Working Document presented to the ICES Working Group on Cephalopod Biology and Life History, Tenerife (Spain), 8-11 June 2015

Cephalopod studies by the IEO-Tenerife team in Central-East Atlantic waters, past and present

Verónica Duque [1,a], M. Nazaret Carrasco [1,b], Alba Jurado-Ruzafa [1,c], Catalina Perales-Raya [1,d].

[1] Instituto Español de Oceanografía, Centro Oceanográfico de Canarias, Tenerife
[a] veronica.duque@ca.ieo.es; [b] nazaret.carrasco@ca.ieo.es; [c] alba.jurado@ca.ioe.es;
[d] catalina.perales@ca.ieo.es

ABSTRACT

The area off the Northwest African coast is one of the richest fishing grounds in the world. Cephalopod fishery in this area takes place on the continental shelf along the coasts of Western Sahara, Mauritania, Senegal, Gambia, Guinea Bissau and Guinea. Bottom trawlers started operating in the sixties; number of vessels increased to 297 in 1980 and has been oscillating since then. Target species are octopus (*Octopus vulgaris* Cuvier, 1797), cuttlefish (*Sepia hierredda* Rang, 1835 and *Sepia officinalis* Linnaeus, 1758) and squid (*Loligo vulgaris* Lamark, 1798). The main landing port of this fishery in EU has been "Puerto de La Luz y Las Palmas" in Gran Canaria Island.

Since the early seventies, scientists from the Centro Oceanográfico de Canarias (COC) settled in Tenerife have developed a sampling and monitoring system in order to collect and manage fishery data to contribute for the assessment of cephalopod stocks in this area. Thirty two exploratory trawl-fishing surveys have been conducted and a great amount of studies have been carried out: reproductive and growth cycles, estimation of population parameters as well as dynamics, environmental variables causing changes in abundance, feeding habits and differences between populations are the main fields of research.

***Keywords**: Cephalopod fishery, Northwest African coast, assessments and stock evaluation.*

1. BACKGROUND

The area off the Northwest African coast is characterized by the occurrence of a permanent upwelling caused by the almost constant Northeast trade wind and the Canary Current flowing parallel to the coast in south direction. This is the cause of an extremely high productivity and holds one of the richest fishing grounds in the world (Valdés *et al*., 2015).

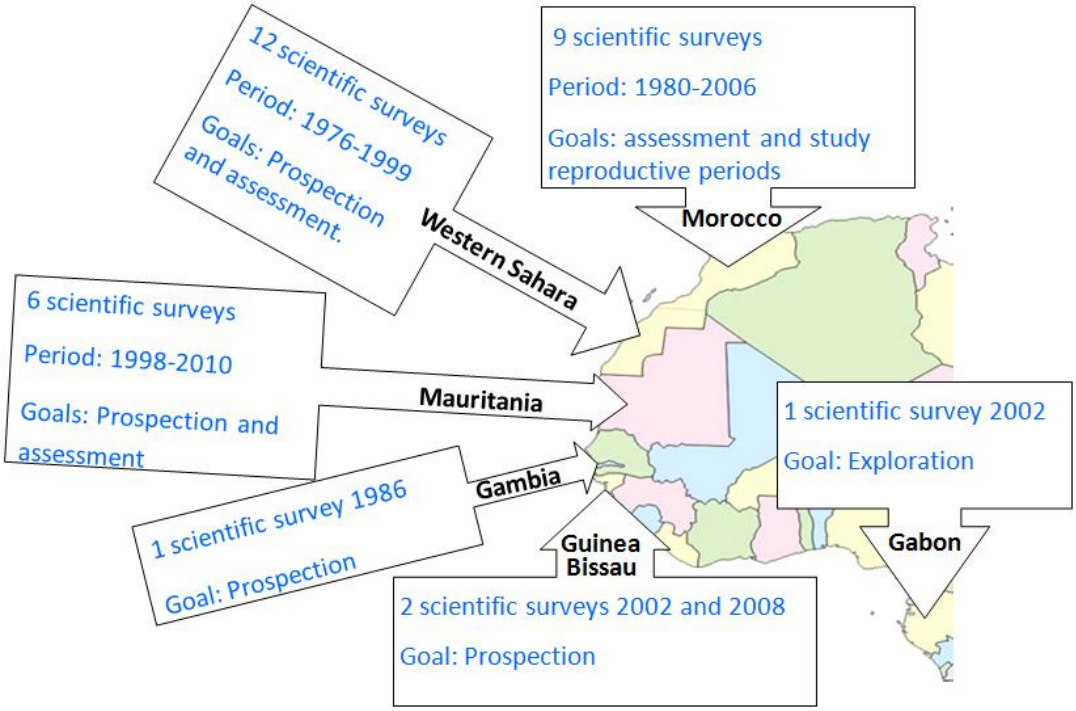
Cephalopod fishery in this area started operating during the sixties. In the seventies bottom-trawls freezers replaced fresh fish trawlers and the number of vessels increased during the

eighties, oscillating up to the present, depending on the number of fishing agreements between Spain or the EU and third countries. The main port of landing, until 2008, was Puerto de La Luz and Las Palmas in Gran Canaria Island. From 2008 to 2012 (when finished the agreement between Mauritania and EU) most of the landings took place at Nouadhibou (Mauritania) being after transported by freighters to Gran Canaria Island. At this moment, there is only one fishing agreement between EU and Guinea Bissau (signed in 2014) and the main landing port is Dakar (Senegal).

2. SCIENTIFIC SURVEYS

In 1971 took place the first Spanish exploratory trawl-fishing survey in the area (between 27º40'N and 17ºN), called Sahara I, onboard the Spanish Oceanographic vessel "*Cornide de Saavedra*" (Bas, 1974). *Octopus vulgaris* was found all over the sampled area, the highest density between 23º and 25º N, near the coast and 20m deep. The highest abundance of *Loligo vulgaris* and *Loligo forbesii* was northern of Cape Blanc, *L. vulgaris* in more coastal waters whereas *L. forbesii* in offshore and deeper waters. *Sepia officinalis* was found in all the area.

After this first survey there have been 31 more:



3. FIELDS OF RESEARCH

Since the end of seventies, a sampling and monitoring system have been carried out by the scientific team of the COC. That has allowed information gathering on size composition of the catches and recruitment. Catch and effort data have been also available at customs and/or shipping agents. During nineties, the biological sampling program for cephalopods focused on the estimation of growth and reproductive parameters, allowed to obtain significant achievements in the life-cycle of cephalopod populations. Moreover, surveys have provided

information about the relative biomass and abundance indexes for these stocks (Bravo de Laguna, 1999). In 2003 the Data Collection Framework ("Programa Nacional de Datos Básicos" in Spain) an EU framework for the collection and management of fisheries data have been placed. One of the fisheries to be monitored has been the Spanish Cephalopod Fishery (freezer trawlers vessels) in waters off third countries, under European fishing agreements. Biological data such as length, weight, sex, and maturity state, as well as catch and effort data have been reported. The main results and achievements by species are:

- **Octopus (*Octopus vulgaris*)**

First information-gathering system was established in the seventies, when the fishery became relevant in terms of landings and economical value. The first data about size composition of catches and growth parameters estimation based on size distribution is available for the period 76-80 (Bravo de Laguna, 1988).

In 1996 a new study was developed to update and complete the knowledge on the key aspects of reproductive cycle of Saharan *O. vulgaris* in order to provide the basis for optimizing the management of this resource (Fernández-Núñez *et al*., 1996).

The oscillation on the spatio-temporal abundance of octopus in Western Sahara was studied by means of Geographic Information System (GIS) and by applying Generalized Addictive Models (GAM) as exploratory tools (Balguerías *et al*., 2002). They observed an important regular intra-annual fluctuation but a major change at an inter-annual level; annual oscillation of octopus production in the area was clearly linked to the success or the failure in the recruitment. They also observed maximum abundances in years with SST bellow the average.

Fishers in the region reported that octopuses from Mauritania and Western Sahara were different in texture and coloration though no systematic comparisons have been carried out. A study about genetic differences between octopus in both areas proved the presence of a degree of genetic isolation, which meant that the octopus from the Mauritanian fishery were not supported by inflow of paralarvae from the Western Sahara fishing area, or vice versa (Murphy *et al.*, 2002).

At the same time, and due to the need of information about octopus' feeding habits in the area, a preliminary research of octopus' diet analysing 373 individuals was conducted. The study showed that the diet is mainly based on crustaceans (55%), fishes (33%) and molluscs (12%). Moreover, it was proved that the ratio is not constant during the year and it changes with the size of octopuses (Rodríguez-Pino *et al.*, 2002).

An image compilation of octopus' gonads in the different reproductive stages were compiled for an ICES Workshop on Cephalopods Maturity stages in 2010 in order to review the maturity scales used in different laboratories and to come to an agreement on the adoption of common maturity scales. Knowledge of the maturation process is vital in understanding the life cycle of octopus, in recognising spawning populations and in identifying possible control factors (Jurado-Ruzafa *et al*., 2010).

In 2009 there was a need to know the real state of octopus stock in Mauritania in order to renew the fishing agreement for the Spanish-trawler fleet. A total of 4044 octopuses were analyzed from January 2010 to September 2011 and a review of reproductive aspects was addressed (Jurado-Ruzafa *et al*, 2014). Using some of these samples, an inventory of organisms trapped in octopus' mantle during the trawling was documented, including 38 species of fish and 44 of invertebrates (Jurado-Ruzafa *et al.* 2012). Furthermore, sustainable strategies for the study and exploitation of octopus stock in Mauritania were reported to FAO in order to get to a geometric approach and sustainable total allowed catches (S-TAC's) (Solari, 2012).

In the nineties started a very important field of work in the COC, the cephalopod's age and growth studies, analysing the increments in calcified structures of the target species in the area (cuttlefish, squid and octopus). Beaks, statoliths, lens and stylets were tested and the team developed, for the first time, the age estimation in an octopus species (Raya and Hernández-González, 1998). Afterwards, the two methods available for age estimation in octopus beaks were improved to reduce the time of sample preparation and to enhance the appearance of the increments. These techniques aim to observe and analyse growth increments in the rostrum sagittal sections (RSS) and lateral wall surfaces (LWS) of octopus beaks. The study recommends counting growth increments in LWS of beaks to age adult common octopus (Perales-Raya *et al*., 2010). Octopus' maximum age in nature was estimated counting increments on beaks of senescent males and females. During this study the team detected, for the first time, stress marks in beaks of wild octopuses which were related to SST fluctuations (Perales-Raya *et al*., 2014a).

Recently, daily increments in octopus' beaks have been validated for the whole size and age range of the species using chemical and environmental marking, as well as known-age specimens, for both RSS and LWS in octopus beaks (Perales-Raya *et al.*, 2014b). Currently the team is working on the stress registered in beak microstructures (capture, handling, environmental changes...) to analyze environmental and biological factors that affect the life of octopuses, both in the pelagic-paralarval (Franco-Santos *et al*., 2015) and benthic-adult stages (Perales-Raya et al., in preparation).

- **Cuttlefish (*Sepia hierredda*** and ***Sepia officinalis*)**

The first specific study of cuttlefish caught off the northwest African coast was accomplished from 15 July to 12 August 1970 onboard the Spanish vessel "*Isla Alegranza*". Five species of *Sepia* were found and described (*Sepia oficinalis officinalis, Sepia officinales hierredda, Sepia bertheloti, Sepia elegans, Sepia orbignyana and Sepia elobyana*). The distribution and reproductive aspects of *S. officinalis hierredda* were also studied (García Cabrera, 1970).

In 1989 fishing effort regulations established seasonal fishing closures in the area, in order to protect spawning and recruitment periods of the main cephalopod species. Identifying the basic key aspects of life cycle in the Saharan *S. hierreda* population was essential to estimate the effects of those management measures. In 1994 data on size at first maturity, sex ratio, spawning periods and recruitment indexes were provided (Fernández-Núñez *et al.* 1994).

There was also a need to elucidate the age of these species to provide this information for the stock assessment in FAO Working Groups. The COC team developed, for the first time, age estimation in a *Sepia* species. It was an innovative study about direct age estimation using micro increments related to age in statoliths of *S. hierredda*, the team suggested a daily deposition (Perales-Raya *et al.*, 1994). Direct ageing using statoliths of *S. officinalis* in captivity was the first attempt to validate daily deposition. This study showed that rings are formed before hatching. Marks were used to calibrate ring periodicity and to establish the temporal relationship between ring number and age (Fernández-Núñez *et al.*, 1995). Daily deposition of statolith increments in *Sepia officinalis* in captivity were later validated by Bettencourt and Guerra (2001).

An image compilation of cuttlefish's gonads in the different reproductive stages were compiled for an ICES Workshop on Cephalopods Maturity stages in 2010 in order to review scales used in different laboratories and to come to an agreement on the adoption of common maturity scales (Duque Nogal *et al*., 2010)

New studies about age and growth estimation of *S. hierredda* were carried out by (Perales-Raya, 2001). She estimated the maximum age (near a year) in the Saharan Bank, and compared the sequence of growth lamellae in cuttlebones with daily increments in statoliths.

- **Squid (*Loligo vulgaris*)**

It is the third cephalopod species most caught by the Spanish freezer-trawler fleet operating in the Northwest coast of Africa. Although the Saharan Bank fishery had been described by many authors, a specific study on the reproductive biology of this species has not been conducted until 1999 (Raya *et al*, 1999). Authors used monthly samples during a year (May 1993-April 1994) to estimate maturation and recruitment patterns as well as the age and growth using statoliths in order to complete the life cycle of *L. vulgaris* on the Saharan Bank.

Years later, in the context of the DCF Program, an image compilation of squid's gonads in the different reproductive stages were compiled for an ICES Workshop on Cephalopods Maturity stages in 2010 in order to review scales used in different laboratories and to come to an agreement on the adoption of common maturity scales (Carrasco Henarejos *et al*., 2010).

In collaboration with international institutions, differences in biological characteristics of *L. vulgaris* from North France, Northwest Portugal, the Saharan Bank, and the Greek Seas were analyzed (Moreno *et al.*, 2002). They found a high degree of biological variation across its geographic distribution.

The COC team has also collaborated with other Research Centres to study the embryonic development of *L. vulgaris* (Villanueva *et al*., 2003). The two objectives of the study were analyse the relationship between egg incubation temperature and embryonic statolith growth (studding eggs incubated under laboratory conditions) and measure the width of the embryonic increments in statoliths of wild *L. vulgaris* individuals from different, well differentiated, geographic regions (North-West Iberian Peninsula, Sahara Bank, Central Mediterranean and Eastern Mediterranean). Based on this study, embryonic development lasts from a few weeks to a few months depending on the environmental water temperature, and

analysing the embryonic areas of statoliths we can obtain information about past events in squid's early life.

There is very little published information about the biology and diet of the pelagic cephalopod *Architeuthis* (giant squid). In 1994 was reported the first specimen in the South of Tenerife (Fernández-Núñez *et al,* 1995). A total of fourteen specimens have been analyzed since then in waters off Tenerife Island. When possible, length, weight, sex, maturity and all biological characteristics have been registered.

4. ON-GOING AND FUTURE STUDIES

Recent agreement between EU and Guinea Bissau allowed some Spanish trawlers to start fishing cephalopods in this country in 2015. An observers program for sampling on board of this fleet is planned in order complete the DCF requirements (concurrent sampling of captured species at sea, capture and discards, etc.).

CephsInAction (COST-Action) is a research network created to improve cephalopod welfare in aquaculture and fisheries. One of the goals of the COC team within this project is to analyze the stress produced by different capture methods in the wild and the stress produced during physiology experiments in captivity (2013-2017).

Project **OCTOWELF** studies health and welfare in first stages of life of *O. vulgaris* and the effects caused by diet and environmental aspects (2014-2016).

To know more about octopus' habitat and the organisms that share its living grounds, taxonomical and ecological studies of species trapped into the octopus' mantle would be conducted.

New studies of octopus' necrotic feeding habits in fishing grounds are planned to compare among discarded species, octopuses from fishing grounds and octopuses from other grounds based on stable isotopes analyses.

REFERENCES

Balguerías E., Hernández-González C., Perales-Raya C., 2002. On the identity of *Octopus vulgaris* Cuvier, 1797 stocks in the Saharan Bank (Northwest Africa) and their spatio-temporal variations in abundance in relation to some environmental factors. Bulletin of Marine Science, 71(1), 147-163.

Bas C., 1974. Distribución de especies demersales recogidas durante la Expedición Oceanográfica «Sahara I». Suplemento Investigación Pesquera, 187-247.

Bettencourt V., and Guerra, A., 2001. Age studies based on daily growth increments in statoliths and growth lamellae in cuttlebone of cultured Sepia officinalis. Marine Biology, 139: 327-334

Bravo de Laguna J., 1999. Managing an international multispecies fishery: The Saharan trawl fishery for Cephalopods. Marine Invertebrates Fisheries, 591-611.

Carrasco Henarejos M.N., Sancho Rafel A., Jurado Ruzafa A., Duque Nogal V., Pascual Alayón J.P., 2010. Maturity stages of squid *Loligo vulgaris* (Lamark, 1798) in the CECAF area (FAO 34). Working Document for the WKMSCEPH Workshop on Cephalopods Maturity Stages.

Duque Nogal V., Sancho Rafel A., Jurado Ruzafa A., Carrasco Henarejos M.N., Pascual Alayón J.P., 2010. Maturity stages of cuttlefishes *Sepia hierredda* (Rang, 1835) and *Sepia officinalis* (Linnaeus, 1758) in the CECAF area (FAO 34). Working Document for the WKMSCEPH Workshop on Cephalopods Maturity Stages.

Fernández-Núñez M.M., Hernández-González C.L, Cejas-Pulido J.R., Balguerías E., 1995. Rearing experiences of *Sepia officinalis* Linnaeus, 1758 in the Canary Islands: growth rates and statolith analysis. In Guerra A., E. Rolan and F. Rocha (eds.), Abstract of the 12th International Malacological Congress, p180.Fernández-Núñez, M.M., Hernández-González, C.L., 1995. Report of a specimen of *Architeuthis* Steenstrup, 1856 caught in Canarian waters (28D02'N-16=45'W). In Guerra A., E. Rolan and F. Rocha (eds.), Abstract of the 12th International Malacological Congress, p245.

Fernández-Núñez M.M., Hernández-González. C.L., Raya C.P., Balguerías E., 1996. Reproductive Biology of octopus *Octopus vulgaris* Cuvier, 1797 from North Western African coasts. Shellfish Committee C.M. 1996/K:15.

Franco-Santos R.M., Perales-Raya C., Almansa E., De Troch M., Garrido D., 2015. Beak microstructure analysis as a tool to identify potential rearing stress for *Octopus vulgaris* paralarvae. Aquaculture Research, 1-15.

García Cabrera R.C., 1970. Especes du genre Sepia du Sahara Espagnol. Symposium sur les Ressources Vivantes du plateu continental Atlantique Africain du Dêtroit de Gibraltar au Cap Vert. Conseil Internationl pour l'Exploration de la Mer. Rapports et Procès-Verbax de Réunions. Vol 159, 132-139.

Jurado-Ruzafa A., Sancho Rafel A., Duque Nogal V., Carrasco Henarejos M.N., Pascual Alayón J.P., 2010. Maturity stages of octopus *Octopus vulgaris* (Cuvier, 1797) in the CECAF area (FAO 34). Working document for the WKMSCEPH Workshop on Cephalopods Maturity Stages.

Jurado-Ruzafa A., Duque V., Carrasco M.N., González F.J., Porto M., 2012. Inventory of trapped organisms under *Octopus vulgaris* (Cuvier, 1797) mantle, caught off Mauritania by Spanish freezer trawlers. Conference paper for the XIII International Symposium on Oceanography of the Bay of Biscay.

Jurado-Ruzafa A., Duque V., Carrasco M.N., 2014. Reproductive aspects of *Octopus vulgaris*, Cuvier 1797 (Cephalopoda: Octopodidae), caught in Mauritanian waters by the industrial Spanish fleet (NW Africa). Vieraea Vol. 42, 149-164.

Moreno A., Pereira J., Arvanitidis C., Robil J.P., Koutsoubas D., Perales-Raya C., Cunha M.M., Balguerías E., Denis V., 2002. Biological variation of *Loligo vulgaris* (Cephalopoda: Loliginidae) in the Eastern Atlantic and Mediterranean. Bulletin of Marine Science, 71(1) 515-534.

Murphy J.M., Balguerías E., Key L.N., Boyle P.R., 2002. Microsatellite DNA markers discriminate between two *Octopus vulgaris* (Cephalopoda: Octopoda) fisheries along the Northwest African coast. Bulletin of Marine Science, 71(1), 545-553.

Perales-Raya C., Fernández-Núñez M., Balguerías E., Hernández-González C.L., 1994. Progress towards ageing cuttlefish *Sepia hierredda* from the Northwestern African coast using statoliths. Marine Ecology Progress Series. Vol. 114, 139-147.

Perales-Raya C., 2001. Determinación de la edad y estudio del crecimiento de choco (*Sepia hierredda* Rang, 1837), el calamar (*Loligo vulgaris* Lamarck, 1798) y el pulpo (*Octopus vulgaris* Cuvier, 1797) de la costa Noroccidental Africana. PhD Thesis Universidad La Laguna, 192 pp. Canary Islands. Spain.

Perales-Raya C., Bartolomé A., García-Santamaría M.T., Pascual-Alayón P., Almansa E., 2010. Age estimation obtained from analysis of octopus (*Octopus vulgaris* Cuvier, 1797) beaks: Improvements and comparisons. Fishery Research 106(2), 171-176.

Perales-Raya C., Jurado-Ruzafa A., Bartolomé A., Duque V., Carrasco M.N., Fraile-Nuez E., 2014a. Age of spent *Octopus vulgaris* and stress mark analysis using beaks of wild individuals. Hydrobiologia Nº 725, 105–114.

Perales-Raya C., Almansa E., Bartolome A., Felipe B.C., Iglesias J., Sánchez F.J., Carrasco J.F., Rodríguez C., 2014b. Age validation in *Octopus vulgaris* beaks across the full ontogenetic range: beaks as recorders of live events in octopuses. Journal of Shellfish Research, Vol. 33, Nº 2, 1–13.

Raya C. and Hernández-González C.L., 1998. Growth lines within the beak microstructure of the octopus *Octopus vulgaris* Cuvier, 1797. South African Journal of Marine Science 20:135-142.

Raya C.P., Balguerías E., Fernández-Núñez M.M., Pierce G.J., 1999. On the reproduction and age of the squid *Loligo vulgaris* from the Saharan Bank (North-West African coast). Journal of Marine Biological Association of the U.K. 79(1) 111-120.

Rodríguez Pino R., Balguerías E., 2002. The diet of *Octopus vulgaris* in the Sahara Bank. Le poulpe *Octopus vulgaris* Sénégal et cotês Nord-Oest Africaines, 325-326.

Solari A., 2012. Sustainable Strategies for the Study and Exploitation of Octopus Stocks in the Islamic Republic of Mauritania: Geometric Approach and Sustainable Total Allowed Catches (S-TAC's). Repport for the Project GCP/MAU/032/SPA (FAO).

Valdés L. and Déniz-González I., 2015. Oceanographic and biological features in the Canary Current Large Marine Ecosystem. IOC-UNESCO, Paris. IOC Technical Series, No. 115: 383 pp.

Villanueva R., Arkhipkin A., Jereb P., Lefkaditou E., Lipinski M.R., Perales-Raya C., Riba J. Roche F., 2003. Embryonic life of the loliginid squid *Loligo vulgaris*: comparison between statoliths of Atlantic and Mediterranean populations. Marine Ecology Progress Series. Vol. 253, 197-208.