# Vexing question on fisheries research: the study of cephalopods and their parasites

## Un asunto embarazoso en investigación pesquera: el estudio de los cefalópodos y sus parásitos

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ABSTRACT

For the beginning of this century it is evident that support for research will be increasingly dependent upon the results of that research having relevance to society's needs and public benefits. Within this web and coupled with the transfer of scientific knowledge is the opportunity to more effectively explain the society the benefits it receives for its investments in research. This viewpoint paper enlighten the general public on the scientific, industrial and commercial relevance of the research on cephalopods and their parasites. In a comparative analysis with other commercially-important taxa, a historical negligible financial support for research on diseases in this important animal group was noted. Because of that policy-makers on Fisheries Research should balance this public debt in the future.

RESUMEN

En el comienzo de este siglo es evidente que el apoyo a la investigación se incrementará en función de la relevancia que para las necesidades de la sociedad y de los beneficios públicos se obtenga de los resultados de dicha investigación. En este contexto y paralelamente a la transferencia de conocimientos científicos, surge la oportunidad de explicar más eficazmente a la sociedad los beneficios que recibe de su inversión en investigación. El punto de vista de este artículo ilustra al público en general sobre la relevancia científica, industrial y comercial de la investigación de los cefalópodos y sus parásitos, así como de la histórica e insignificante financiación destinada a la investigación de las enfermedades en este importante grupo animal. Un análisis comparativo con otros taxones comercialmente importantes, sugiere que los gestores de la política de Investigación Pesquera deberían equilibrar esta deuda pública en el futuro.

KEY WORDS: cephalopod, parasite, fisheries research.
PALABRAS CLAVE: cefalópodo, parásito, investigación pesquera.

## INTRODUCTION

Cephalopods are fast-growing carnivorous molluscs that play an important role in the trophic webs of marine ecosystems (CLARKE, 1996). Moreover, cephalopod stocks are of great international importance in commercial fishe-

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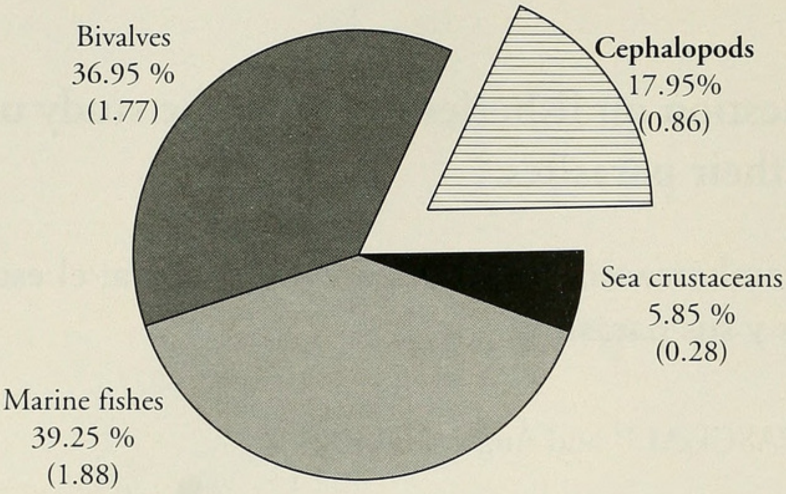


Figure 1. Percentage values and ratios (in parentheses, ¥10-6) which represent the relative scientific effort by nominal catch unit for each group of species. Ratios are calculated as the total number of publications that address parasitology and associated-pathology (mean for the period 1992-98: source of information in Biological Abstracts) and the nominal catch per group of species (mean number for the period 1992-98: source of information in F.A.O., 2000).
*Figura 1. Porcentajes y ratios (en paréntesis ¥10-6) que representan el esfuerzo científico relativo por unidad de captura nominal para cada grupo de especies. Los ratios se han calculado como número total de publicaciones sobre parasitología y patología asociada (media del periodo 1992-98; fuente: Biological Abstracts) y la captura nominal para cada grupo de especies (media para el periodo 1992-98; fuente: F.A.O., 2000).*

ries (Boyle, 1990; Guerra, 1992; Josupeit, 1995). World catch statistics record a total catch of 3.5 million metric tons in 1999 (Josupeit, 2000), with a rate of increase significantly greater than that for finfish species for the period 1970-1992 (Boyle, 1990; Caddy, 1995). For the combined marine catch, all categories, between 1970-1992 there was an increase rate of 2%per year. In contrast, for cephalopods, the rate of increase over the same period averaged 8% per year. Because of their importance as a human food resource (Pierce and Guerra, 1994) and because cephalopods have proved to be valuable as experimental animals for biomedical and behavioural research (Gilbert, Adelman and Arnold, 1990; Abbot, Williamson and Maddick, 1995; Hanlon and Messenger, 1996), scientists have spent considerable time and money studying cephalopods in the last two decades: how many species are there, how long do they live, how fast do they grow, how do they respond to changes in fishing intensity and environmental conditions, how do they find food, escape from enemies, migrate, signal to one another and reproduce, how does their nervous system function and what is their fishery potential in terms of biomass. By comparison, in the last decade marine scientists have devoted very little time and money to the study of cephalopod parasites and parasite-induced pathology in wild and cultivated populations.

## SCIENTIFIC PRODUCTIVITY

Among 700,000 scientific papers a year published around the world (see Scientific Citation Index), almost nothing is written on cephalopod diseases (Fig. 1). Based on current trends there also appears to be an overall decline in the number of recent papers that treat taxonomy and basic research on parasites of other, non-commercial marine invertebrates. This may be due in part to the loss of parasite workers (specially taxonomists) through lack of funding support or redirection of research efforts to the study of human pathogens or ecological studies. Nevertheless, despite the obvious scarcity of scientific effort, recent world literature has stressed the important role of squids, cuttlefishes and octopuses as reservoirs for all taxa of marine eukariotic parasites at both macro- and microgeographic sampling levels (HOCHBERG, 1990; PASCUAL, GESTAL, ESTEVEZ, RODRIGUEZ, SOTO, ABOLLO AND ARIAS, 1996). Most large free-living, mature cephalopods carry some microscopic (viruses, bacteria, fungi, protists) and macroscopic parasites (metazoans) in almost all their tissues and organs (HOCHBERG, 1990). This author, in an extensive survey of the literature, record a total of 225 parasite species in cephalopods world-wide. Since the HANLON AND FORSYTHE (1990) review on diseases caused by microorganisms and the HOCHBERG (1990) contribution on diseases caused by protistans and metazoans, only 32 scientific papers have dealt with cephalopod pathology. Of these, only 16 papers have been published in international scientific journals, 4 of these being chapter reviews within a zoological and/or fisheries biology context. Despite the fact that cephalopod landings have increased over the period 1992-1998, the number of people involved in this field and the number of papers on cephalopod pathology is still remarkably low. In fact, the scientific effort dealing with cephalopod parasites and associated pathology related to relative nominal catch by group of species account less than 54% of that on parasitic diseases of other commercially-important invertebrates (bivalve molluscs) and marine fish (Fig. 1). Why is this so?

Diversity of hosts *versus* number of researchers is a key factor. Thus, there are approximately 700 species of cephalopods and very few researchers compared with about 100,000 species of fishes and numerous researchers. Nevertheless, the scientific productivity with regard to papers on cephalopod parasites actually is not too bad considering how few researchers there are in the field.

## THE SPANISH POLICY

In this context, we may look at the Spanish situation which is comparable with other fish-catching countries in Europe. Spain is the fifth largest cephalopod consuming country in the world, the first in Europe. In Spain cephalopods represent an important component of the diet (4 Kg./inhabitant/per year), yet no financing has been directed at research on cephalopod parasitic diseases. Although over 4 million US $ per year is assigned by Plan Nacional de Investigación y Desarrollo (Comisión Interministerial de Ciencia y Tecnología) to Research and Development (hereafter RandD) to finance research activities and projects on Marine Science and Technology, nothing was assigned to the investigation of cephalopod diseases in the last decade. In this context, it is relevant that cephalopod landings in Spain (averaging 110,000 metric tons per year for that period) contributed 308,000,000 US $ per year to our domestic economy. It seems quite remarkable that at least a small portion of the money derived from the fishery and manufacture processes profits should be returned to support research on diseases of wild and cultured cephalopods. The absence of support for a technology transfer mechanism clearly indicates that the responsibilities of the Spanish research funding agencies does not closely follow current fishing trends to support both established and emerging activities as the management of the ecological impact of parasitism in wildlife and cultured populations are (GRENFELL AND GULLAND, 1995). In other words, this indicates that in this field the Science-Technology-Industry Spanish System (STISS) still has an imbalance between the scientific and productive spheres. As regards STISS (involving parasitologists), it appears to be particularly stimulated by the production of scientific publications and thus, the most important yardstick to promote researches is the number of publications within the Scientific Citation Index (SCI). STISS lacks, however, of sufficient support to employ young trained scientists in research activities and seems to be insufficiently motivated by the food technological and sanitary aspects that imply a suitable development of the research on parasitic-caused cephalopod pathologies. In the case of Food technology, STISS have an important drawback which is the low level of interest of many private companies to deal with the necessary innovation of its products or processes. Consequently, financial and human resources being assigned by public policy and the private sector to develop research activities aimed at a scientific assessment of the impact of infectious processes in cephalopod stocks are patently insufficient. This situation is made worse when public organizations or businessmen have to solve serious problems related to the treatment and control of cephalopod diseases at present day in industrial processes. And the situation will be still worse if, following the successful results in experimental rearing of planktonic common octopus from hatching to settlement (VILLANUEVA, 1995) and on growing of this species in floating cages (HEBBERECHT, 1996; MORAL-RAMA, 1996; GUERRA, unp. data), the industrial culture of the octopuses become a business that rent good profits. In this regard, a recent study by the Industrial Research and Development Advisory Committee of the European Commission (1994) warns of the obvious danger of economic stagnation, unless there is a greater coordination between the productive system (extraction or production, processing and marketing of the resource) and the much-needed scientific environment (comprising the RandD groups).

## FUTURE RESEARCH DIRECTIONS

In this article we should not forget some of the general trends emerging from the study of cephalopod parasitic diseases in the 1990's. Such a brief synopsis is urgently required in the light of the many advances which have been made utilizing new techniques.

Although older reports of infectious diseases emphasized description and systematic classification of cephalopod parasites, considerable confusion exists. The identifications of the parasites and sometimes even the hosts are often in doubt, with high synonymy rates (close to 70%) for numerous parasitic nominal species identified by light microscopy (PASCUAL, ARIAS AND GUERRA, 1995; MATTIUCCI, NASCETTI, CIANCHI, PAGGI, ARDUINO, MARGOLIS, BRATTEY, WEBB, DÁMELIO, ORECCHIA AND BULLINI, 1997). Researchers trained in modern techniques, new trends in systematic, and improved technologies for detecting and defining species have allowed us to elucidate and re-evaluate the taxonomic status and the host-parasite relationships of many already described species. For example, recent papers dealing with scanning and transmission electron microscopy (SEM and TEM) and atomic force microscopy (AFM) studies have showed how much a combination of increased depth of field, resolution and magnification is needed in the identification and examination of the morphology, microtopography, topometry and cell biology of cephalopod parasites and the host-parasite interface (GESTAL, PASCUAL, CORRAL AND AZEVEDO, 1999).

Additionally, our understanding of the epizootiology (which involves investigations on the demographic infection values, patterns of transmission, and disease control) of many parasitic species in cephalopods is severely hampered by morphological characters of difficult interpretation The existence of morphologically identical cryptic species and parasitic races or morphotypes which can reflect selection pressure rather than taxonomic affiliation are problems faced by all taxonomists, but present particular difficulties because of the plasticity of body structures in endoparasites. Moreover, when histological, isolation and purification processes and parasitic dissection techniques are all needed to reveal diagnostic characters of some protozoan and metazoan ectoparasites, respectively, a high degree of skill (and training) is required. A number of molecular techniques should be developed to overcome these problems and should be applied worldwide as useful taxonomic tools for parasite detection and their species identification in cephalopods.

Diseases and pathology caused by microparasites on wild and cultured cephalopods have been reported in a few cases (HANLON AND FORSYTHE, 1990; POYNTON, REIMSCHUESSEL AND STOSKOFF, 1992; GESTAL, 2000). However, it should be noted that in Spain, during the massive culture of paralarvae and juveniles in system crowding, high mortalities rates have been assigned to several environmental factors including diseases by bioagressors (GESTAL, ABOLLO AND PASCUAL, 1998). Furthermore, despite cephalopod macroparasites typically have been considered symbionts (HOCHBERG, 1990), histopathological analysis on heavily parasitized cephalopods revealed the destruction of vital organs and potential loss of their functionality (PASCUAL, 1996; ABOLLO, GESTAL, LOPEZ, GONZALEZ, GUERRA AND PASCUAL, 1998). Unfortunately, in the past although attention has been paid to the presence of parasitic diseases in wild cephalopods, most of the early studies can be classified as single or short-time observations. Seasonal and continuous long-term parasite studies are missing, resulting in the current absence of reliable data to be used in comparative analysis. These data will improve our knowledge about whether present disease prevalence in wild exploited cephalopod stocks exceed natural prevalence, change with abiotic parameters and/or are influenced by host exploitation rates and discarding practices. These studies will be also very useful for mapping the existence of hot-spot areas by using the grid systems of International Fishery Organisations. To obtain base-line data, cephalopod disease recording in standard stock-assessment surveys is potentially useful since it agrees with demographic parameters observed during special cephalopod disease surveys in the same area (PASCUAL, 1996).

Although an extensive literature dealing with diseases and defence mechanisms is available for other commercially-important molluscs, little emphasis has been placed on the defence mechanisms of cephalopods. Despite humoral and cellular defence associated responses having been described for cephalopods maintained in closed sea-water systems for biomedical studies or fattening against potential bacterial pathogens (HANLON AND FORSYTHE, 1990; FORD, 1992), the effects of other microscopic and macroscopic parasites on phagocyte capabilities, inflammation, wound healing and functional morphology of cephalopod haemocytes has not been investigated in depth. The study of inmunobiology of cephalopods is just starting (MALHAM, 1996; MALHAM , DUNHAM AND SECOMBES, 1997). A better understanding of host defence reactions in cephalopods would also help to avoid or control outbreaks of parasitic diseases in commercial mariculture conditions where animal densities, intensive husbandry and stress may increase occurrence of parasitic disease. Because cephalopods are a food source in many regions of the world, the effects of parasitic infections on the biochemical composition and physiological characteristics including condition, growth rate, nutrient assimilation and protein/energy ratio of cephalopods in nature and culture systems should also be evaluated.

Most wildlife parasitic diseases have been investigated via pathological post-mortem examinations, or by producing lists of parasites identified in small samples of hosts. There have been few attempts to assess the impact of a disease at the population rather than individual level, or to describe the distribution of the disease agent in a manner sufficient to understand its epidemiology. PASCUAL, GESTAL AND ABOLLO (1997) considered the statistical distribution of parasites throughout the host species population, and confirmed the negative effect of gill macroparasites on the condition of exploited ommastrephid stocks. That study clearly suggests the existence of causal relationships, expressed in negative modifications of ecological potential, between parasitic infection and cephalopod stock productivity. Finally, an economic loss is present (PASCUAL, GONZALEZ AND GUERRA, 1998). Although further biochemical data on infected and parasite-free cephalopod tissues should be recorded to ascertain the physiological interactions between cephalopods and parasitic infections, parasites may have a considerable effect on infected stocks or individuals, as has been recently noted by GESTAL (2000). Less obvious to most fisheries scientists is the important role of parasites in regulating the general "well-being or fitness" of the host population (i.e. in regulating host abundance or fecundity). To this end, we should attempt to blend mathematical models for host-parasite relationships with those used by fisheries biologists to determine how parasites can affect the dynamics of exploited cephalopod populations, following the seminal articles of CROFTON (1971), ANDERSON AND MAY (1978, 1979), SINDERMANN (1987), DOBSON AND MAY (1987) and GRENFELL AND GULLAND (1995). The complications introduced by the presence of parasitic disease will in general further increase the levels of uncertainty that cephalopod fisheries managers have to contend with (BEDDINGTON, 1984), this mostly in relation to cephalopod condition and its potential fecundity (i.e., its recruitment dynamics).

Roughly 10% of the known species of living cephalopods (i.e. over 80 of the 700 known species) have been either maintained, reared or cultured in captivity (BOLETZSKY AND HANLON, 1983). The vast majority of these 82 species (representing 30 genera) have mainly been maintained or reared, while 12 species (7 genera) have been cultured through their entire life cycle (HANLON, 1987). No signs of diseases were ever observed during small-scale production, but when large-scale culture in high density groups was initiated, fatal infectious diseases occurred (HANLON, FORSYTHE, COOPER, DINUZZO, FOLSE AND KELLY, 1984; GESTAL *ET AL.*, 1998). In Spain, where cephalopod mariculture is changing from experimental to industrial sphere, implementation of procedures for detection and monitoring the pathology and parasitic diseases on a wide scale in the ongrowing cephalopod industry should be common, together with other yet established diseases assessment policy (e.g. on cultured fishes and bivalve molluscs).

Furthermore, parasitoses in cephalopods appears not only as an important problem in the management of infected stocks, but also a zoonotic problem during food-processing. Larval stages of macroparasites are found in many species of squids, cutlefishes and octopuses, which are of commercial importance. The appearance of parasites makes cephalopods unsightly and unappealing to consumers. Moreover, although several species of anisakid nematodes and trypanorhynch cestodes, at the larval stage, can be pathogenic if consumed in raw or improperly cooked cephalopod dishes, few cases of illness by helminths in man have been reported in Spain (ABOLLO *ET AL.*, 1998).

Cephalopod ecologists may also benefit by applying new ideas such as the study of the host-parasite systems. PASCUAL AND HOCHBERG (1996) revised the use of parasites as non-intrusive natural tags of cephalopod hosts in fisheries science. Protozoan and metazoan parasites have been used to assess the status of current stocks of several commercially-exploited cephalopod species. Few examples of the trophic status of cephalopods within food webs and their parasite community structure are available from the literature. The quantification of genetic variation obtained from allozyme frequencies among or within populations of larval anisakid nematodes (i.e., the parasite most frequently employed as tags for marine organisms and the most commonly encountered macroparasite in cephalopods) can provide valuable data on trophic relationships and stock identity of most wild cephalopod stocks.

Through workshops and symposia CIAC (Cephalopod International Advisory Council) aims to present current research and to stimulate and promote future research. Among the almost 40 symposia and workshops on cephalopods held by fisheries biologists from 1973, the 1996 workshop on cephalopod parasites developed on behalf of Commission Internationale pour l'Exploration Scientifique de la Mer Méditerranée (CIESM) by Boletzsky and Hochberg (Laboratory Arago, Banuyls-sur-mer, France) was the first attempt to provide on the parasite diseases processes of wild and reared cephalopods. The contents of this workshop established itself as the main introductory handbook of working techniques on cephalopod parasitology.

Today is well-established that support for research is increasingly dependent upon the results of that research having relevance to society's needs and public benefits. Coupled with the transfer of knowledge is the opportunity to more effectively explain to fisheries managers and companies the benefits they receive for their investments in research (MURRELL, 1996). Bearing in mind all the comments above, we feel that few cephalopod parasitologists have succeeded well in communicating many aspects of scientific and technical knowledge, but they have been less effective in enlightening the general public and private partnerships on the societal value and economic relevance of their research contributions. To overcome this it is imperative to encourage public and private managers, fisheries scientists and parasitologists to contact each other to go one step further in the 2$^{1th}$ century.

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