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IS THERE A SQUID IN YOUR FUTURE: PERSPECTIVES FOR NEW RESEARCH

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ABSTRACT

This paper presents information about future perspectives for research on cephalopods. The objectives and functions of the Cephalopod International Advisory Council (CIAC) are described as an introduction to recognized needs in cephalopod research. Through workshops and symposia CIAC intends to present current research and to stimulate and promote future research. Specifically addressed are new areas of research needed to advance systematic and evolutionary biology, whole-animal biology and fisheries biology. Suggestions stress the application of new techniques and new approaches to augment traditional studies in these fields.

Cephalopods never have been studied so intensely as they are at the present time. While research on cephalopods has shown a steady increase since the mid-1940s, just as in many other groups of organisms, it has increased very dramatically in the past 15-20 years. Why is this so? As basic research scientists, it is easy enough for us to present as a major reason the recognition of the significant role cephalopods play in many marine ecosystems, as they are conspicuous top-level predators as adults and are major prey at all life stages; an understanding of communities requires an understanding of their constituent parts. This has stimulated much-needed research on the biology of cephalopods. Also, we are aware of the extensive use of the squid giant axon in biomedical research; demands for increasing numbers and a year-round supply of animals for neurophysiological and other biomedical applications have stimulated much research on life histories and behavior, especially in relation to rearing and culturing. Less obvious to most North Americans, at least, is the importance of cephalopods as a human food resource. Now, increasing acceptance at home and an ever-increasing demand on the world market have seen the worldwide catch of cephalopods quadruple during the past few decades to around 1.5 million metric tons annually. The desirability to preserve currently exploited stocks on a maximum sustained yield basis, the concomittant necessity to develop new fisheries on underutilized species, and the development of new processing techniques have stimulated a significant amount of research on systematics, distribution, life history, ecology and population dynamics.

The most tangible evidence of the recent intensity of cephalopod research comes from the unprecedented number of comprehensive publications that have been published on a very broad range of topics in the past dozen years. Voss (1973) assessed for the Food and Agriculture Organization of the United Nations (FAO) the cephalopod stocks on a worldwide basis for the first time; this was followed by an updated assessment by Okutani (1977) based primarily on the preeminent Japanese cephalopod fisheries that dominate the worldwide catch statistics. A large volume of papers was published as a result of the symposium honoring Professor J. Z. Young, edited by Nixon and Messenger (1977). The series of papers presented at the 1980 American Malacological Union Symposium on "Functional Morphology of Cephalopods" was published in *Malacologia* (vol. 23, no. 1, 1982). The proceedings of the large international workshop on "The Biology and Resource Potential of Cephalopods" held in Australia in 1981 were published in book format (Roper, Lu, and Hochberg, Eds., 1983). In addition to the 26 research papers, the volume contains a summary of recommendations for future directions in cephalopod research. An international symposium on squid fisheries was held in Boston in 1981, with the proceedings appearing in 1982 (UNIPUB, 1982). The Food and Agriculture Organization (FAO) published an extensive volume assessing cephalopod resources (Caddy, 1983). A very important 2-volume series on life cycles in cephalopods was compiled by Boyle (1983, In press). Another FAO publication was the worldwide catalogue of cephalopods important to fisheries (Roper, Sweeney, and Nauen, 1984). Clark (In press)

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has compiled an important handbook on the identification of cephalopod beaks from the stomachs of predators. Results of species-specific or topic-specific meetings or symposia are published in Anon. (1980); Balch, et al. (1978); Granger (1983); Rowell (1981). Papers that resulted from the Cephalopod Expedition of the *Alpha Helix* are published in Arnold (1983). These recent major publications serve as examples of the expanding interest in research on the biological aspects and resource potential of cephalopods.

The recognition of the growing importance of cephalopods resulted in a burgeoning of research around the world. An increasing number of biologists were being encouraged or assigned to work on cephalopods, often without prior training or exposure to cephalopod biology or taxonomy and the relevant (often difficult to find) scholarly literature. Therefore, results often were variable; papers were published in a wide diversity of biological and fisheries publications, some of them quite difficult to obtain. Because of these circumstances, it became quite clear to a number of cephalopod specialists that a conspicuous lack of direction from the international viewpoint had developed, the continuation of which could lead to much inefficiency, redundancy and misdirection in the field. So, at the International Workshop on the Biology and Resource Potential of Cephalopods, held in Melbourne, Australia in March, 1981, the concept of establishing an international body was introduced and accepted. During the workshop on cephalopod beaks from predator stomachs held at the Marine Biological Laboratory, Plymouth, England in June 1981, the charter members convened a working group to develop the organizational structure for the Cephalopod International Advisory Council (CIAC). The Charter Committee then met at Laboratoire Arago, Banyul-sur-Mer, France, in September 1983 to formally accept the charter and resolutions and to elect the first regular council members.

The membership of CIAC consists of 18 internationally recognized scientists who specialize in research on cephalopods. Membership is on a rotating basis in order to maintain stability and direction and at the same time to provide opportunity for input from as broad a spectrum of cephalopod research interests and geographical representation as possible. The current council consists of members from Australia, Canada, England, France, Japan, South Africa, Spain, and the United States. These members represent the following fields of cephalopod expertise: systematics, zoogeography and evolutionary biology; comparative and functional morphology, embryology, developmental biology and life histories; parasitology; ecology; behavior; mariculture; and fisheries biology and resource development.

The objectives of CIAC are: 1) to stimulate and to influence scholarly research on cephalopods from an international perspective; 2) to provide information, advice, and assistance on all aspects of cephalopod biology, including those associated with the development and management of cephalopod fisheries resources; and 3) to disseminate information on past and current cephalopod research. To achieve these objectives CIAC will monitor and review the current status of research on cephalopods on a worldwide basis to provide an overview of results, directions, trends, needs, and problems. This will be accomplished through organization and sponsorship of international workshops, symposia, and training courses; production of handbooks, computerized, cross-indexed bibliographies, "state of the art" papers and a periodic newsletter on living cephalopods (i.e., Recent, not fossil); maintenance of a list of experts available as consultants to any individual, organization, or government requiring information, advice, and assistance on any aspect of cephalopod biology and fisheries. CIAC is especially interested in working with scientists, students, and organizations of developing countries, both in terms of delineating their cephalopod fauna taxonomically and biologically and of determining the potential for developing these cephalopod resources for domestic consumption and for foreign exchange.

CIAC has become affiliated with the International Council of Scientific Union's International Association of Biological Oceanography (IABO), sponsored through UNESCO. Further, the CIAC charter provides for a representative of the Food and Agriculture Organization of the United Nations to serve as a permanent observer on the Council.

The preceding introduction provides the background for the comments that follow. If these suggestions seem tied closely to the CIAC objectives it is because of my close association with the conception, establishment, and functioning of that organization and of my conviction that CIAC will provide the international direction and stability needed for future development of cephalopod research. CIAC and its precursor, the Workshop on the Biology and Resource Potential of Cephalopods, have addressed the topic of future research needs and directions. This is the very subject of our symposium dedicated to Mel Carriker, and since the CIAC organization, objectives, and plans have not yet been introduced to the malacological community at large, I take this opportunity to do so and to develop themes currently under discussion in CIAC. In doing so, I draw from and acknowledge the following sources: the introduction and papers published in the Proceedings of the Workshop on Biology and Resource Potential of Cephalopods (Roper, Lu, and Hochberg, Eds., 1983); and, especially, personal communications with Roger T. Hanlon, Marine Biomedical Institute, Galveston, Texas; F. G. Hochberg, Santa Barbara Museum of Natural History, Santa Barbara, California; and Warren Rathjen, formerly National Marine Fisheries Service, Gloucester, Massachusetts; currently Florida Institute of Technology, Melbourne, Florida. I am most grateful for the discussions with these three colleagues that contributed in a major way to the development of this paper. I am very grateful to Prof. T. Okutani, Tokyo University of Fisheries, who reviewed the paper and provided many helpful suggestions. I also acknow-

ledge with gratitude the helpful comments of two anonymous reviewers.

THE FUTURE

The establishment of CIAC by working scientists as a recognized international organization has enabled the rapid implementation of objectives. For example, as a result of a written survey of many cephalopod scientists from around the world, CIAC concluded that the single most urgent problem facing cephalopod researchers is the inability to identify "larval" and early juvenile stages of cephalopods. Here was a clearly recognized need to which CIAC was able to respond by organizing and sponsoring an international workshop, followed by a larger symposium on the Biology and Distribution of Early Juvenile Cephalopods, held in June, 1985, at Laboratoire Arago, Banyul-sur-Mer, France. Since the beginning of studies on cephalopods, the identification of virtually all stages of young and juvenile forms has been a confusing and problematic endeavor; the inability to identify the young stages has created a serious impediment to progress of research in cephalopod ecology, systematics, and fisheries. This is especially the case for neritic and oceanic species, those that constitute the huge biomass upon which the major fisheries are based, including the numerous species of *Loligo*, the adults of which provide the giant nerve axons used in biomedical research. In recognition of the urgent need for new techniques of identification, scientists from a variety of disciplines participated in the workshop, e.g., comparative morphology, biochemistry, systematics, and behavior of living "larvae", participated in the workshop.

The specific aims of the workshop were to 1) develop and refine standardized methods of identifying larval and early juvenile growth stages of cephalopods to the species level; 2) report current research on various aspects of biology of early growth stages of cephalopods, especially concerning identification, distribution, abundance, ecology, behavior, and prey-predator relationships; 3) formulate future research directions based upon a worldwide view of cephalopod resources available for basic and applied research; 4) discuss future workshops and collaborative programs based upon needs and views of the workshop participants and 5) publish a handbook resulting from the findings of the larval workshop and a special volume in "Vie et Milieu" of the papers presented at the symposium.

The 12-day Banyuls workshop followed the format established during the successful workshop held in Plymouth, England in June, 1981 on cephalopod beaks from predator stomachs, results of which are published in a handbook format (Clarke, In press). Thirty-five cephalopod researchers from around the world participated in the Banyuls workshop, with an additional 20 attending the symposium.

In attempting to address future perspectives in cephalopod research, I find it convenient to subdivide the field into basic components. While this serves the purposes for discussion, we recognize that most research entails a mixture of these components.

Systematics and Evolutionary Biology. Estimates of the number of living species of cephalopods vary from about 500 to perhaps 1,000, depending upon the number of undescribed species one wishes to incude. My guess is about 1,000. The rate of discovery of species new to science remains high, especially in geographical areas and inaccessible habitats previously little studied. While the description of new species certainly serves an important function, the real challenge that continues to face systematists is to produce revisionary and up-to-date monographic works, including functional keys to identification, on genera and families based upon comprehensive collections and utilizing modern systematic techniques. The status of systematic knowledge of most cephalopods is relatively primative and this situation creates impediments to progress in research in many other fields of cephalopod biology, e.g., ecology, behavior, and fisheries. If an ecologist or fishery biologist is unable to distinguish biological species with certainty, the research results or resource management plans surely will be flawed.

While some very fine systematic work has been done on cephalopods (see reviews in Voss, 1977; Roper, 1983), certainly fewer than 100 species are well understood from the systematic standpoint. The excellent volume entitled "Cephalopod Life Cycles" edited by Peter Boyle (1983) demonstrates my point. The 23 species discussed are among the best known biologically of all cephalopods. Yet, 17 of these species belong in the four families designated by an international workshop of cephalopod experts as being in critical need of systematic revision on a world-wide basis: Sepiidae, Loliginidae, Ommastrephidae, Octopodidae (see Introduction in Roper, Lu, and Hochberg, Eds., 1983). Of the remaining six species, only *Nautilus macromphalus* Sowerby, 1848 is in a taxonomically stable family.

Illex illecebrosus (Lesueur, 1821), an ommastrephid, is the major commercial species of squid in the western North Atlantic, where annual catches in Canadian and U.S. waters now occasionally exceed 100,000 metric tons. Because of the commerical importance of this species, much research has been done on its biology and population dynamics (see O'Dor, 1983), but several important factors remain unknown, e.g., mating and spawning sites and early life history of hatchlings and juveniles in relation to distribution, water masses, etc. Systematic problems still exist in spite of the large amount of knowledge gained in the past decade. *Illex illecebrosus* seems to be the only species of *Illex* north of the Mid-Atlantic Bight, but southward to Florida *I. oxygonius* Roper, Lu, and Mangold, 1969 occurs sympatrically. These two species also occur in the Gulf of Mexico where they are joined by *I. coindetii* (Verany, 1837), an amphi-Atlantic species. Adult members within the genus *Illex* in the northern Atlantic are easy to identify; in the area of sympatry, only the adult males of *I. illecebrosus* and *I.*

oxygonius are easily identified, while the females and immature individuals are nearly indistinguishable. Matters are worse in the Gulf of Mexico, where unreconcilable forms coexist with the three species. Larval specimens within the genus *Illex* are relatively easily distinguished from other ommastrephid larvae, but species identifications are still impossible. Further, western North Atlantic spawning sites for the three species are unknown; the larvae are "pelagic" at hatching and apparently are quickly intermixed and dispersed by oceanic currents. All fisheries catches of *Illex* are listed as *I. illecebrosus* and that species designation is applied to most of the research subjects as well. Because of the systematic problems, fisheries biologists are greatly hampered in their objectives to develop the fishery and their ability to make meaningful predictive judgments necessary for the development of rational utilization and management plans. Until the systematics are thoroughly understood, knowledge of all other aspects of *Illex* biology and resource utilization will remain incomplete.

Octopus vulgaris Lamarck, 1798 certainly is the most ubiquitous and extensively studied cephalopod in the world (Mangold, 1983). It is considered a world-wide species in tropical, subtropical and temperate waters and its identification is certain in the Mediterranean and eastern Atlantic where it is the only, or one of a very few, species of *Octopus*. Elsewhere, *O. vulgaris* is the name of choice applied to almost any nondescript medium-sized muscular octopus, whether it occurs alone or with a number of congeners. It is extremely important in fisheries as well as being the premier research cephalopod. Enough uncertainities exist about identification of *O. vulgaris* from less-studied areas, that it is risky automatically to apply biological knowledge acquired for the Mediterranean species to the supposed conspecifics in Southeast Asian waters, for example. On the other hand, to describe a new *O. vulgaris*-like species from an unstudied area can lead to just as many problems.

The point of these examples certainly is not to malign cephalopod systematists, but rather to demonstrate the very great need to encourage and support intensified systematic studies.

Future perspectives can be very encouraging for solving many systematic problems, especially through a combination of approaches. Of course, morphology remains the cornerstone of systematics; there simply is no substitute for fine, detailed morphological studies to show phylogenetic relationships. However, future systematic studies will benefit from increased attention to other aspects of cephalopod biology. Certainly zoologists and paleontologists can work more closely to gain a better understanding of the evolution and phylogenetic relationships of extant cephalopods, as well as an impression of the biology of forms long extinct. The work of Peter Ward and his colleagues is an example (e.g., Ward, 1979a and b). New analytical techniques will enhance the collaboration between paleontologists and zoologists. The best example of this is the x-ray photographic technique pioneered and developed by W. Stuermer (1970), by which delicately fossilized soft parts of animals can be detected in the slate matrix. Heretofore, only shells, beaks, and gladii were available in the fossil record of cephalopods. Now with the ability to "see" other significant anatomical features of systematic value, the door is open for major progress in cephalopod evolutionary studies. To that end, Professor Stuermer and I began collaborative studies in the summer of 1985.

Biochemical analyses, such as techniques for electrophoresis and mitochondrial DNA studies that are being conducted on other molluscan groups, should be applied to cephalopods as well. These could prove to be valuable tools for cephalopod systematists in conjunction with more traditional approaches.

Any future systematic work must recognize the great need to explore morphological features that may prove to be useful as systematic characters. Objective analytical techniques, such as must be applied, as was so well demonstrated in the paper by Voss and Voss (1983) that utilized cladistics. But systematists now should be prepared to go beyond working only with preserved specimens. A wealth of information applicable to systematics, as well as to other biological interests, can be acquired by observing living animals where their natural habitats are accessible to observers or when they can be maintained in the laboratory. For example, cephalopods are capable of producing extensive color changes, body patterns, and skin sculpturing that reflect specific behavioral responses to predators, mates, the environment, etc. (Packard and Hochberg, 1977). Observations are needed on whole-animal behavior: how color, patterns and sculpture are used; how prey are located, stalked, and captured; how mates are selected and mating proceeds; in short, how the animal makes its living in the real world—what are the living characteristics that distinguish it from its closest relatives? The living animals observed in the field will provide hints and ideas that will allow systematists to go back to the laboratory to study well-preserved specimens and to look for the detailed morphological differences. Eric Hochberg (pers. comm.) experienced a vivid example of this in Japan when two specimens of octopus were brought into the lab and kept alive; they were immediately identifiable as separate species based upon their skin patterning, even though preserved specimens seemed indistinguishable because the patterns disappear. Subsequent morphological study revealed consistent and characteristic differences, but no name could be assigned because the character had not been examined in that area before.

Because systematic informaton is so urgently required and because an animal's behavior, ecology, and habitat ultimately reflect a species-specific individuality in concert with morphological uniqueness, systematic biologists are challenged to undertake innovative approaches to solving age-old systematic problems.

Biology. An exciting future is seen for biological research on cephalopods. Recognition of the critical role cephalopods play in various marine communities as upper-level predators and as prey to apex predators, such as fishes, marine mammals and birds, and other large cephalopods, insures that they must receive future research attention. Cephalopods generally are highly mobile, short-lived, fast-growing, large-sized and highly fecund predators. Their distribution, habitat, feeding habits and behavior all can change with sequential growth stages. These and other generalities are well established in the literature. Now we need to accumulate the solid details to hang on the skeleton of existing knowledge.

Behavior may be at the central core for understanding most other aspects of cephalopod biology, e.g., seasonal and vertical migration; prey-predator interrelationships and strategies; reproductive biology; fisheries potential. The behavioral repertoire of cephalopods compared to that of other mollusks is staggering, and comparisons with highly evolved marine fishes show important parallels (Packard, 1966, 1972). Reflect for a moment on a pelagic squid versus an oyster; concurrent with the enormous morphological changes required for a soft-bodied animal that has abandoned its shell for a free-living, predatory existence, are the enormous neurophysiological and behavioral changes required to run the system.

Even though a great deal of research has been done on cephalopod behavior, to date it has been limited mostly to discrimination behavior, centered on a single sensory system such as the visual system of shape and brightness discrimination. Further, most of this work has been done on a single species, *Octopus vulgaris* (see Wells, 1978 and Boyle, 1983 for references). This pioneering work has laid the foundation for a new kind of behavioral research—call it behavioral ecology, ethology or whole-animal behavior. These comprehensive behavioral studies must be carried out in the field whenever possible, supplemented by laboratory studies for confirmation and extension of field observations. Conversely, results of laboratory studies must be compared with parallel studies in the natural habitat. Laboratory studies on captive or reared animals, however, always must recognize the potential for aberrant or adaptive behavior, thus verifying the importance of *in situ* studies for validation of laboratory observations.

At the same time, we recognize that verification of laboratory results in the field may be impossible to obtain. The pioneering work on functional behavior of bioluminescence in cephalopods, fishes, and crustaceans by R. E. Young in Hawaii is a case in point (Young and Roper, 1976, 1977; Young, et al., 1979; Young and Mencher, 1980; Young, 1981; Young, et al., 1982). Shipboard observations and experiments are the only approach possible at this time for studying these living deep-sea animals. An exciting prospect for future research lies in the potential offered by mobile, sophisticated submersibles; it has long been our desire to test our observations on counterillumination and other bioluminescent phenomena in the deep sea. I am confident this will happen.

Whole-animal behavioral studies will provide information on precisely how certain cephalopods fit in to specific marine communities; for example, what is the role and significance of octopus in intertidal and subtidal communities (Ambrose, 1982)? We believe they are the keystone predators in these habitats and perhaps in deeper habitats, as well. New, comprehensive, *in situ* behavioral studies will help answer these questions, as well as provide information on breeding, reproduction, abundance, niche partitioning, etc.

As important as these studies will be, however, they will be limited primarily to benthic, epibenthic and near shore-species and as such will concentrate on octopods, sepiids, sepiolids, and loliginids. Certainly there will be no lack of research opportunities! I point this out to indicate that a significant proportion of cephalopods, the oceanic, neritic, and deep-sea forms, will not be studied in the detailed way proposed for the other forms because they are still largely inaccessible in a technological sense. These animals will be studied at the populational and regional levels rather than at the individual and community levels. Research will be concerned with ecology, population dynamics, and resource development and utilization.

I referred to *Illex illecebrosus* earlier in relation to systematic problems and how they relate to other research and to fisheries. Acquisition of knowledge about neritic and oceanic species is absolutely dependent upon one critical factor whether the research is conducted by a systematist, ecologist, biological oceanographer or fisheries biologist. That critical factor is sampling. Regardless of the target species and the kind of data required, we cannot advance our knowledge without carefully designed and executed sampling programs. Quantitative sampling programs must account for such factors as the nature of the data desired, the size and behavior of the species involved, geographical and vertical distributions, oceanographic parameters, net avoidance, patchiness, sampling gear characteristics, mode of fishing, etc. Paramount here, of course, is the availability of modern, well-equipped research ships. These problems in relation to cephalopods have been addressed in the literature (Clarke, 1977; Roper, 1977; Okutani and Watanabe, 1983; Wormuth and Roper, 1983; Vecchione and Roper, 1985), but their importance cannot be overemphasized.

Future perspectives for research in oceanic cephalopods are very encouraging so long as objective, critical, and comprehensive quantitative sampling regimes are established. Existing technology might not be applicable to cephalopods, so new techniques and procedures may have to be developed to solve unique problems, e.g., sonic techniques for assessing harvestable populations. Then the much-needed answers will be forthcoming about breeding and spawning sites and times; spatial and temporal abundance of hatchlings, early life stages, and adults; seasonal and diel distribution; population and stock assessment; prey-predator relationships; interrelationships with other cephalopods and other groups, e.g., fishes, crustaceans; parasites and epibiots.

Laboratory Maintenance and Culture. A rapidly developing field of research on cephalopods holds great promise for the future, that of laboratory maintenance and culture of cephalopods. Boletzky and Hanlon (1983), Hanlon, et al. (1983), Hanlon and Forsythe (1985), Bergstrom and Summers (1983), Boletzky (1983) have thoroughly reviewed the subject. Loliginid and sepiolid squids and octopuses now can be cultured through several generations. Initially, intensive research on developing capture and maintenance techniques, followed by culturing techniques, was intended to provide a steady, year-round supply of squid giant axons for neurophysiological research. These objectives have been accomplished to the extent that it now seems realistic to use laboratory cultured squids for biomedical and neuroscience research. Research upon the squid third-order giant axon has led to the understanding of the mechanism of the nerve impulse, and more recently it has been used as a model of the cell membrane. These results have widespread relevance to nervous and cellular function in other phyla and the squid giant axon continues to be used in over 70 percent of all large-axon neuroscience research (R. Hanlon, pers. comm.). Other components of the squid nervous system are becoming prominent research objects, including the giant synapse as a model for studying mechanisms of synaptic transmission at the molecular level (Charlton, et al., 1982); the vertebrate-like eye for physiological and biochemical studies (Messenger, 1981); the statocysts, best developed of all invertebrates (Budelmann, 1979; Colmers, et al., 1983); the chromatophores for unique functional morphology and physiology (Hanlon, 1982; Packard, 1982). Learning and behavior studies also have begun on squid (Flores, 1983).

Similar success has been achieved with octopuses so that large-scale octopus culture now is feasible (R. Hanlon, pers. comm.; Itami, et al., 1963). Until now research on octopuses in the U.S. has been minimal because indigenous species do not occur in large, easily accessible populations. In the Mediterranean, however, abundant supplies of *Octopus vulgaris* to the laboratories at Naples, Italy and Banyuls, France have made this species the best studied of all cephalopods and possibly of almost any other marine invertebrate; its anatomy, physiology, and behavior are especially well known and *O. vulgaris* has become the experimental model for studies on a vast array of biological mechanisms (see reviews in Wells, 1978 and Mangold, 1983). Octopuses are particularly well suited to research on correlations between behavior and the nervous system because they are the only invertebrate with a closed circulatory system (Wells, 1983) and a highly vascularized brain in which the lobes are separated (Young, 1971). Octopuses make excellent experimental animals because they are easily narcotized for long periods, they withstand operative procedures, and they recover and heal readily.

Research using octopuses undoubtedly will continue to increase, particularly in learning experiments because their behavior is similar to vertebrates, they are adaptable to reward and punishment experiments, and they possess long- and short-term memory stores (R. Hanlon, pers. comm.). Hanlon also lists other research prospects for octopus that include studies of blood-brain barrier physiology, chemical transmission in the central nervous system, immune mechanisms, toxicology, eye physiology, angular acceleration, chromatophores and color patterning, nerve regeneration, endocrinology, and aging.

The proven techniques of culturing squids and octopuses open the door to many types of research, both on the biology of the cephalopods themselves, as well as using them as comparative models.

Finally, with the first indications of depletion of wild stocks of cephalopods now being reported, we may need to reevaluate the potential for mariculture of cephalopods for human consumption. Currently, mariculture is feasible only for biomedical research purposes, but it could become feasible for specialty food production within the decade where demand and price are very high and supply is low (Hanlon, In press).

Fisheries. Future development of cephalopod fisheries will increase markedly and specialized research will be necessary to insure high quality protein source at reasonable prices. In addition to the biological information required, as pointed out above, research is needed to aid in economically and safely harvesting the highest quality product. For example, an understanding of schooling and defensive behavior patterns and responses relative to fishing gear may lead to the development of new techniques to aggregate and harvest schools quickly and efficiently, just as currently is done with the squid jigging techniques. A great need exists to develop selective (species-specific) fishing gear to insure capture of target species, instead of having mixed species catches that are inefficient, damaging to the soft-bodied cephalopods, and indiscriminate in capturing abundant and depleted species alike (W. Rathjen, pers. comm.). Further, more attention must be paid to on-board handling of cephalopod catches, to insure the highest quality product. While most of the fisheries for cephalopods in the United States have concentrated on species of *Illex* and *Loligo* squids, a 3-year research program investigating the potential for an *Octopus* fishery using selective gear currently is underway on the Florida Gulf Coast (G. L. Voss, pers. comm.). Finally, an educational process is required to inform some people, primarily in North America and northwestern Europe, that cephalopods are a superior food source. Fisheries biologists and cephalopod behaviorists, systematists, and biologists will need to work together to achieve these objectives.

Research on cephalopods is at an exciting point in its development. Much has been accomplished, yet many important challenges remain. CIAC can provide guidance and analysis to point out areas of need and most productive directions in cephalopod research. The expansion of traditional research combined with the aplication of new techniques will lead to valuable increases in knowledge about cephalopods, their role in the natural world, and their potential for utilization by mankind.

So, if we need an answer to the question raised in the title of this paper, I believe it will be a resounding, "Yes!"

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