Bio-ecological aspects of the decapod crustacean fisheries in the Western Mediterranean

Francisco Sardà

Instituto de Ciencias del Mar, Paseo Nacional s/n, 08039 Barcelona, Spain.

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Abstract

This presentation describes a series of experiments designed to study the biology and fisheries of decapod crustaceans in the Western Mediterranean in the framework of research programmes carried out by Instituto de Ciencias del Mar (CSIC) in Barcelona. The results have been used to highlight the importance of bio-ecological studies on commercial species in instituting fisheries management programmes. A series of examples are used to demonstrate how integrating knowledge of the effects of biological and ecological aspects (growth, reproduction, migrations, aggregations, environmental factors, sexual dimorphism, behaviour, etc.) in the fisheries, is essential to avoid sampling errors and errors in stock assessment. Finally, potential directions for future research in this area are discussed.

Keywords: Crustacea, Decapoda, fisheries, biology, ecology, Mediterranean, *Nephrops, Aristeus*, Norway lobster, shrimp.

Bio-ecológicos aspectos de crustáceos decápodos en el Mediterráneo occidental.

Resumen

La presente conferencia recoge una serie de experiencias en el estudio de la biología y pesca de los crustáceos decápodos en el Mediterráneo Occidental, a partir de los programas de investigación llevados a cabo en el Instituto de Ciencias del Mar de Barcelona (CSIC). Los resultados se utilizan como base para resaltar la importancia de los estudios bio-ecológicos sobre las especies comerciales, ante la alternativa de iniciar programas de gestión en sus pesquerías. Se presentan una serie de ejemplos a través de los cuales se demuestra como la integración de los conocimientos bio- ecológicos (crecimiento, reproducción, migraciones, agregaciones, influencia factores ambientales, dimorfismo sexual, comportamiento, etc.), a la pesquería es fundamental para evitar errores en los muestreos y en la evaluación del recurso. Finalmente se dan pautas de posibles líneas de investigación en este campo.

Palabras claves: Crustacea, Decapoda, pesquería, biología, ecología, Mediterráneo, *Nephrops, Aristeus*, cigala, gamba.

INTRODUCTION

The fisheries in the Mediterranean Sea can on the whole be classified as multispecies fisheries. However, the decapod crustacean fisheries can be said to be directed at specific target species, chiefly the Norway lobster *Nephrops norvegicus* or the pink shrimp *Aristeus antennatus*.

Production-based assessment models are rather inefficient for evaluating such fisheries in most countries on account of the difficulty in collecting sufficiently reliable statistics for both catches of and real effort expended on a particular resource.

Analytical models have recently been applied to crustaceans (Demestre, 1991; Sardà, 1993). These include virtual population analysis (VPA) and yield per recruit (Y/R) methods, which require a series of biological parameters that can be collected directly from samples of exploited populations, growth parameters, size at 50% maturity, size-weight relationship, mortality, as well as catches. Most of the parameter values can be obtained from routine size-frequency analyses.

However, in the case of the two species mentioned above ecological factors (behaviour, recruitment, aggregation, seasonality and fluctuations in catches, feeding, predators, etc.) are an impediment to the proper estimation of the exact biological parameters. Problems relating to insufficient knowledge of the bio-ecology of exploited species are often encountered, where bio-ecology is defined as those processes responsible for spatio-temporal variations in specific biological parameters.

Caddy and Sharp (1988) raised this issue when they stated that a better understanding of system behaviour is becoming a necessity. The present emphasis on quantitative evaluation as an assessment tool has not proved overly useful to managers because of its scant predictive value. Perhaps a more qualitative understanding of the functional characteristics of the system integrating the biology of individual species would be more useful to managers when adopting regulatory measures. Thorough knowledge of the biological characteristics of exploited species might provide clues as to which species will respond best to a given type of regulatory measure or will best withstand a given type of effort. Research of this type designed to provide a picture of the bio-ecology of species and their interrelationships both with other species and with the physical environment will probably have a major impact on the way we assess and administer fisheries. It is therefore important for managers and scientists to review the present state of actual knowledge of the biology of each species, local systems, and the accuracy of the data provided by fishermen's associations and based on landings.

These same authors suggested that research aimed at collecting precise information on the local marine systems on which fisheries depend should be encouraged. Relevant research topics included:

- mapping: distribution, associations, communities,
- trophic interactions,
- life histories: reproductive processes, recruitment, seasonality,
- ecology and environment: migrations, rhythms, aggregations and
- description of the oceanography of the region.

In this context, specific features with a bearing on our decapod fisheries are still unexplained, e.g., the interaction between *Aristeomorpha foliacea* and *Aristeus antennatus*, the absence of *Parapenaeus longirostris* from certain areas, and the apparent stability of *Nephrops norvegicus* populations.

In recent years the Instituto de Ciencias del Mar in Barcelona has been conducting research projects intended to expand the existing base of knowledge on the bio-ecology of the above-mentioned crustacean species and on the fisheries for those species, with funding provided by the Spanish Ministry of Research and Science and also by EC General Directorate XIV.

Sequential seasonal fluctuations have been observed in landings of decapod crustaceans caught in the Catalan Sea, yet catches may vary considerably in any given month from one year to the next. Sudden absences of the resource lasting days or weeks without any plausible biological explanation have also been recorded. In addition, although yearly landings remain relatively stable, they do not accurately reflect the actual catches, since small individuals are not itemized on sales invoices, and consequently a substantial proportion of the total catch is not recorded by the Administration. This is the true situation in most ports in all the Mediterranean countries and it prevents proper application of the models.

Studies on the bio-ecology of these species aimed at putting together an overall picture of species behaviour provide a better understanding of the system and make it possible to identify qualitative systems for monitoring and managing these resources.

Norway lobster (*Nephrops norvegicus*)

Studies on selectivity and spatial distribution using geostatistical methods have been carried out in a clearly defined area off Barcelona. A problem connected with using selectivity as a regulatory method is that, as mesh size increases, the escapement size range also increases, rendering the process less effective (Sardà *et al.*, 1993). The mesh sizes presently authorized for use in the Mediterranean (38 mm) retain nearly all sizes.

Studies on distribution have disclosed a spatial distribution pattern consisting of concentric shells of abundance some seven km across in which there appears to be no correlation between distribution and segregation by sex, size, or time of capture (*fig.* 1). Nevertheless, there are considerable variations in the biological parameters and sex ratio values in different critical months, because of the burrowing behaviour of this species. Accordingly, in certain months (autumn) the presence of ovigerous females decreases substantially in the catches. On the other hand, VPA suggests that the Norway lobster stock is not heavily overexploited and has stabilized near the equilibrium level (Sardà and Lleonart, 1993). This is borne out by the absence of very large individuals and the relatively large numbers of individuals at an age associated with 50% maturity. The stock would appear to be extremely sensitive to recruitment, and a

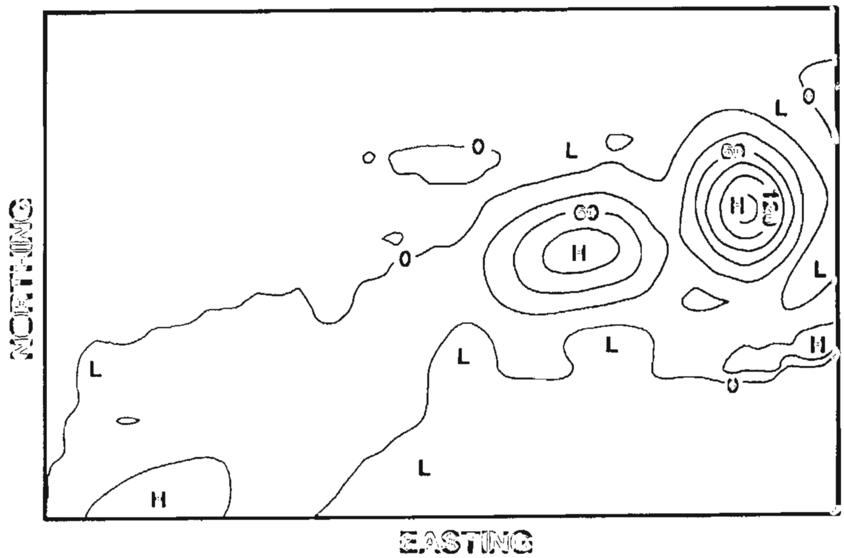

Figure 1. – Estimates and distribution of total weight of *N. norvegicus* in Catalan Sea by geostatistic methods (from Conan *et al.*, 1992). Total surface of 144 square miles. Total random samples, 56 hauls. Northing and Easting are geographical relative references. Numbers are densities (n°/square mile). H, high density; L, low density.

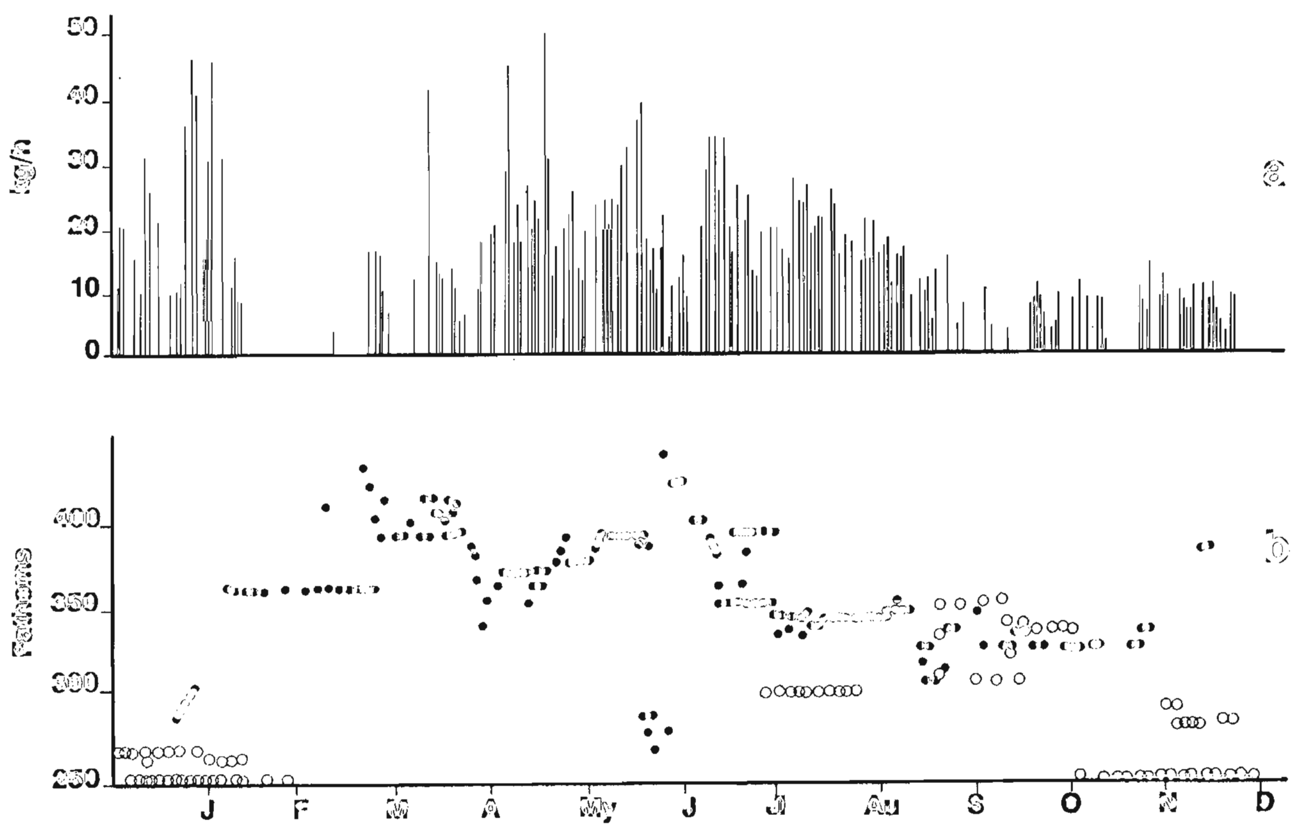

Figure 2. – Relationship between fishing effort (a, kg/h) and capture by habitat and depth (b), according to boat distributions for *A. antennatus*, for one year. Black points, upper slope hauls; white points, canyon hauls (from Tobar and Sardà, 1987).

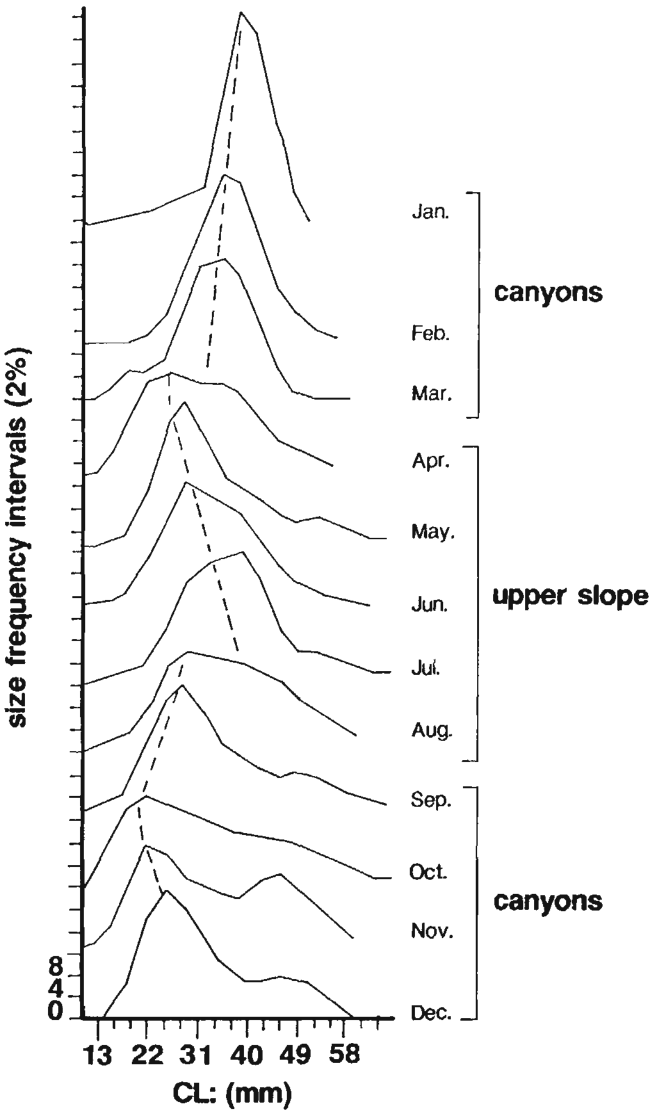

Figure 3. – Effect of the negative growth on *Aristeus antennatus* population when size-frequency distributions are considered for different habitats (data rewritten from Demestre, 1990). CL, carapace length.

small (10-15%) increase in effort should not have a significant effect on the Norway lobster population.

Adequate management therefore depends crucially upon understanding of the processes which affect recruitment.

From this it is possible to derive a series of concepts which are directly applicable in fisheries regulation, based on the biology of this species, and this involve a more away from assessment models. For instance, it is particularly important to maintain the sea bottoms inhabited by *Nephrops norvegicus* in good condition. The protection afforded by burrows to both recruits and ovigerous females would appear to be a primary factor defending the population from fishing and predation. Thus, the use of gear with

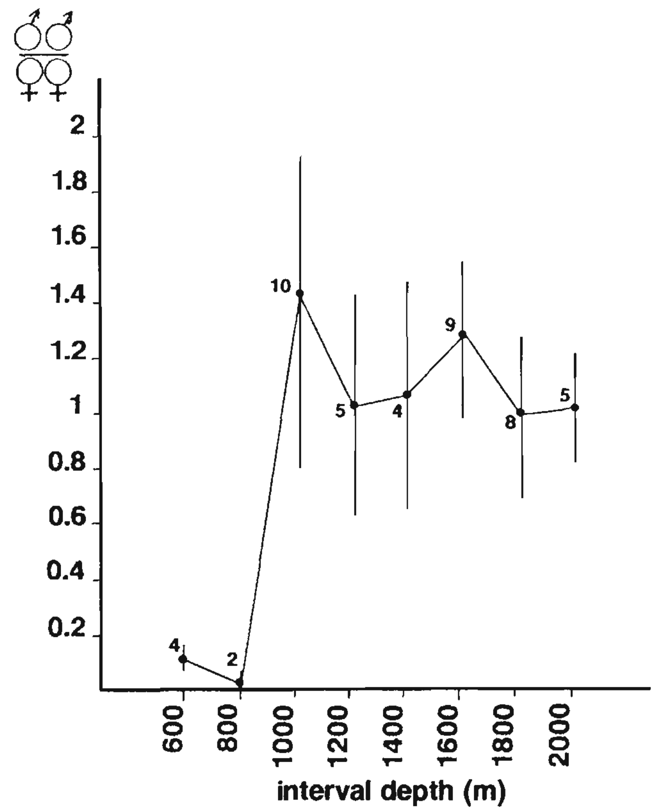

Figure 4. – Sex-ratio-relationship between sex-ratio of *A. antennatus* and depth. Numbers are sample hauls (from Sardà and Cartes, 1993).

the smallest possible impact on the bottoms should be encouraged. Furthermore, the time factor in the collection of samples for assessment (e.g., swept area and scientific assessment surveys) should be taken into account in order to avoid underassessment, which is substantial in any case because of the tendency of Norway lobsters to spend large amounts of time hidden away in their burrows. As a result, VPA is the most satisfactory method for this species, while geostatistical spatial analysis is extremely well-suited for distribution studies.

Based on the results reported for other countries, a series of studies can either be recommended or disadvised: for instance, local studies and studies dealing with comparative biology between areas should be encouraged, since there is evidence that biological parameters may differ significantly; studies on the activity cycle of populations located above 300-400 m could be undertaken; selectivity-based regulations involving a small or moderate increase in mesh size can be disadvised. Another basic aspect enabling management of a fishery is a knowledge of postlarval settlement and the role of bottom sediment type on the settling in and residence of recruits. Distribution and density of Norway lobsters according to bottom sediment type is another subject that should receive attention. In any case, precise assessment of the Norway lobster stock should be based on the relationship existing between the number of burrows (openings) and the estimated number of individuals. It is clear that experiments of this type cannot be carried out in the framework of fisheries alone; rather, an ecological framework is called for, with application of visual (photographs, videos) or laboratory techniques which are not strictly unrelated to fisheries and are not overly expensive. For a review of these aspects see Sardà (1993).

Pink shrimp (*Aristeus antennatus*)

This is one of the species that holds out both major interest for the future and a set of complicated bioecological issues, first because presently there is a large stock of this species with a high market value, and second because the special ecology of the species makes population structure and behaviour difficult to understand.

At first glance the main factors working to protect this species would appear to be the great depth at which the shoals are located, sudden local fluctuations, and this species' high reproductive potential. More thorough studies have defined spatiotemporal migrations and have reported concentrations of shrimp shoals exhibiting a characteristic population structure at great depth (around 700-800 m) on the middle slope in spring. In autumn and winter shoal density decreases, and the shoals spread out towards shallower areas (500-600 m) and towards the fishing grounds located along the edges of the submarine canyons in the area (*fig.* 2). The size distribution and sex ratio vary considerably over the spatiotemporal pattern. As a result, growth parameter values calculated using monthly samples from traditional commercial fishing areas may appear skewed in certain months and may even yield the «negative» growth values typical of migratory species, depending upon the precise location of capture (*fig.* 3). Variations in the sex ratio have also been observed with depth (*fig.* 4).

Thus, size frequency analysis must be sure to take into account the spatiotemporal distribution at the time and the sex ratio by season and bottom location. First of all, growth values will be negative from winter to spring-summer, when the modes shift to the positive, as would be expected. That is why we recommend estimation of growth parameters using the annual-return matched samples method, in other words, by following the modes in the same months in consecutive years. Statistical testing has shown that equality in the size frequencies is more significant in spring than in winter and autumn.

Other ecological observations relating to catchability may also be very useful in managing stocks of this type. One of these is the fact that peak catches per unit effort are normally attained in hauls carried out first thing in the morning (two hours after sunrise); this is highlighted by variations in the catches made before and after the official changeover to daylight saving time in springtime (*fig.* 5). Thus, it would be interesting to consider setting back the time for

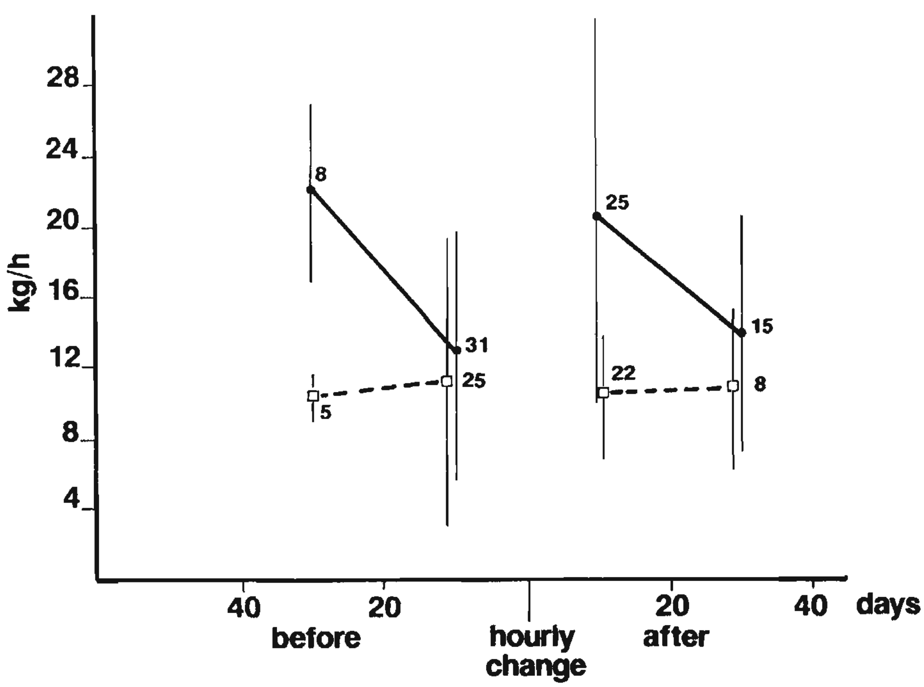

Figure 5. – Differences between the means for catches taken 20 days before and after and 40 days before and after the official changeover from standard time to daylight saving time, black square, first haul; white square, second haul. Hourly change, change to daylight saving time. Numbers are the numbers of hauls (from Tobar and Sardà, 1992).

shooting the first haul of the day as a means of reducing effort. Another aspect, the fact that *A. antennatus* distribution extends down to more than 2 000 m, has implications for management or stock recovery, namely, the huge potential for regeneration that remains in a pristine condition beyond the reach of fishing gear (although density is much lower, the distribution area is extremely large). The contribution of this important biomass to the exploitable stock is completely unknown (*fig.* 6).

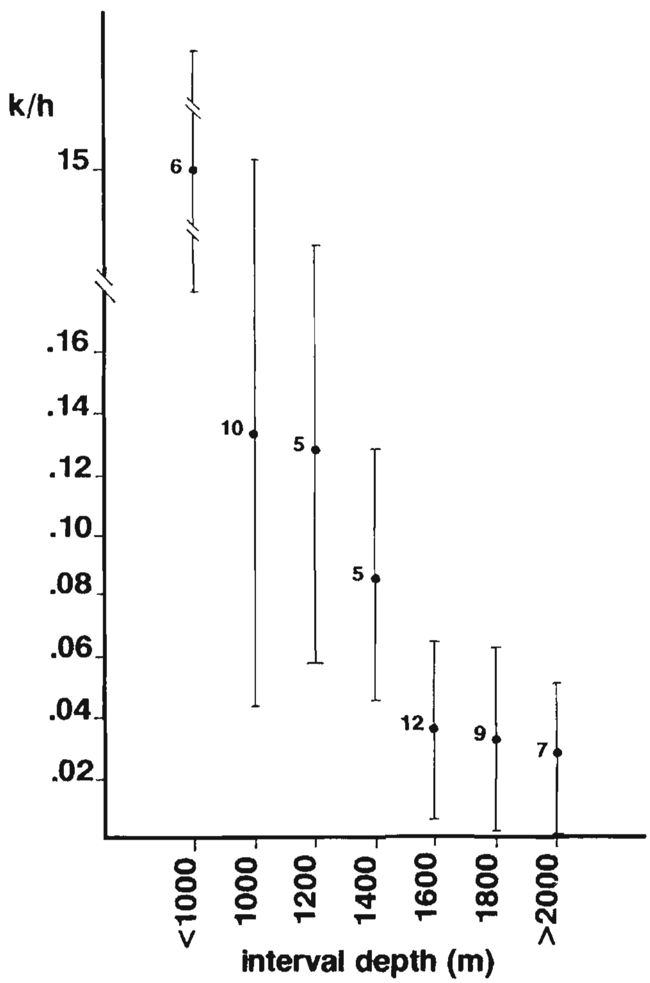

Figure 6. – Abundance - Relationship between abundance of *A. antennatus* and depth. Numbers are sample hauls (from Sardà and Cartes, 1993).

Future research topics for this species include those based on methods using fixed sampling stations on the slope and submarine canyons occupied monthly for studying the real population structure in the habitat concerned. Other aspects such as nychthemeral migrations within the water column, diel (morning/evening) migrations, etc. could also prove extremely useful in management.

GENERAL ASPECTS

Broadly speaking the life strategies of the two species considered here are completely opposed, and their fishing grounds are mutually exclusive. They are excellent representatives of the *k* and *R* strategies. We reiterate the need to compare their biological features and local behaviour patterns and to try to elucidate the most poorly understood aspect in the bounds of existing knowledge – recruitment in both species – while paying due attention to the influence of physical oceanography on the recruitment process. A rather simple but perhaps not obvious factor is the sampling period: the standard monthly sampling period may be sufficient for certain aspects such as growth, but it may not be adequate for such other aspects as reproduction. In several shrimp species two-week sampling periods have detected the existence of serial spawning within the spawning period as a whole. Lastly, it may be appropriate to underscore the need to determine interspecific trophic relationships and each species' predator-prey requirements.

The main thrust of the foregoing examples has been to underline the importance of and need for bio-ecological studies on species subject to a regime of intense local exploitation or for which such a regime of exploitation is being developed. Such studies will provide information in the charateristics of the stock and its critical aspects and on the applicability of different types of regulatory measures in each area. This does not mean to say that the importance of such studies goes unacknowledged *per se* but instead that they are often not regarded in a practical light and that managers prefer to deal with landings data and figures enabling commercial exploitation to be viewed from a purely economic and/or social perspective rather than to invest economic and scientific resources in gaining real insight into the natural mechanisms regulating the stocks. There is evidence that global data can be collected, organized, processed, and presented over short spans of time that can be measured in months, whereas bio-ecological studies not only have a time frame of several years but also have implicit requirements for specialist training and experience of the research teams that carry them out. However, the effect and performance of such studies are also measurable over the same extended time frame. Studies based on catch and landings data are likely to be short-lived and will need to be repeated constantly, whereas the results of bioecological studies remain valid for decades. There is no question that the sooner a country is able to elucidate and react to the ecological structure of its exploited populations, the better. The problem of multispecific aspects and how to apply regulatory and management measures to multispecies fisheries still remains. Nonetheless, points of agreement can be found in respect of mesh sizes, closed seasons and closed areas, minimum sizes, working regulations, gear design, etc. that act upon the system as a whole so as to ensure that they will protect one or more target species.

It is likewise clear that the foregoing comments are equally extrapolatable to other species of commercial interest that offer similar problems, such as *Aristeomorpha foliacea* or the shrimps of the genus *Plesionika*.

Lastly, the following points summarize the proposed priority objectives for the study of the bio-ecology of decapod crustacean resources, whether they are exploited or not:

- Variations in biological parameter values in local stocks;

- Reproductive strategies, life cycles, and recruitment;

- General ecology of fisheries resources: distribution, sex ratio, aggregation, fluctuations, feeding habits, etc.

- Comparative regional studies to pinpoint differences in local stocks and systems of exploitation.

In conclusion, based on the results discussed above, it is recommended that studies into all those bio-ecological aspects that can be expected to contribute to a better understanding of exploited species with a view to implementing a more conceptual strategy of regulation of systems should be promoted generally.

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