baby Bare, a basement basalt outcrop, at about 2660 m depth in the North Pacific Ocean (Mottl et al. *Geology* 26: 51; Voight and Grehan, 2000 *Biol. Bull.* 198:94). Comparing the number of octopuses of *Graneledone* observed by submersible over the 44 ha surface area of Baby Bare to the rate at which these octopuses are collected by trawls from depths greater than 2700 m shows that these octopuses are roughly three times more abundant on the outcrop than on the sedimented sea floor. The increased abundance of potential prey animals at the outcrop or the availability of hard substrates that the octopuses appear to require for egg brooding may cause this increase in octopus density. Both hypotheses are consistent with high octopus abundance, but they have distinctly different implications for gene flow among these deep-sea octopuses. If prey are abundant, the octopus may complete their entire life cycle at the outcrop; genetic isolation of the populations may be expected to result. In contrast, if gravid females seek out hard substrate on the outcrop and at other areas isolated from the surrounding sea floor, and mature males follow and copulate with egg-producing females, gene flow may be increased. Analysis of biological samples collected from Baby Bare do not strongly support the hypothesis that potential prey are abundant. Collections of about 4 L of sediment from the Baby Bare thyasirid clam bed in 1997 and 1998 yielded over 350 valves, but only 25 live clams and no other live animals that could serve as octopus prey. Although the Baby Bare fauna also contains abundant sponges and ophiroids, which deep-sea octopuses are known to eat, ophiroids are not considered to significantly contribute to a predator's diet. In contrast, the distribution of sediment in the North Pacific supports the hypothesis that hard substrate may be limiting. Turbidite sediments that were deposited during the Pleistocene cover the sea floor in a layer up to 700 m thick. Sediment buries the basal 220 m of Baby Bare; only about 75 m of its tip extends above the sediment. The sediment cover in the North Pacific clearly indicates that hard substrate is exceptionally rare in this area. If mature female octopuses 1) are not philopatric, 2) require hard substrate to produce eggs, and 3) attract mature males and copulate with

them, local concentrations of brooding octopuses may increase gene flow among populations of these octopuses over time.—*Department of Zoology, The Field Museum of Natural History, 1400 S. Lake Shore Dr., Chicago, Illinois 60605.*

MESOSCALE OCEANOGRAPHY OF HATCHING GROUNDS: INFLUENCES ON RECRUITMENT VARIABILITY IN *ILLEX ARGENTINUS* by *Claire M Waluda^{1,2}, Paul G Rodhouse¹ and Phil N Trathan¹.*—*Illex argentinus* is an important fishery resource in the Southwest Atlantic. This species has a complex life cycle and undertakes long-distance migrations between spawning and hatching grounds on the northern Patagonian Shelf and feeding grounds in the south. The fishery for *I. argentinus* is subject to large inter-annual variability in recruitment strength. Previous work in the Falkland (Malvinas) Islands fishery suggests that large-scale oceanographic variability in the hatching grounds during the early life stages of *I. argentinus* is important in influencing recruitment to the fishery. The hatching area is a region of high oceanographic variability dominated by the confluence of the Brazil and Falkland (Malvinas) Currents. In this study we attempt to refine the relationship observed between *I. argentinus* and large-scale low resolution oceanography, with a more detailed investigation of the high resolution mesoscale surface oceanography of the hatching area. Indices of oceanographic activity were derived from remotely sensed sea surface temperature (SST) images and compared with an index of *I. argentinus* recruitment for the period 1987 to 1999. We examined the relative influence of the Brazil and Falkland Currents and inter-annual variability in mesoscale oceanographic processes in the hatching area. Results are discussed with respect to retention mechanisms and transport processes, and consideration is given to the implications for fisheries management in the Southwest Atlantic.—¹ *British Antarctic Survey, Natural Environment Research Council, High Cross, Madingley Road, Cambridge, CB3 0ET, U.K.* ² *Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, U.K.*

THREE-DIMENSIONAL IMAGING OF STATOLITHS IN THE VEINED SQUID *LOLIGO FORBESI* by *Chia-Hui Wang, Audrey J. Geffen and Richard D.M. Nash.*—Growth rate calculations of squid can be based on statolith micro-increments, as is done with otolith increments in teleost fishes. However, the asymmetry and curvature of statoliths may cause inaccurate calculations by choosing different axis for measurements. To evaluate the best sectioning plane and potential for bias in back-calculation, a three-dimensional statolith model was constructed by sectioning the statolith serially, digitizing the sections, and reconstructing the statolith using three-dimensional-image processing. One single statolith from a veined squid, *Loligo forbesi* with 13.4 cm mantle length was embedded in a petropoxy resin block. Short sections of 0.5 mm diameter metal thread were placed against the glass side to estimate the preparation thickness simultaneously with the manual grinding, while two 0.25 mm diameter metal threads were placed perpendicular to the grinding plane to be used for fiducial reference when taking images and aligning all the sections. Images of the each section surface were taken with a video camera mounted on a compound microscope using reflected light. The outline, clearer checks and nucleus were traced using image analysis software to produce the coordinates. Due to the curved growth axis in the statolith, the sagittal plane may be better for increment counting under LM in comparison with transverse plan. However, bias-calculation between length of the polishing surface and the actual longest axis between the end

of dorsal dome and rostrum tip might exist. The curvature of the statolith growth axis in the rostrum results in the location of different increments at different focal planes. Preparing the statolith section as thin as possible can reduce this problem.—*Port Erin Marine Laboratory, School of Biological Sciences, University of Liverpool, Port Erin, Isle of Man IM9 6JA.*

SPATIO-TEMPORAL PATTERNS OF CUTTLEFISH ABUNDANCE AND ENVIRONMENTAL INFLUENCE IN THE ENGLISH CHANNEL AND ADJACENT WATERS by *J. Wang, G. J. Pierce and P. R. Boyle.*—A study of spatial and temporal patterns of cuttlefish abundance and relationships with environmental factors in the English Channel and adjacent waters was carried out under the auspices of a project funded by the European Commission's Fisheries and Agro-Industrial Research programme (FAIR CT 1520). Fishery landings per unit effort (LPUE, kg h⁻¹) data for French and UK trawlers were used as an abundance index. Monthly average LPUE values for the period 1989–97 were calculated for each International Council for the Exploration of the Sea (ICES) statistical rectangle. Total landings by UK-registered fishing vessels landing their catches in England and Wales and French-registered fishing vessels landing in France were summed and divided by the total effort for the two fleets. Environmental data (SST, SBT, SSS, SBS, bathymetry) were also averaged by ICES rectangle and (where appropriate) by month. Long-term averages for each variable were obtained for each month and rectangle, as the mean of individual annual values. Data were integrated in a Geographical Information System (GIS) base on UNIX ARC/INFO, PC ArcView, and an ACCESS database. The spatial and temporal distribution patterns of cuttlefish abundance were analysed by use of GIS, statistical and geo-statistical methods. Directional empirical variograms in the directions of 0°, 30°, 60° and 90° east of North (angle tolerance for each direction = ±15°) were calculated using (a) monthly long-term average cuttlefish LPUE and (b) monthly cuttlefish LPUE for a single year (1991). In January and October, cuttlefish abundance shows strong trends along south-north (0° and southwest-northeast (30°) axes. Variograms for April and July show less clear trends. Environmental correlates of cuttlefish abundance were investigated by calculating spatial correlations between cuttlefish abundance and contemporaneous and time-lagged sea surface temperature (SST), sea bottom temperature (SBT), sea surface salinity (SSS), and sea bottom salinity (SBS). The correlation between cuttlefish distribution and SST distribution is generally positive. High sea temperatures in the first half-year apparently have a strong positive influence on the local cuttlefish abundance in following winter. The correlation between cuttlefish distribution and salinity distributions is negative. Patterns of spatial correlation between cuttlefish distribution and SBT, SSS and SBS are however complex and may indicate time-lagged effects. The highest abundance of cuttlefish is localized in a relatively small area located in northern part of English Channel and deep water in winter and shifting southwards to the French coast in summer.—*Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, U.K.*

SPATIAL PATTERNS OF SQUID ABUNDANCE IN THE NORTHEAST ATLANTIC: CLASSIFICATION AND ENVIRONMENTAL INFLUENCE by *J. Wang¹, G. J. Pierce¹, P. R. Boyle¹, X. Zheng¹, J. M. Bellido¹, and I. T. Jolliffe².*—The spatial distribution of loliginid squid *Loligo* spp. in the Northeast Atlantic, and the influence of environmental variation on distribution, were studied using abundance indices derived from UK and

French fishery data (covering 1980-97 and 1989-97 respectively; no spatially referenced French data were available for 1980-88). Average overall monthly landings per unit effort (LPUE, $\text{kg}\cdot\text{h}^{-1}$) for each International Council for the Exploration of the Sea (ICES) statistical rectangle was used as the abundance index in the analysis. Environmental data used include SST, SBT, SSS and SBS. The spatial distribution of squid abundance was firstly objectively classified into five main areas based on historical trends in the seasonal pattern of abundance, using PCA and cluster analysis. Directional empirical variograms were calculated for the whole study area and each classification, using long-term average data. The variograms for the whole area show that, in January, variance increases with increasing distance, regardless of direction, with some evidence of two plateaux, at different ranges. Abundance patterns are thus clearly structured in January. In the other three seasons, the shape of the variogram depends on direction, with spatial autocorrelation most evident along the North-South axis (0°) and virtually absent on the east-west axis (90°). Directional variograms were also calculated for squid abundance data from a single year. The variograms for different seasons in each area show the same pattern, indicating that each area has the same seasonal auto-correlation patterns in these directions. The spatial correlations between the distributions of LPUE and SST, SBT, SSS, and SBS show differences between areas and differences between seasons. Although *Loligo* abundance shows some relationship with all four environmental variables, there is no simple relationship between *Loligo* abundance and any single environmental variable, which entirely accounts for the overall pattern of abundance for each area.—¹ *Department of Zoology, University of Aberdeen, Tillydrone Avenue, Aberdeen, AB24 2TZ, U.K.* ² *Department of Mathematical Sciences, King's College, University of Aberdeen, Aberdeen, AB24 3UE, U.K.*

HOW SLOW CAN THEY GROW? NOT ALL COLEOID CEPHALOPODS LIVE FAST AND DIE YOUNG by *J. B. Wood and R. K. O'Dor.*—Coleoid cephalopods are thought to have high growth rates and short life spans. While this generalisation holds for the traditionally studied shallow-water, near-shore species, it does not for at least some deep-sea species. The deep-sea is the largest habitat on earth and it contains many species of cephalopods. From *Architeuthis* to *Bathypolypus*, deep-sea cephalopods are important prey for marine mammals like sperm whales to commercially important fish like cod. In comparison to shallow water cephalopods, we have found very low growth rates, long estimated life spans, low fecundity, extended brooding period, low activity, starvation resistance, and lower quality diets for *Bathypolypus arcticus*, a benthic deep-sea octopus. Low temperatures do not fully explain these differences. These traits point to a strategy that differs from the live fast and die young life cycle typical of coleoid cephalopods. Instead, these deep-sea octopuses seem to have traits that suggest relaxed predation pressure (low fecundity, long time to maturity, no use of lairs) but increased food limitations (large hatchlings that can survive a median of 57 days without food, reduced activity, ingestion of low quality prey like brittle star arms). These traits have important ecological ramifications as they point to much lower production and population recovery rates than for traditionally studied near-shore species.—*Dalhousie University, Department of Biology, Halifax, Nova Scotia, Canada B3H 4J1.*

BEAK LENGTH ANALYSIS OF *LOLIGO FORBESI*, *TODARODES SAGITTATUS* AND *TODAROPSIS EBLANAE* FROM THE NORTHERN NORTH SEA by *Karsten Zumholz and Uwe Piatkowski*.—A detailed analysis of lower rostral beak length (LRL) to body size and wet body mass measurements was carried out for the squids *Loligo forbesi*, *Todarodes sagittatus* and *Todaropsis eblanae*. Specimens were sampled in the northern North Sea during two research cruises of FRV WALTHER HERWIG III in January/February of 1998 and 1999. Altogether 241 specimens of *Loligo forbesi* (ML = 45–376 mm), 108 specimens of *Todarodes sagittatus* (ML = 173–325 mm) and 97 specimens of *Todaropsis eblanae* (ML = 30–127 mm) were investigated to correlate lower rostral beak length with both mantle length and wet body mass. Linear relationships between LRL and mantle length and powerfunctional relationships between LRL and wet body mass were calculated for all three species. By calculating these correlations separately for males and females, no obvious sex-specific relationships were found. The presented data will upgrade the information on beak/mantle length/body mass relationships of major cephalopod species of the North Sea. They provide essential information for future use in estimates of cephalopod prey biomass in North East Atlantic top predators such as whales, seals, seabirds and fishes.—*Institut für Meereskunde, Universität Kiel, Düsternbrooker Weg 20, D-24105 Kiel, Germany.*