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Status and challenges for advancing lobster aquaculture

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Abstract

Production from world lobster fisheries has been more or less static for many years, and a number of major fisheries have declined in recent years. Further declines in the landings of lobster fisheries are very likely due to the combined effects of overfishing, climate change, disease, habitat destruction and coastal pollution. Despite the increasing consumer demand, and the high market value of lobsters, commercial scale aquaculture of lobsters has been very slow to develop. Lobster aquaculture research began over 100 years ago and has only become a commercial reality in the last decade and is already struggling to increase production. This is largely due to the biological obstacles to the successful aquaculture of lobster species, including territoriality, cannibalism, complex larval development and weak resistance to disease. This paper reviews the status of global lobster aquaculture and identifies the major challenges for generating alternative global supplies of lobsters from aquaculture for the future.

Keywords: Aquaculture, spiny lobster, clawed lobster, slipper lobster, phyllosoma

Introduction

Marine lobsters are amongst the most highly valued seafood species and are the basis of significant commercial fisheries in many countries around the world (Holthuis, 1991). The marine animals that are generally called "lobsters" and are consumed as seafood fall into three taxonomic groups; the clawed lobsters (Nephropidae), the spiny lobsters (Palinuridae) and the slipper lobsters (Scyllaridae). Within the Nephropidae there is the genus, *Homarus*, which includes the European clawed lobster (*H. gammarus*) and the American clawed lobster (*H. americanus*) which are of particular importance as seafood species. The Nephropidae also includes a number of species within the genera *Nephrops* and *Metanephrop*s which are commonly known as deep-water lobsters or scampi. The best known and most important species in terms of production is the Norway lobster, *Nephrops norvegicus* (Bell *et al.,* 2006).

Lobster fishery production

Between 1979 and 1997 the fishery production of *Homarus* spp. doubled to over 80,000 t (FAO – Fishstat Database) (Fig. 1). The majority of growth in production was from the American clawed lobster which makes up around 95% of the annual global landings of *Homarus* spp. However, since 1997 the landings of *Homarus* spp. have fluctuated between 80,000 and 87,000 t, although an exceptional peak of annual production of nearly 100,000 t was achieved in 2006. These figures suggest that fisheries for *Homarus* spp. are now fully exploited with increases in production unlikely.

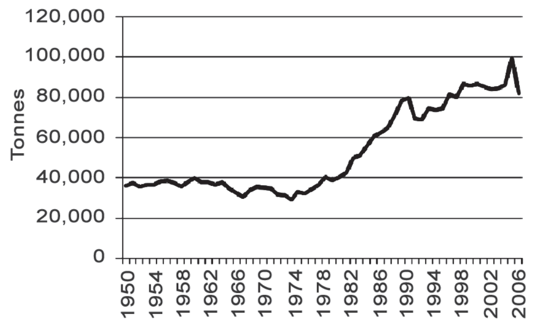

Fig. 1. Annual global fisheries production of *Homarus* spp. up until 2007 (Source: FAO - Fishstat Database, 2010)

Spiny lobster fisheries, which rely on more than 20 species around the world, also appear to have been fully exploited for many years (Lipcius and Eggleston, 2000; FAO – Fishstat Database, 2010) (Fig. 2). Annual global production from spiny lobster fisheries has fluctuated between 70,000 and 87,000 t since 1983, except in 2007 when total annual landing reached its lowest level in 30 years of 67,000 t. The single most important spiny lobster fishery is for the Caribbean or Florida spiny lobster, *Panulirus argus*, which contributes around half of the global landings of spiny lobsters (Lipcius and Eggleston, 2000).

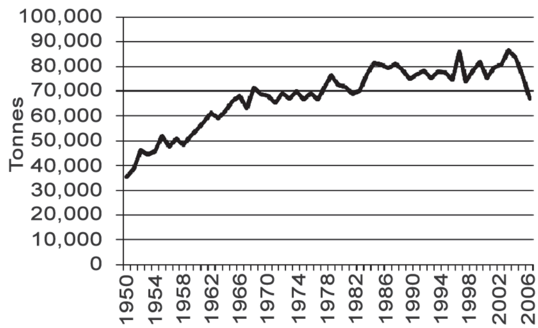

Fig. 2. Annual global fisheries production of spiny lobster species (Panuliridae) up until 2007 (Source: FAO - Fishstat Database, 2010)

Annual global fisheries landings of deep-water lobster species have ranged between 50,000 and 62,000 t since 1982, except for an increase of over 70,000 t from 2006 (FAO - Fishstat Database, 2010) (Fig. 3). This recent increase reflects increased fishing activity in parts of the European fishing grounds for the Norway lobster, *N. norvegicus*. This species is the dominant contributor to total global fisheries landings of deep-water lobsters.

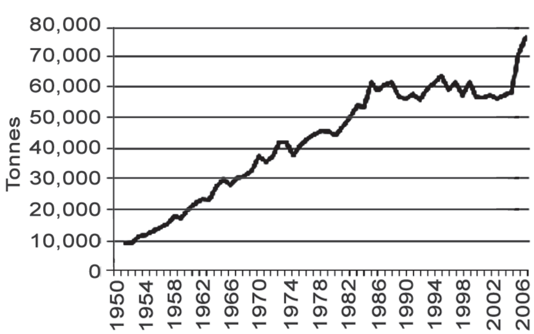

Fig. 3. Annual global fisheries production of deep-water lobster species up until 2007 (Source: FAO - Fishstat Database, 2010)

The global landings from slipper lobster fisheries have grown substantially since 1970 and after 1990 have fluctuated between 2,500 and 5,400 t (FAO – Fishstat Database, 2010) (Fig. 4). The most significant portion of the global catch of slipper lobsters is the species known as Moreton Bay bug or Bay lobster, *Thenus orientalis*, which is harvested mostly in parts of Asia. Overall, the global supply of lobsters from wild fisheries for all species combined appears to be at, or close to its maximum.

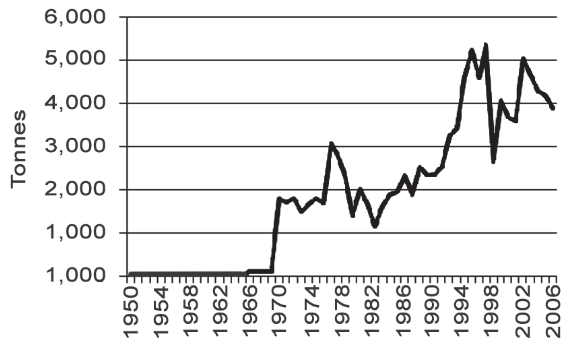

Fig. 4. Annual global fisheries production of slipper lobster species (Scyllaridae) up until 2007 (Source: FAO - Fishstat Database, 2010)

Trade in lobsters

Since the 1980s the international trade in lobster products has grown enormously due to increasing demand and new techniques for processing and handling lobster products, especially live lobsters (Anon., 2006). The largest importer of lobsters is the USA, which accounts for around 35% of all global lobster imports (FAO – Fishstat Database, 2010) (Fig. 5). The volume of imports and price paid for lobster products imported to the USA market have grown steadily for the past 30 years reflecting the increasing demand for lobsters in this market. Other markets for lobster products have also grown including Hong Kong, Canada, France, Spain and Italy (Anon., 2006). For example, imports of lobster products to Hong Kong and China increased by over 9,000 fold between 1982 (2 t) and 2007 (18,712 t) driven mostly by a rapidly increasing standard of living in these countries which created an increased demand for luxurious seafood (FAO – Fishstat Database, 2010). It is anticipated that the global demand and prices for lobster products will continue to increase, while wild fisheries production remains constrained.

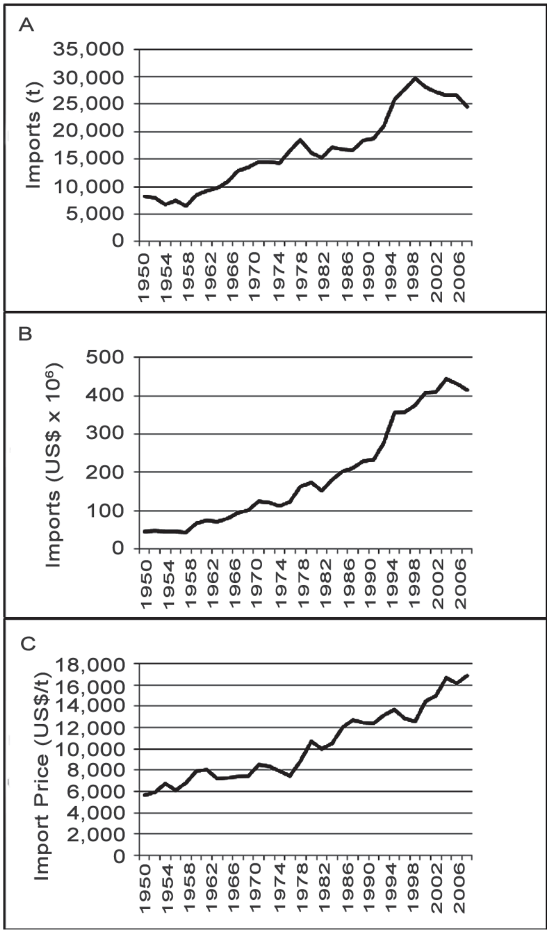

Fig. 5. Total annual import quantity (A), value (B) and price per tonne of import (C) of lobster products to the United States up until 2007 (Source: FAO - Fishstat Database, 2010)

Outlook for global lobster production from fisheries

Although some new lobster fisheries have been discovered in recent years, it is highly unlikely that any major new lobster fisheries will be developed that will provide a significant increase in the global supply of lobsters (Webber and Booth, 1995). In contrast, there are a number of factors which may further constrain or reduce the production of lobsters from wild fisheries.

A number of diseases in lobster populations have emerged as having the potential to very significantly reduce the productivity of some fisheries. Shell disease, which consists of bacterial infection of lobster exoskeletons, has caused considerable concern in some *H. americanus* fisheries because heavy infections are associated with abnormal molting and death (Sindermann, 1991; Castro and Angell, 2000; Smolowitz *et al.,* 2005; Castro *et al.,* 2006; Wahle *et al.,* 2009). The underlying cause of the disease is uncertain, although there are some indications that its presence may be associated with anthropogenic activities (Magel *et al*., 2009). Juveniles of the Caribbean spiny lobster (20-55 mm carapace length) were found to be vulnerable to a recently discovered virus, PaV1 (*Panulirus argus* Virus 1) (Shields and Behringer Jr., 2004; Behringer *et al.,* 2008; Butler *et al.,* 2008; Huchin-Mian *et al*., 2008; Briones-Fourzán *et al*., 2009). The virus attacks some types of haemocytes and connective tissue and can be transmitted via food, contact with infected lobsters, or through water over short distances. In the Florida Keys up to 37% of juveniles in some areas have been found infected with the virus, although lower levels of infection were generally found in the population in this area (Shields and Behringer Jr., 2004).

Habitat loss and environmental degradation are also emerging as important factors in reducing the productivity of lobster fisheries. For example, anthropogenic changes in catchment dynamics appear to have led to the loss of shallow water sponge populations in parts of Florida Bay which were important habitat for the recruitment of juvenile Florida spiny lobster (Butler, 2003; Butler, 2005).

Overfishing of lobster populations is the most likely cause of decline in the production from global lobster fisheries because many of these fisheries are considered to be poorly managed and overexploited (Lipcius and Eggleston, 2000; WECAFC, 2003). For example, the spiny lobster fishery of Namibia almost completely collapsed as a result of abolition of size limit in the late 1960s combined with natural changes in the coastal environmental conditions (Lipcius and Eggleston, 2000).

Most lobster populations are characterised by large inter-annual fluctuations in recruitment and fisheries production, which are thought to be driven by environmental processes influencing larval processes (Lipcius and Eggleston, 2000; Sheehy and Bannister, 2002; Wahle *et al.,* 2009). Long-term climate change is very likely to impact on these recruitment processes (Caputi *et al.,* 2010). Spiny lobster species and fisheries are likely to be most vulnerable to climate change impacts because their life cycle is characterised by larvae with a long developmental period (9-24 months) that traverse into offshore waters, and also appear to have a metabolically constrained post-larval stage (Lipcius and Eggleston, 2000; Jeffs *et al.,* 2001; Fitzgibbon *et al.,* 2010; Frusher *et al*., 2010).

Many commercial lobster fisheries are among the most inefficient fisheries in terms of quantity of catch per unit effort due to the relatively low density spatial arrangement that adult lobsters tend to adopt. Potting and hand gathering methods typically require substantial areas to be traversed by commercial fishers, often with vessels of a sufficient size to be able to carry and lift large lobster pots (Caputi *et al.,* 2000). As a result, future likely increases in energy costs will have a disproportionate impact on the cost of production and market prices of lobsters from wild fisheries.

Lobster aquaculture production

Despite the apparent opportunity for lobster aquaculture to increase the global production, the emergence of aquaculture has been slow. This is largely due to the biological characteristics of lobsters which are not all together well-suited for aquaculture, despite their high value.

The clawed lobsters tend to have slow growth because they are cold water species (Bell *et al.,* 2006; Cobb and Castro, 2006). They are also highly territorial and aggressive, such that if they are communally-housed they are cannibalistic. Together, these characteristics have frustrated ongoing efforts to develop commercial aquaculture, especially for *H. americanus* and *H. gammarus*.

In contrast, slipper lobsters appear to generally gregarious in aquaculture situations, although many species are slow growing and/or have long and complex larval development (Mikami and Kuballa, 2007; Sekiguchi *et al.,* 2007). However, a group of species of the genus *Thenus* (previously *T. orientalis* and *T. indicus* but now multiple species - Burton and Davie, 2007) have emerged as the species of greatest interest for commercial aquaculture development by a number of groups around the world due their short larval duration (around 30 days) and more rapid growth to the commercial size (250 g in around 400 d) (Burton and Davie, 2007; Jones, 2007; Mikami and Kuballa, 2007; Rogers, 2010). Although small experimental scale aquaculture production of *Thenus* spp. has taken place in Australia for more than five years, the large scale commercial aquaculture production of slipper lobsters remains to be established.

The aquaculture of spiny lobsters has been of considerable research and commercial interest for many years, as these species possess many of the characteristics that make them suitable for aquaculture; gregariousness, tolerance of a wide range of environmental conditions, fast growth in some species, relatively few diseases, and accepting of a wide variety of natural foods (Booth and Kittaka, 2000; Kittaka, 2000; Jeffs and Davis, 2003). However, the greatest hurdle to the development of aquaculture of spiny lobsters has been their long and complex larval life which lasts for more than 300 days in culture for some species of spiny lobster. Extensive research on larval rearing over the last 40 years or more in Japan, Australia, New Zealand, India and other countries has demonstrated that whilst the larval culture of spiny lobsters is technically possible, it remains a significant challenge to commercialise for several reasons. Firstly, maintaining the health of the phyllosoma larvae over a long-term culture period requires meticulous husbandry as well as a high degree of culture water and food sanitation (Kittaka, 2000; Ritar *et al.,* 2006). Secondly, the feeding of the phyllosoma larvae currently relies heavily on prepared natural foods, especially ongrown *Artemia* and chopped mussel gonad, which are relatively expensive to prepare and the production of which may be difficult to scale up for commercial production (Kittaka, 2000). Finally, the majority of spiny lobster larval culture systems have been designed and operated on a small scale for the purposes of laboratory research, and it is unclear if their effectiveness will transpose to a larger commercial scale and with higher densities of larvae in culture (Kittaka, 2000; Murakami *et al.,* 2007). Despite these challenges there has been significant research progress in recent years, especially with the larval culture of fast growing tropical spiny lobster species, such as the Caribbean spiny lobster (*Panulirus argus*) and the ornate spiny lobster (*Panulirus ornatus*), which appear to have a relatively short larval period (< 150 d) (Booth and Kittaka, 2000; Goldstein *et al*., 2008; Smith *et al.,* 2009). One group is now in the process of beginning to commercialise this new hatchery technology for the ornate spiny lobster (Rogers, 2010).

In the absence of a hatchery-reared supply of seed lobsters, the ongrowing of seed and juvenile spiny lobsters collected from the wild has begun in a number of countries, foremost in Vietnam, but also to a much lesser extent in the Philippines, Malaysia, Thailand, India, Indonesia, Taiwan, New Zealand, Mexico, and Australia (Booth and Kittaka, 2000; Jeffs and James, 2001; Jeffs and Davis, 2003; Biusing and Lin, 2004; Juinio-Menez and Gotanco, 2004; Thuy and Ngoc, 2004; Hung and Tuan, 2009; Vijayakumaran *et al.,* 2009). In Vietnam very large numbers of wild seed lobsters are gathered for aquaculture using a variety of methods including fine mesh nets used at night to catch swimming post-larvae (pueruli), moored collectors for settling pueruli made out of a variety of materials, and the collection of larger benthic juveniles by divers and trammel nets (Thuy and Ngoc, 2004; Hung and Tuan, 2009; Long and Hoc, 2009). Between 2005 and 2008, over 5 million *Panulirus ornatus* and 2.5 million *Panulirus homarus* seed lobsters were harvested in Vietnam for aquaculture ongrowing (Long and Hoc, 2009). While there are concerns about the sustainability of intensive harvesting of the settling stages of spiny lobster, previous research on two other species of *Panulirus* have indicated very low rates of natural survival for the first year after the pueruli settle (Marx, 1986; Herrnkind and Butler, 1994; Phillips *et al.,* 2003). The juveniles harvested from the wild in Vietnam are cultured in simple sea cages and fed on harvested marine life such as small fishes, bivalves and crustaceans (Hung and Tuan, 2009). This type of sea cage culture has expanded rapidly in Vietnam since it begun in 1992, until in 2006 there were about 50,000 sea cages producing around 1,900 t of lobsters valued at US$90 million (Thuy and Ngoc, 2004; Hung and Tuan, 2009). Since that time lobster aquaculture production in Vietnam has decreased as a result of the outbreak and rapid spread of a bacterial infection of lobsters known as 'milky disease' (Hung and Tuan, 2009).

The relative success of simple sea cage aquaculture methods for spiny lobsters in Vietnam and elsewhere clearly demonstrates the technical feasibility of ongrowing spiny lobsters. However, further improvements are needed in artificial feeds, growing systems (sea cage and land-based) and disease control if a large and sustainable commercial industry is to be developed in the future that can take full advantage of the advent of hatchery-raised seed. These are the areas in which further scientific research needs to be directed in the short-term. This development is most likely to take place in tropical regions of the world where the fastest growing spiny lobster species are found, and where labour and aquaculture operating costs are frequently lower.

Overall, there are good future prospects for aquaculture production of lobsters meeting the increasing global demand for lobster products with a constrained existing supply from wild fisheries.

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