Contributed papers

The cultivation of marine invertebrates indigenous to the Wider Caribbean Region: established culture techniques and research needs for molluscs

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ABSTRACT

Bivalve and gastropod molluscs have supported artisanal and commercial fisheries throughout the Caribbean for generations and they remain today an important source of protein and foreign exchange for many countries in the Region. Although fisheries for conch, top shells and bivalve molluscs have played an important historical role in the economies of the Caribbean and Latin America, commercial-scale mollusc farming has limited precedent there. This paper will briefly review the characteristics associated with mollusc farming and summarize current methods for hatchery production of selected bivalve and gastropod molluscs indigenous to the Region.

RESUMEN

Los moluscos bivalvos y gasterópodos han sostenido las pesquerías artesanales y comerciales en todo el Caribe durante generaciones y aún hoy siguen siendo una importante fuente de proteínas y de divisas para muchos países en la Región. Aunque la pesquería del caracol pala, burgao y moluscos bivalvos han desempeñado un importante papel histórico en las economías de América Latina y el Caribe, el cultivo de moluscos a escala comercial ha tenido un desarrollo limitado. Este documento presenta en forma breve las características asociadas a la cría de moluscos y resume los métodos utilizados en la Región para la producción de moluscos bivalvos y gasterópodos nativos en criaderos.

INTRODUCTION

The fundamental differences between bivalves and gastropods are associated with feeding and motility, characteristics that dictate to a great degree site selection and farming methods during grow-out to harvest. Bivalves are filter feeders, consuming microalgae (phytoplankton) from the water column. As a result, bivalves are non-motile during their juvenile and adult stages and they thrive best in locations with high primary productivity in the form of phytoplankton standing crop (or density). In contrast, gastropod molluscs are herbivorous benthic grazers or carnivores that often have a high degree of motility. Although these characteristics will play a role in choosing appropriate locations for farming, and subsequently, the species composition and source of broodstock for a hatchery facility, most of the fundamental techniques for culturing mollusc larvae are similar. This report first will discuss the culture methods and potential for bivalves followed by a discussion of selected gastropod molluscs.

BIVALVE MOLLUSCS

Bivalve molluscs have been cultured for centuries throughout the world, largely because they are relatively easy to farm; as filter feeders, they consume phytoplankton from natural sources, seed can be collected from the wild, they are non-motile and typically reside in shallow coastal waters.

The Caribbean Sea is a partially enclosed extension of the North Atlantic Ocean comprised of the islands of the Greater and Lesser Antilles and the continental countries of Latin America from the United Mexican States to the Federative Republic of Brazil. The coastal shelf on most islands is small, while it is much more extensive along the continental coast. The greatest portion of the Caribbean is quite deep, usually exceeding 1 800 m. It is characterized by nutrient-poor surface waters which results in low phytoplankton productivity throughout most of the eastern Caribbean and presents a major constraint to bivalve culture. Generally, low nutrient levels limit phytoplankton productivity to less than 250 mg C/m^2/day. The larger islands of the Greater Antilles have a limited capacity for bivalve cultivation in protected bays, lagoons and estuaries with phytoplankton productivity 250–500 mg C/m^2/day. Nutrient inputs in the embayments are primarily from terrestrial runoff, but the areal extent of these sites is usually limited, and industrial and domestic pollution may pose public health risks associated with bivalve culture.

Nutrient-rich waters occurring in upwelling areas along the coasts of the Bolivarian Republic of Venezuela, the Republic of Colombia, the United Mexican States, the Republic of Guyana and the Republic of Panama support the highest phytoplankton productivity in the Caribbean Sea, exceeding 500 mg C/m^2/day. Enhanced by terrestrial nutrient input from rivers, many estuaries and coastal lagoons support fisheries for several species of oysters, mussels and scallops. As a result, the potential for bivalve farming in these countries has been recognized for several years; the Bolivarian Republic of Venezuela and the United Mexican States, in particular, have significant experience in mollusc culture.

Hatchery production

Hatchery production of seed for bivalve molluscs essentially is the same for most species; the major differences are related to spawning requirements (temperature/salinity), duration of the larval veliger stage, and specific requirements for settlement (burrowing into substrate vs. attaching to hard surfaces). The common requirement for hatchery production of bivalves is the provision of cultured phytoplankton as feed; it represents the most technically demanding and costly aspect of the operation. However, methods for phytoplankton culture are well documented in the literature and a relatively straight-forward component of bivalve hatchery operations (Creswell, 2010; Hoff and Snell, 2008). Several species of microalgae are well adapted to warm, tropical conditions, notably *Isochrysis galbana* (Tahitian strain, T-Iso), *Chaetoceros gracilis*, *Tetraselmis* sp., and *Nannochloropsis oculata*. Nonetheless, stock algae cultures require a cool, temperature-controlled illuminated environment that requires cleanliness standards consistent with a microbiology laboratory (Helm, Bourne and Lovatelli, 2004).

Ripe bivalves, either collected from the wild during the appropriate season or conditioned in a hatchery broodstock system, can be induced to spawn by either temperature or salinity changes. At higher latitudes, temperature is usually the environmental factor that initiates gametogenesis, while in lower latitudes salinity serves as the environmental cue. In either case, the initiation of ripening and spawning is associated with phytoplankton productivity in the environment. Broodstock are placed on a spawning table, or individual holding containers in cool (22 °C) high salinity seawater (35‰), and gradually the temperature is raised to 30 °C and freshwater is added to reduce the salinity to 20‰). This process may be repeated for one to six hours. Adult bivalves are usually spawned on a shallow water table or trays, often with a black background to facilitate identifying eggs and sperm. Typically, the females are removed to separate containers when they begin to release eggs to avoid polyspermy (a condition when too many sperm will enter the egg and cause abnormal development). If the males fail to release sperm from temperature or salinity induction, some may be sacrificed and sperm stripped from the gonads and provided to the females. The eggs are collected on a 20–35 µm screen and rinsed to remove excess sperm and placed in a larviculture tank, typically at a density of 10–20 eggs/ml. Bivalve molluscs are highly fecund, and each female may release several million eggs during a single spawning.

The fertilized eggs develop rapidly, through a ciliated *trochophore* stage, and become shelled, veliger larvae within 24 hours (if not sooner). The *veliger* is the larval stage of all bivalve molluscs. The ciliated velar lobes filter phytoplankton as food for the developing larva and provide motility. In warm tropical waters, the larviculture water is exchanged (100 percent) each day through a drain at the bottom of the tank. The veligers are collected on fine-mesh screens, usually beginning with 35–50 µm screens, gradually increasing the mesh size to over 250 µm at the pediveliger stage (pre-settlement), depending on species. Culturists routinely grade the larvae to select the fast-growing, more robust veligers by using the screen mesh-size to remove a portion of the population that will result in a larval density of around 1/ml at the pediveliger stage (Figure 1).

Phytoplankton are fed daily, usually after the water exchange, at a density of 10 000–50 000 cells/ml depending on larval density and size. Observing and quantifying the clearance rate of phytoplankton by the veligers will help define the feeding regime as the larvae grow and their density changes. Providing more phytoplankton than necessary can result in rejection of algal cells by the larvae and bacterial contamination in culture tanks. Brightly illuminated tanks can promote algal blooms and should be avoided.

The duration of the veliger larval stage and the size at the time they are competent to metamorphose (settle) is variable. Typically bivalves will be competent to settle in one to three weeks at a size of 200–350 µm. Most larvae prior to metamorphosis develop a clearly observable umbo (called umbo-stage) followed by the pediveliger stage (a noticeable foot) and active "searching" behaviour and extension of the foot. At this juncture, the larvae are harvested and usually placed in smaller containers with

FIGURE 1
Bivalve veliger larvae

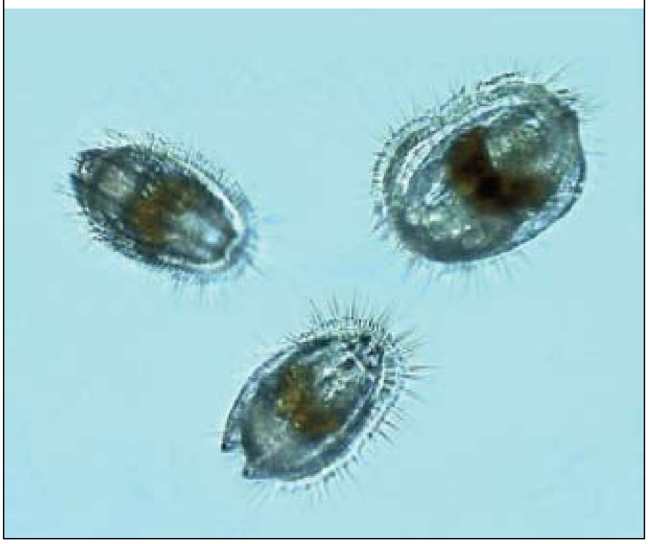

PHOTO: M.M. HELM

appropriate substrates for settlement. These vary considerably for different species and it represents the most significant departure in methods for culturing bivalves. In most cases, bivalve larvae do not require any chemical or environmental cues to induce settlement (as do many gastropods), however the proper substrate may be essential to post-settlement survival and it also defines how the bivalves are held in nursery systems before out planting for grow-out in natural waters.

GASTROPOD MOLLUSCS

The reproductive biology and larval development of gastropod molluscs are far more variable than for bivalves. Some gastropods are broadcast spawners, the eggs being fertilized externally in a similar fashion to bivalves; others are internally fertilized and produce egg masses that later hatch as veliger larvae, and some produce egg cases where larval development is completed within the capsule and benthic juveniles emerge (e.g. buscyonidae). Gastropods are commonly benthic feeders (unlike filter feeding bivalves), either herbivorous grazers (e.g. strombids, trochids and turban shells) or carnivorous predators (e.g. muricids, vase shells).

Hatchery production

The veliger larvae of gastropods utilize their ciliated velar lobes for motility and to filter phytoplankton in similar fashion to bivalve molluscs (although in many cases, such as the strombids, the velar lobes will bifurcate into four and then six extended lobes during the course of larval development). Gastropod larvae are usually much larger than bivalve veligers and, as a result, they are stocked at lower densities in culture tanks (approximately 50/litre for newly hatched queen conch).

Flow-through systems are considered more appropriate for these larger veligers because larger mesh screens can be used on standpipes, and the larvae are less likely to become impinged. The regular circulation is a significant improvement in water quality and bacterial contamination control over static water exchange systems.

The queen conch, *Strombus gigas*, is the most economically important gastropod mollusc in the Caribbean Region. Since the 1970s it has been the subject of study for managing the fishery, understanding its ecology and population biology and developing culture techniques (Brownell and Stevely, 1981). D'Asaro (1965) conducted early experiments related to the reproductive biology of queen conch and described their larval development. In the early 1980s, the refinement of hatchery techniques for queen conch was achieved at the University of Puerto Rico (Ballantine and Chanley, 1981; Ballantine and Appeldoorn, 1983) and at the University of Miami (Siddall, 1983; Creswell, 1984).

Most of these early efforts to produce queen conch in hatcheries was predicated on their reintroduction to enhance populations depleted by overharvesting. To date there have been no large-scale reseeding efforts with hatchery reared queen conch juveniles despite efforts by the Florida Fish and Wildlife Conservation Commission – FFWCC (Berg and Glazer, 1991), the University of Puerto Rico, Caribbean Marine Research Center (Stoner, 1994) and the United States Agency for International Development (USAID) in Belize. These studies concurred that release of small juveniles (1–2 cm) resulted in unacceptably high mortality and that released animals should be at least 7.5 cm SL and provide some degree of predator exclusion. Given the high cost of hatchery-produced conch seed (from USD 0.20 each for 2 cm seed to USD 0.75 for 7–9 cm seed), stock enhancement may not be economically feasible. A significant body of research was compiled with the 35th Gulf and Caribbean Fisheries Institute (GCFI), held in Miami, Florida (United States of America) in 1983 (Iversen, 1983; Siddall, 1983; Davis and Hesse, 1983; Goodwin, 1983; Laughlin and Weil, 1983). A report of the "Evaluation Team on Conch Mariculture" from the 35th GCFI provided several insightful recommendations (Berg *et al.*, 1983), among them:

- Because hatchery-restocking programmes appear quite costly, adequate fishing data should be obtained before a commitment to an extensive restocking programme is made.
- Considerable progress has been made in studies of the potential of restocking programmes, but information is needed concerning stocking densities, age at stocking and benefit of the restocking programme.
- From the data presented, it appears that harvested conch products may not be sufficient to pay hatchery costs in restocking programme.
- Given the present value of the resource (1983) and predicted costs for production of market-size or adult conch by any of the means discussed at these meetings, commercialization of conch aquaculture does not seem economically feasible at this time. However, changes in the price structure could change this. The present technology for conch aquaculture could be adapted to commercial scale ventures if such changes occur.

Considerable interest in queen conch culture has continued to present with studies being conducted by the Research and Advanced Studies Center of the National Polytechnic Institute of Mexico (Centro de Investigación y de Estudios Avanzados del Instituto Politécnico Nacional - CINVESTAV-IPN) (Aldana Aranda, 2003), the Florida Fish and Wildlife Conservation Commission (Glazer and McCarthy, 1996), the Harbor Branch Oceanographic Institute (HBOI Florida Atlantic University) (Davis, 2000), and Mote Marine Laboratory in Florida (Davis, 2005). To date, methods for maintaining broodstock, acquiring and incubating gametes, larviculture, metamorphosis induction and nursery culture and early feeding are well established. Grow-out of queen conch in land-based ponds and cage structures have successfully reared queen conch to market size (18 cm SL) in 20 months (0.15–0.20 mm/day). Davis (2005) provides a detailed review of production of half a million queen conch from egg stage to legal market size. The paper also discusses the economic potential for culturing queen conch for alternative markets, such as sub-legal juveniles for escargot and the aquarium trade, both of which would require some forms of regulatory variance.

Trochids are found in both temperate and tropical waters; reproductive development, as well as spawning in the laboratory and larval development has been described for several temperate species (Holyoak, 1988). Spawning and larval development for five tropical species from the Pacific and Red Sea (Heslinga, 1981; Heslinga and Hillmann, 1981). Bell (1992) presented a detailed study of spawning and larviculture of *Cittarium pica* and further elucidated the prospects for mariculture of the West Indian tops hell for restocking depleted populations (Bell, 1996).

The West Indian top shell, *C. pica*, is a broadcast spawner with a lecithotrophic veliger larva with short duration (3.5–4.5 days to metamorphosis). Larvae settle when exposed to algal film and the juveniles are generalist herbivores. Present constraints to successful mariculture are larval and early juvenile survival and spawning induction. Many techniques used for other gastropod molluscs, and specifically Indo-Pacific trochids could be adapted for *C. pica*, suggesting that stock enhancement of this important Caribbean gastropod from hatchery-produced seed could be feasible.

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Past and current oyster culture in Jamaica

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ABSTRACT

The Fisheries Division of the Ministry of Agriculture, Jamaica, in 1976 concluded that the wild stocks of mangrove oysters (*Crassostrea rhizophorea*) were in an advanced state of decline. The cultivation of this oyster species was seen as a viable solution. In 1977, the Oyster Culture (Jamaica) Project commenced operations with the following aims: 1) to identify suitable culture sites; 2) to conduct research and develop a low-cost commercial method for collecting wild spat; and 3) to support the establishment of a sustainable farming industry. The project has succeeded in identifying production sites and developing commercial collection methods, however, it has failed in developing a sustainable industry. In order for Jamaica to have a commercially viable oyster culture industry, market planning and socioeconomic investigations must be key components of a targeted development plan for this industry.

RESUMEN

La División de Pesca del Ministerio de Agricultura y Pesca de Jamaica, concluyó en 1976, que las poblaciones silvestres de ostras de mangle (*Crassostrea rhizophorae*) se encontraban en un avanzado estado de deterioro. El cultivo de esta especie de ostra se visualizó como una solución viable. En 1977, el Proyecto Cultivo de Ostras (Jamaica) inició sus operaciones con los siguientes objetivos: 1) identificar sitios apropiados para el cultivo; 2) realizar investigaciones y desarrollar un método comercial de bajo costo para la colecta de semilla silvestre; 3) apoyar el establecimiento de una industria sostenible de cultivos de ostras. El proyecto ha tenido éxito en la identificación de sitios de producción y desarrollo de métodos comerciales de colecta, sin embargo ha fracasado en el desarrollo de una industria sostenible. Para que Jamaica tenga una industria viable de cultivo comercial de ostras, la planificación de mercado e investigaciones socioeconómicas deben ser componentes clave de un plan de desarrollo específico para esta industria.

INTRODUCTION

The mangrove oyster, *Cassostrea rhizophorea*, is extensively distributed throughout the Caribbean and is usually found in the narrow intertidal zone typically attached to the roots of red mangrove (*Rhizophora mangle*) (Wade *et al*., 1980; Roberts, 1991). In 1976, the Fisheries Division of the Ministry of Agriculture concluded that the wild stocks of mangrove oysters around the island were in an advanced state of decline due to unsustainable exploitation practices. One solution forwarded at that time was the cultivation of the mangrove oysters. The feasibility of developing such an oyster industry was investigated through the establishment in 1977 of the Oyster Culture (Jamaica) Project (OCJ), involving Ministry of Agriculture (Fisheries Division), the University of the West Indies (UWI) and the International Development Research Centre (IDRC) of Canada.

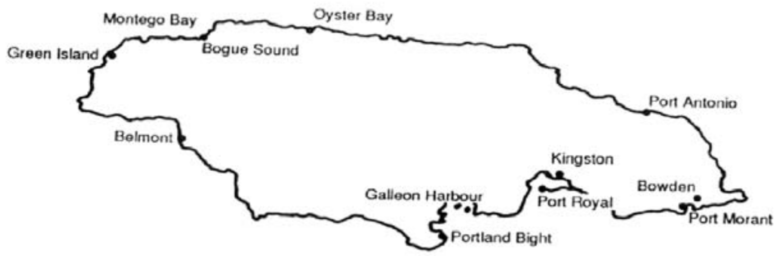
The project was rolled out in three phases: Phase 1 investigated the nature, biology and habits of the animals and suitable culture method for Jamaica; Phase 2 aimed at launching commercial farming operations; while, Phase 3 targeted economic research with the view of expanding the industry (Roberts, 1991). The project lasted 12 years, but failed in this period to develop a sustainable oyster industry.

HISTORICAL BACKGROUND

The project years: 1977–1991

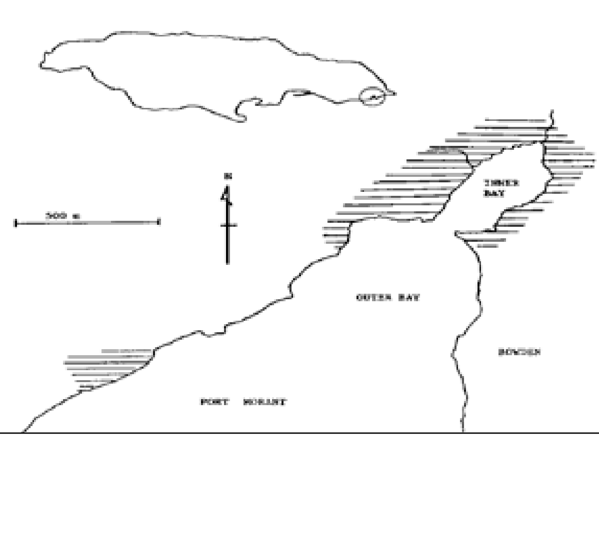
Phase 1 of the project lasted for three years and had two objectives. Firstly, locate and investigate viable population sites around the island. The UWI and IDRC were the lead agencies, providing funding and technical expertise. Preliminary surveys were conducted island-wide in mangrove areas which were characterized by having protected bays, consistently high seawater salinity levels and eutrophic water movement and a significant wild oyster population (Clarke, Little-Saunders and Newkirk, 1991). Eleven such sites were located, however, Bowden Bay in Saint Thomas was deemed the most favourable for collecting and grow-out purposes (See Figures 1 and 2).

FIGURE 1
Eleven survey sites for oyster farming



Source: from Alexander, 1991.

FIGURE 2
Bowden sites in Saint Thomas



Source: from Alexander, 1991.

Secondly, research was conducted, focusing on the life cycle and natural habitat of the mangrove oysters, as well as, the development of suitable culture methods under the existing conditions in Jamaica. In 1980, three years after Phase 1 was commenced, a viable methodology was introduced for collecting seed in intertidal zones.

Phase 2 commenced in 1982 with reduced emphasis on biological research and a greater focus on establishing a self-sustaining industry. To this end, the government at the time acted on recommendations forwarded by the Oyster Culture (Jamaica) Project for an Oyster Culture Unit within the Ministry of Agriculture to be set up (Wade *et al*., 1981; Alexander, 1991).

The duration of this phase was marked by the establishment of Bowden site, Saint Thomas, as a major seed/spat centre and the development of technology and techniques, thereby, facilitating greater spat collection. Richards (1992) summarized the six major interventions undertaken. These were:

1. The introduction of long-lines to overcome choppy seas.
2. Reduced mortality via the movement of seeds at a size of 2.5 cm as compared to 1.5 cm.
3. Introduction of easily adjustable racks ("Slip-down Racks") aimed at reducing the need to adjust cultch levels as a result of tidal range movement.
4. Reduction of cultch numbers from 10 to 5, thereby, allowing better fit in the lower region of intertidal zones.
5. Increased distance between spat collection spacers from 1.0 to 2.5 cm.
6. Incorporation of other stakeholders, such as the Scientific Research Council, Ministry of Health, Bureau of Standards and National Water Commission, to assist with industry development.

Alexander (1991) reported that spat catch rates increased to 60 percent within the period 1980–1985, preceding the aforementioned interventions.

Phase 3 was the final project phase and focused on the enterprise development and the creation of appropriate institutional support structures for a sustainable oyster industry. Alexander (1991) and Richards (1992) pointed to three main outputs for this phase:

1. The development of a credit support programme in 1988 which provide financing for new and existing oyster farmers.
2. The development of governmental support, regulatory and management oversight.
3. Biotechnical research aimed at increasing efficiency and reducing spat mortality (see Littlewood, 1991a, 1991b; Roberts, 1991).

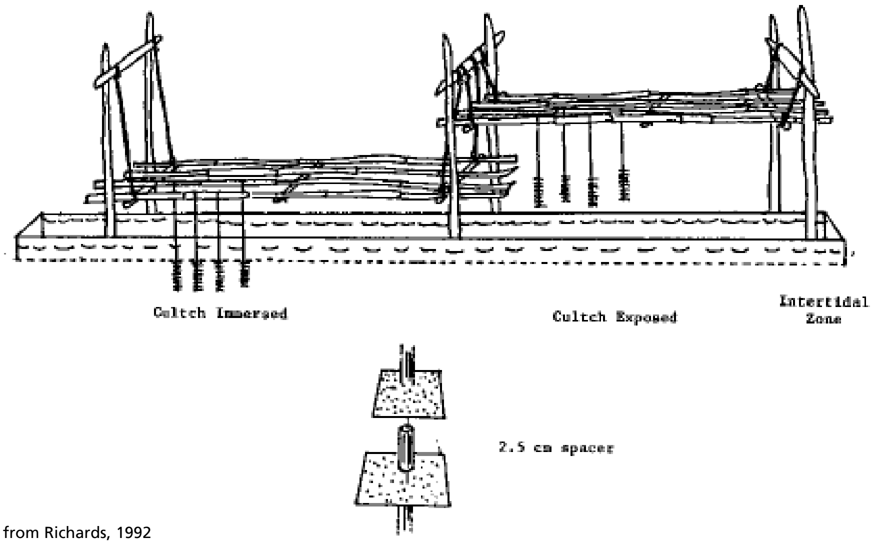
OYSTER CULTIVATION TECHNIQUES IN JAMAICA

Cultivation of mangrove oysters involves two distinct activities: (1) spat collection; and (2) grow-out.

Spat collection

The collection of spat has evolved since the inception of mangrove oyster farming in 1977. Currently, it involves the use of 8 x 8 cm tire cultch with 2.5 cm spacers, hung from adjustable bamboo structures, referred to as "Hanson Racks" (Figure 3). These cultches are placed in the water, where they remain until the spat have set. When enough spat have settled, the cultches are exposed fortnightly for four to six hours to air dry. This eliminates most fouling organisms, such as barnacles. The cultches are sorted and transferred to the grow-out at the end of six weeks or when the spat have attained an average size of 2.5 mm, whichever comes first.

FIGURE 3
Arrangements of the oyster seed collecting clutches



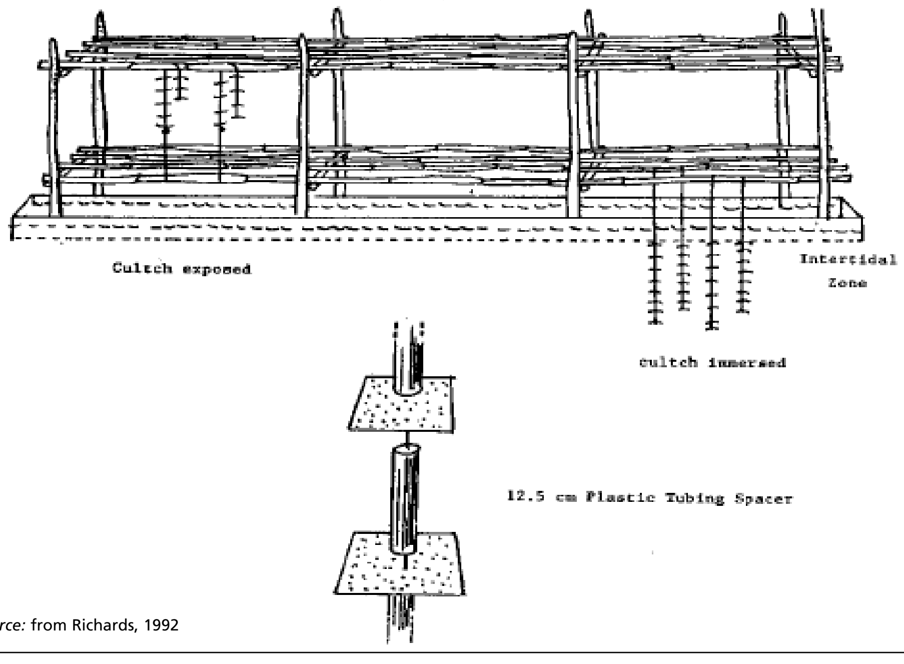
Source: from Richards, 1992

Grow-out

Cultches are removed and spat density assessed. Cultches with a spat density of 10–15 are considered optimum and selected for grow-out. The sorted cultch is strung with a 12.5 cm spacer (i.e. using a section of drip irrigation hose) with a maximum of eight per string. Two hundred and fifty strings are then hung on grow-out racks for the duration of the cultivation process, usually six months (Figure 4).

However, the cultivation method used in Jamaica, while taking advantage of the mangrove oyster's ability to thrive in subtidal waters, tends to facilitate the propagation of fouling organisms. To combat this problem, aerial exposure is undertaken every two weeks for four to six hours. This process is continued for the four-month duration of the grow-out period or until a shell length of 40–70 mm is obtained.

FIGURE 4
A representation of the oyster grow-out structures and cultch



Source: from Richards, 1992

INDUSTRY CHALLENGES

Many of the challenges associated with mangrove oyster cultivation and the failure to develop a sustainable industry can be traced back to technical and socio-economic issues.

Firstly, the technical challenges include the absence of a reliable supply of spat and this continues to be a major hindrance to the industry's chance of recovering and developing. In Jamaica, mangrove oysters have two distinct spat periods. Hence, the production of oysters is centered on these two periods and consequently, the supply of oysters and its associated products will be seasonal. To ensure a continuous and reliable supply of spat, Jamaica must invest in the development of an oyster hatchery.

Secondly, there are socioeconomic issues related to the absence of a market-driven production strategy. Since the commencement of oyster farming, with the oyster culture project in 1977, limited attention has been paid to developing and sustaining markets. In fact, it was not until 2009 that a market study was undertaken by the Fisheries Division, aimed at developing a strategy for repositioning the industry to be more market-driven. Further compounding the problem is the fact that currently, there are no commercial oyster farmers.

Additionally, regulations governing the industry need to be developed. Currently, no laws exist to allow farmers and potential farmers to lease sea floor and its associated exclusive rights. Farmers will be unwilling to undertake major investment unless guaranteed tenure and right to protect their investment. Moreover, there are no production standards.

PROSPECTS FOR THE FUTURE

It is estimated that Jamaica imported some 2 000 kg of mollusc in 2007, which was comprised of clams, scallops and oysters. Oysters account for a large portion of total imports (STATIN, 2010). The hospitality industry is responsible for the majority of the importation and consumption of mollusc. However, at present, oyster cultivation is confined to the Ministry of Agriculture experimental facility in Bowden, Saint Thomas. There are no commercially-operated farms currently in Jamaica and it appears that this industry will not be re-established in the near future unless several pressing issues are resolved.

Foremost among these is marketing. In 2009, the Aquaculture Branch of the Fisheries Division commissioned a market study and a market plan for oysters and related products. The results from this study form the basis for a development plan the sole purpose of which is to provide a roadmap aimed at ensuring development and future viability in the oyster industry. This plan is composed of four objectives: (1) increase public awareness and brand identification; (2) re-enlistment of oyster farmers and development of a structured marketing apparatus; (3) development of value added products to create a market pull effect; and (4) research for the development of new product offerings.

This study highlighted some advantages such as a growing tourist industry and the potentially large uptake by locals, if product offerings were expanded. It is with this in mind that significant resources must be brought to bear on achieving these objectives, if Jamaica intends to re-establish its oyster industry.

CONCLUSION

After 33 years of oyster culture activity, Jamaica has a workable low cost mangrove oyster (*Crassostrea rhizophorae*) cultivation technology and a significant repository of technical information. However, it has not managed to develop a sustainable industry. In fact, there are currently no active oyster farmers/farms apart from the Bowden facility managed by the Fisheries Division.

A review of the industry has identified the following challenges: i) seasonal irregularities of spat; ii) high mortality during the grow-out periods; iii) absence of a marketing plan; iv) absence of a post harvesting facility; and v) regulatory framework for sea floor lease agreements.

If the aforementioned issues were addressed, greater success would be forthcoming in the development of the industry and Jamaica could potentially boast a sustainable oyster industry.

RECOMMENDATIONS

1. Formulation of a steering committee which is tasked with identifying issues and ways of restarting and enhancing oyster production, while at the same time, integrating it with the national goal of poverty alleviation.
2. Address the regulatory framework that deals with securing leasing rights to the sea floor in production localities.
3. Formation of production cooperatives to take advantage of markets and collective lobbying;
4. Improve technical competence and business practices of farmers via the design of training programmes for new farmers.
5. Formulation of marketing strategies to address the development of value added products and new product offerings.
6. Re-engage research partners, such as the University of the West Indies, to address production issues such as inconsistent spat supply and low survival of oysters during the grow-out periods.
7. Develop an incentive programme to attract new individuals to oyster farming. This could include, but would not be limited to, low-cost interest loans, moratorium on property taxes and duty free importation of related processing equipment.

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Farming native scallop species

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Sarkis, S. 2011. Farming native scallop species. In A. Lovatelli and S. Sarkis (eds). A regional shellfish hatchery for the Wider Caribbean: Assessing its feasibility and sustainability. FAO Regional Technical Workshop. 18–21 October 2010, Kingston, Jamaica. *FAO Fisheries and Aquaculture Proceedings*. No. 19. Rome, FAO. 2011. pp. 95–103.

ABSTRACT

Culture techniques for two native scallop species, the sand scallop (*Euvola ziczac*) and the calico scallop (*Argopecten gibbus*) have been developed and fully-tested in Bermuda. A temporary pilot-scale custom-built facility was designed and built using insulated fiberglass containers, housing a hatchery, nursery and algal area. Both species demonstrated rapid growth rate at all stages of their life cycle, attaining market size within 12–18 months of egg fertilization. This paper describes optimal techniques for all stages of the life cycle, including grow-out methodology, species-specific constraints and estimated costs of spat production. Reproductive cycle in Bermuda's more northern waters is well defined for both species with spawning activity occurring during the winter months. The duration of larval life is 10–14 days accelerated in the hatchery by increasing ambient temperature of 17 to 24 °C. Survival rate to settlement was higher for calico scallops (up to 55 percent) than for sand scallops (maximum of 20 percent). Similarly, the percentage of post-larvae obtained was consistently higher for calico scallops than sand scallops. Spat were reared using two different methods (mesh immersed in tanks and raceways) and size of transfer at sea was tested. Sand scallop spat benefitted from a longer nursery period, growing to 10 mm in <2 months following settlement in outdoor raceways; calico scallops demonstrate a high survival in the field when transferred at 2 mm shell height (or two to three weeks post-settlement). Suspended pearl nets were initially used for both species for grow-out, with an average growth rate ranging from 7–10 mm a month, and a survival rate >90 percent. At 25 mm shell height, sand scallops had to be grown directly on the sand for optimal growth and survival until market size. This proved labour intensive and costly, and grow-out of sand scallop requires further investigation to improve cost-efficiency of production. Calico scallops were identified as the easier culture species, being relatively hardy at all stages of its life cycle, with its only constraint being a smaller market size species.

RESUMEN

Las técnicas de cultivo para dos especies nativas de vieira, la vieira de arena (*Euvola ziczac*) y la vieira cálico (*Argopecten gibbus*), han sido desarrolladas y completamente probadas en Bermudas. Se diseñó y construyó una instalación temporal a escala piloto usando contenedores independientes de fibra de vidrio en donde se establecieron áreas de reproducción, levante y algas. Ambas especies mostraron una rápida tasa de crecimiento en todas las etapas de su ciclo de vida, alcanzando la talla comercial entre los 12 y

18 meses desde la fecundación del óvulo. Este documento describe las técnicas óptimas para todas las etapas del ciclo de vida, incluyendo la metodología para la fase de engorde, las limitaciones específicas para cada especie y los costos estimados de producción de semilla. El ciclo reproductivo de ambas especies está bien definido en aguas más al norte de las Bermudas, ocurriendo actividades de desove durante los meses de invierno. La duración de la vida larvaria está entre 10 y 14 días, más rápida en el criadero mediante el aumento de la temperatura ambiental de 17 a 24 °C. La tasa de supervivencia hasta la fase de asentamiento fue mayor para las vieiras cálico (arriba de 55%) que para las vieiras de arena (máximo de 20%). Del mismo modo, el porcentaje de post-larvas obtenidas fue consistentemente más alto para las vieiras cálico que para las vieiras de arena. Las semillas fueron cultivadas usando dos métodos diferentes (mallas sumergidas en tanques y en canales de flujo rápido o raceways) y evaluando las tallas de transferencia al mar. La semilla de la vieira de arena se benefició de un mayor período en el criadero, aumentando a 10 mm en menos de dos meses luego del asentamiento en los canales de flujo rápido al aire libre; las vieiras cálico mostraron una tasa de supervivencia alta en el campo cuando se transfirieron con una altura de valva de 2 mm (dos a tres semanas posteriores al asentamiento). Se utilizaron redes perleras suspendidas para el cultivo de ambas especies en la fase de engorde, con una tasa de crecimiento promedio en el rango de 7 a 10 mm por mes y una tasa de supervivencia mayor de 90%. Para un crecimiento y supervivencia óptimos, las vieiras de arena con una altura de valva de 25 mm, tuvieron que ser cultivadas directamente en la arena hasta que alcanzaran la talla de mercado. Este trabajo resultó ser intensivo y costoso, por lo que el engorde de la vieira de arena requiere investigación adicional para mejorar la rentabilidad de su producción. Se identificó a la vieira cálico como la especie más fácil de cultivar, siendo relativamente resistente en todas las etapas de su ciclo de vida, con la única limitante de ser la especie de menor talla comercial.

INTRODUCTION

The zigzag scallop, *Euvola (Pecten) ziczac* (L.), also known as the sand scallop, is a sub-tropical and tropical species. It is similar to other pectinids in that the right (lower) valve is very convex, whereas the left (upper) valve is usually flat but has been seen to slightly convex or concave in some cases. It has been fished recreationally and/or commercially in the Federative Republic of Brazil (Pezzuto and Borzone, 1997) and along the Caribbean coast of the Bolivarian Republic of Venezuela and the Republic of Colombia (Velez and Lodeiros, 1990) and has also been seen off Florida (USA) as a by-catch of the calico scallop fishery. Its northernmost distribution is Bermuda (Lodeiros *et al*., 1989).

In its natural state, this scallop is recessed in the sand with the rim of its outer left valve showing. It will swim when disturbed, but does not cover great distances. It has also been observed to bury completely 5–10 cm into the sand when faced with unfavourable conditions. Maximum shell height recorded in Bermuda is 130 mm (Sterrer, 1986). Its life span is thought to approximate five years. Worldwide, population numbers of *Euvola ziczac* have been reported to be low, with a decline seen in the 1990s. In Bermuda, it was known to occur in relatively large abundance during the 1940s and 1950s, and was recreationally fished until the early 1970s. It since has been recorded here and there, with no real evidence of a self-sustaining population. To our knowledge, there is currently no existing commercial hatchery in the Wider Caribbean for this species.

The calico scallop, *Argopecten gibbus* (L.), is largely restricted to the sub-temperate and tropical waters of the western north Atlantic with the major stocks distributed from Cape Hatteras, North Carolina (USA) to the Cape San Blas areas of the northeastern Gulf of Mexico (Waller, 1969). Calico scallops have also been collected from the Greater Antilles, Bermuda, and the western portions of the Gulf of Mexico

(Waller, 1969). The commercially important stocks are located off North Carolina (USA) where it supports a small and transient fishery. The calico scallop has two convex valves, although the right is slightly more convex than the left (Sterrer, 1986). The upper valve is usually mottled with a combination of brown, red, purple, yellow and white. It is found lying on top of the seabed in sandy, rocky and grassy substrates and has been recorded in Bermuda in several inshore waters, as well as on the more exposed north shore of the island. It attains a maximum height of 70 mm in Bermuda. This species, like the sand scallop, was a commonly found bivalve in Bermuda and supported a recreational fishery at one time. Population numbers are at present very low in Bermuda (Sterrer, 1986). There is no existing commercial hatchery in the Wider Caribbean for this species.

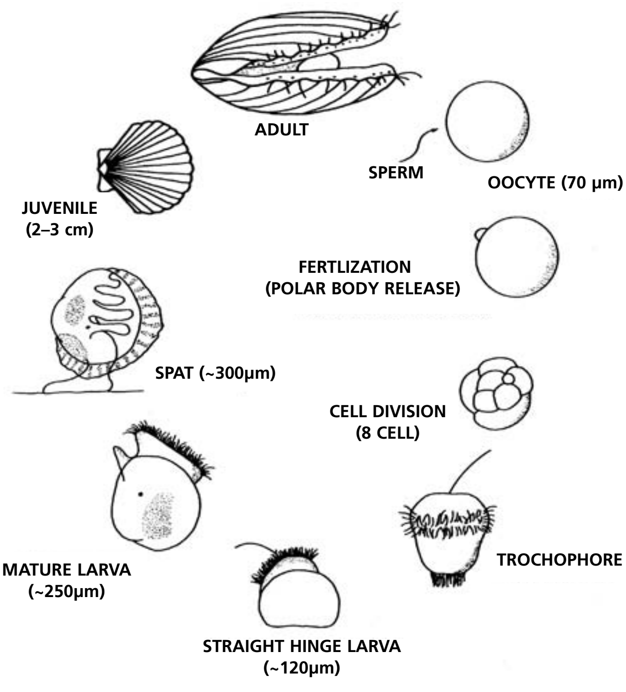
SPAWNING SCALLOPS UNDER CONTROLLED CONDITIONS

The general culture cycle for these two sub-tropical scallop species resembles closely that of other pectinids. Methods for rearing early life stages were optimized in terms of temperature and diet, but were initially adapted from that used for more temperate species. Details of procedures for all aspects of culture for both species are given in Sarkis and Lovatelli (2007).

Assessment of the reproductive cycle is necessary for a hatchery operation and peak spawning activity for both species occurs during the winter months in Bermuda (December to March, with an extended spawning season to end of April for the calico scallops). Gonadic indices and spatfall have been monitored for both species in great detail (Manuel, 2000; Sarkis, Couturier and Cogswell, 2006; Blake and Moyer, 1991). Ripe scallops are characterized by a bright orange colouring of the female roe. Fecundity is similar in both species, averaging six million in *A. gibbus,* and slightly greater in *E. ziczac*, reaching ten million per female in some instances (Sarkis, *unpub.*). Both species are hermaphroditic.

To date, thermoregulation is agreed to be the most efficient method for inducing sperm and ova release. Protocols vary slightly for species mainly with respect to the degree of thermal shock provided and duration of shock required for release. *Euvola ziczac* is more sensitive to stress, requiring a lower thermal differential than *Argopecten gibbus*. For both species however, the strategy is the exposure to an initial cold shock, followed by an exposure to a warm shock. Both species release gametes when exposed to warmer seawater temperatures. Spawning trays are used, where water temperature is controlled and release monitored. Once release is initiated, scallops are isolated into 2-l beakers filled with twice filtered 1 µm seawater and observed closely, changing individuals to new beakers in order to maintain as pure a solution of sperm and egg as possible. In this way, self-fertilization is avoided. Eggs are fertilized with pooled solution of two to three other males, at a ratio of 1 ml sperm : 1 litre eggs. This cross-fertilization ensures chances of survival. Egg solutions are pooled, counted and

FIGURE 1
Generalized life history of a pectinid



Source: Bourne, Hodgson and Whyte, 1989.

transferred to larval tanks at densities of 10–15 larvae/ml for development into larvae. Rearing temperature for both species was 24 °C, salinity at 36 ppt (ambient) and no aeration was used in the first 24 hr of development.

Trochophore larvae are formed within 24 hr of fertilization and D-larvae are developed within two days of fertilization (refer to Figure 1 for life stages). Food is supplemented to the larval culture at the start of Day-1 (trochophore stage) and from here on, larvae are fed daily a food ration consisting of live algal species, cultured on-site. Average yields of D-larvae for calico scallops determined per spawn, range from about 29–58 percent (Sarkis and Lovatelli, 2007). On the other hand, zigzag scallop yields are generally lower and are indicative of the greater sensitivity of this species to handling and bacterial contamination. The range of D-larvae obtained from of fertilized eggs was of about 1–49 percent per spawn over 4-years of operation at a Bermuda bivalve hatchery (see Sarkis and Lovatelli, 2007 for details on culture protocols for both species).

ALGAL CULTURE

The algal culture facility is a vital part of an aquaculture operation. Extreme care must be taken to ensure the production of healthy monocultures of selected algal species. Details on culturing algae are well documented and easily found in the literature. For specific techniques used in Bermuda for the scallop species, see Sarkis and Lovatelli (2007). Several types of algae were cultured as food for scallops namely, *Isochrysis galbana*, *Chaetoceros gracilis*, *Tetraselmis chuii*, *Thalassiosira pseudonana*. These were found sufficient to satisfy the growth and survival requirements of both scallop species to 2 mm spat.

Food ration for Day 1 trochophore larvae was of 7 cells.μl^{-1}, and was gradually increased to approximately 20 cells.μl^{-1} by the end of the larval life. This was determined to be the optimal ration for both species, based on experimental studies (Sarkis and Lovatelli, 2007). Ration was substantially increased for post-larvae once fixed, resulting in a daily ration of 220 cells.μl^{-1} for 2 mm spat. For extended nursery rearing to 10mm, the use of commercially available dry algae was necessary to supply increased volumes needed. Details on suppliers, volumes and species used are given in Sarkis and Lovatelli (2007).

FIGURE 2
Collecting scallop larvae on sieves during water change in static tank system

PHOTO: M.M. HELM

LARVAL REARING

Two types of larval systems were used in Bermuda: 1) 1 000 litre insulated tanks for static systems; and 2) 200 litre conical tanks for flow-through. The latter system proved less labour intensive with similar yields of pediveligers larvae. For a new facility, such a flow-through system is recommended (see Sarkis, Helm and Hohn, 2006 for details).

Static rearing system

Water change is conducted three times a week; at this time, larvae are collected on two sieves of differing mesh size, so that faster growing larvae are separated from the slower growing or dying larvae (Figure 2). Larvae are temporarily placed in small containers (10-litre buckets, while tanks are cleaned and re-filled with treated seawater (filtered twice to 1 µm and heated to 24 °C). Any assessment of larval culture is done during this transfer period, often larvae of similar size are pooled into one tank at suitable densities. Initial density for D-larval rearing is of 5–10 larvae/ml, decreasing to 1 larva/ml at the pediveligers stage. Beginning Day 2 after fertilization, a small supply of air is given to the larvae. Feeding is provided in a single batch at the same time each day.

Flow-through system

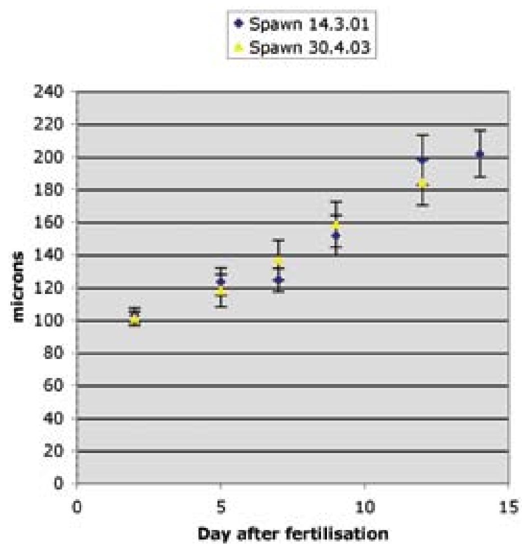
A description of the system developed for calico and zigzag scallops is given in Sarkis, Helm and Hohn (2006). The advantages of a flow-through system include reduced physical handling of larvae, reduced labour demand, increased tankage capacity leading to increased larval density per tank thus reducing space requirements and reduced potential of bacterial contamination. The disadvantages are that routine assessment of the larval culture is difficult.

Conical tanks are best suited to flow-through systems; in Bermuda, available tanks were modified, but it is recommended that steeper cones are used for optimal results. Two important factors to consider are the maintenance of constant seawater flow and continuous supply of food over a 24 hr period. Regarding the former, banjo filters fitted on the outflow preventing larvae from flowing out of the tank, are cleaned twice a day (morning and evening). Food ration is diluted with seawater and gravity fed from a carboy; a continuous drip system is installed for this. Results obtained in flow-through larval culture with calico scallops were promising, yielding comparable growth and survival to the pediveligers stage (Sarkis, Helm and Hohn, 2006).

Larval growth and survival

Shell growth for zigzag and calico scallops have been well documented and are comparable to that recorded for other pectinid species (Sarkis and Lovatelli, 2007). Figure 3 provides shell growth data for *Argopecten gibbus* reared in routine hatchery operation. Yields of calico scallop pediveligers ready for settlement were in the range of 17.8–55.4 percent; pediveliger yields are calculated as percentage of Day 2 D-larvae. As mentioned previously, zigzag scallops are more sensitive, reflected in lower yields ranging from 2.1–11.7 percent. Duration of larval life for both calico and sand scallop is of 10–14 days depending on batches.

FIGURE 3
Results of shell growth (length) for *Argopecten gibbus* larvae reared in Bermuda. Two curves show maximal and minimal range obtained over four years of operation



Source: taken from Sarkis and Lovatelli, 2007.

SETTLEMENT AND POST-LARVAL REARING

Once larvae are considered mature according to set criteria – based on behaviour, morphological development and size – setting is initiated. This usually occurs on Day-12 or Day-13 after fertilization for both calico and zigzag scallop species. Figure 4 illustrates zigzag scallop pediveligers ready for set.

Two methods for setting are used, dependent on space available, time of year and estimated time of transfer to sea.

FIGURE 4
Day-11 pediveligers of *Euvola ziczac*, showing eyespot and a well-developed foot in and out of the shell

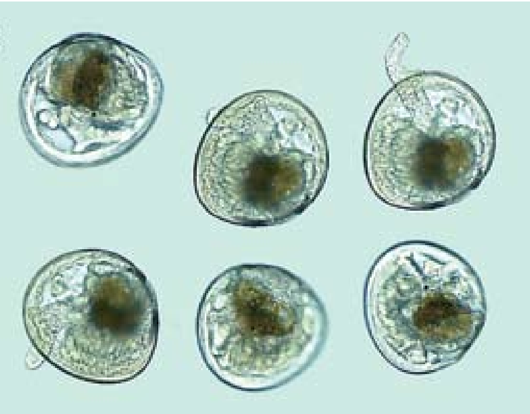


PHOTO: S. SARKIS

FIGURE 5
Cultch made of 3 mm black polyethylene mesh, filling 450 litre tanks used for set

PHOTO: M. M. HELM

Rapid transfer approach

Circular fiberglass tanks (450 litre) are filled with cultch made of black 3 mm polyethylene mesh, acting as substrate for pediveligers (Figure 5). This provides a large surface area for settlement of larvae. Temperature is maintained as for larval rearing (24 °C). Stocking density is around 4 larvae.ml^{-1}. The duration of the setting period, where the maximal number of pediveligers metamorphoses and becomes fixed, is determined by assessing the culture over time; usually, pediveligers are set within ten days of being provided with a substrate. Aeration and daily algal ration is provided daily. Water is exchanged three times a week as for larvae, but procedure differs in that setting larvae are not removed from the setting tanks, as they need to be continually submerged; for this reason, water level in the tank is maintained constant. Towards the end of the setting period, temperature acclimation to ambient seawater is achieved by decreasing set temperature by 1 °C every two days. Once maximal number of larvae is set, setting system is changed to an open flow seawater system, where seawater is filtered to 1 µm and supplied continually to the tanks; an air-lift driven recirculation system enhancing water exchange within the tank is initiated. Algal food supply is provided continuously over 24 hr by drip-feed. Young spat are reared in this way for a further 20 days, when they reach approximately 1.5 mm. After which, they are transferred to grow-out sites.

Raceway set

Mature pediveligers are transferred to 120 µm or 150 µm 25 cm diameter sieves, at a density of 50 000 larvae per sieve. Sieves are suspended in raceways and placed on a semi-recirculating system, with inflow of 1 µm filtered seawater at a rate of 3 litre.min^{-1}. Similarly to the rapid transfer approach, larvae are allowed to set with minimal flow and no other disruption for approximately ten days (see Sarkis and Lovatelli, 2007 for further details on raceway system). Food supply is provided from 20 litre carboys, and placed on a 24 hr drip-feed; this accounts for 50 percent of the ration. The second half of the ration is distributed in the sump tanks and distributed through the re-circulating system. Semi-recirculation ensures that all algae supplied is consumed and also allows for temperature control of seawater. As the end of the setting period approaches, post-larvae are slowly acclimated to ambient temperatures as described above. After Day-10, flow of raceways is set according to biomass and density (or biomass) per sieve is adjusted weekly, re-distributing spat in other sieves as they grow. If biomass per sieve, and per raceway system, is not controlled, slow shell growth and high mortalities will ensue.

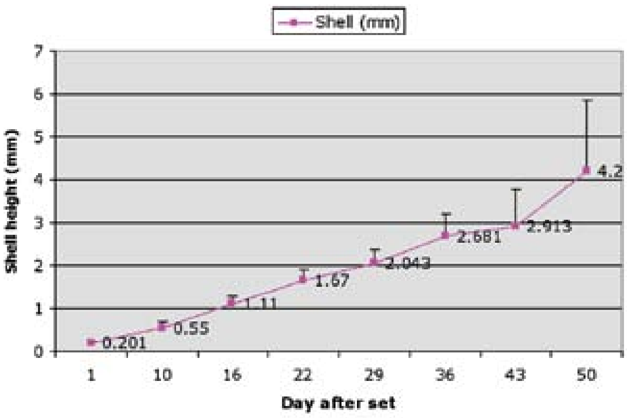
Spat are maintained in this system up to two months, or until they reach 3.5 mm shell height. At which time, they are ready for the secondary nursery stage, i.e. transfer to the outdoor raceway for further growth to a minimum of 5 mm shell height. Figure 6 illustrates growth of calico scallops reared in a raceway system.

Secondary nursery stage

This raceway system differs from the primary nursery raceway system in the following: sieve characteristics, seawater treatment and algal food composition. Sieves used are of a greater surface area, and can accommodate a larger biomass of spat. Sieves are set on an upwelling system, rather than downwelling, reducing clogging of mesh with detritus. Finally algal food supply is provided from dry algal cultures purchased commercially (see Sarkis and Lovatelli, 2007).

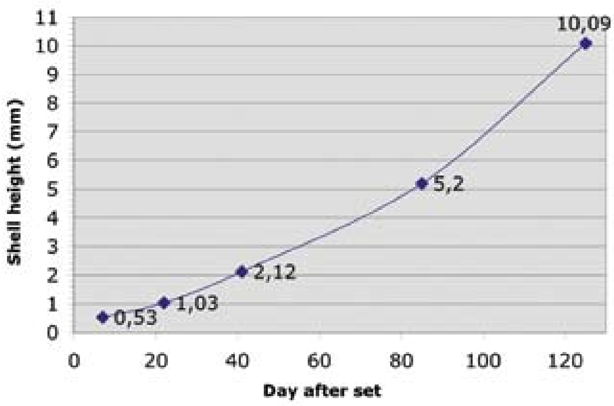
The role of the outdoor raceway is to maximize growth enabling the transfer of spat directly into 3 mm pearl nets and enhance survival rate in the field. This system has proved especially beneficial for zigzag scallops, due to their increased sensitivity. It is more time consuming, hence more costly, and is not necessary for hardier species, such as the calico scallop. Figure 7 illustrates the growth of zigzag scallops, from Day-10 after set in the primary nursery system, to four months after set in the secondary nursery system.

FIGURE 6
Shell height for calico scallop spat reared in raceway system



Source: taken from Sarkis and Lovatelli, 2007.

FIGURE 7
Shell growth (height) of the zigzag scallop following settlement



Source: taken from Sarkis and Lovatelli, 2007.

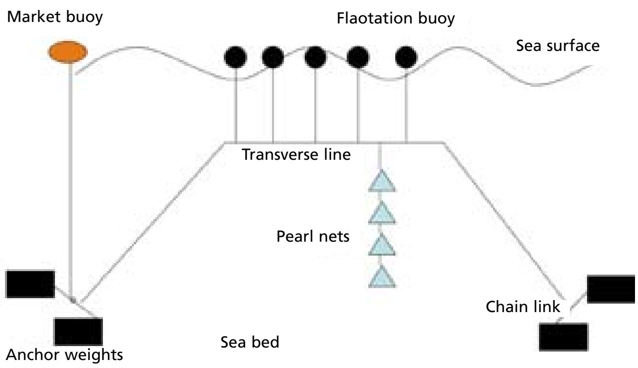
GROW-OUT OF CALICO AND ZIGZAG SCALLOPS

Grow-out methods differ slightly between the two species and depend on the size of transfer at sea.

Calico scallops

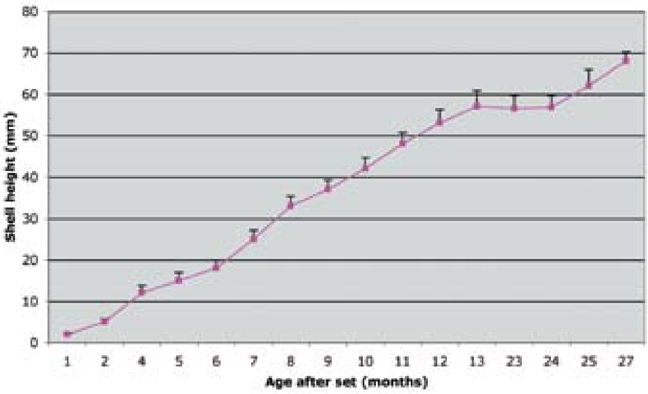
Spat set in 450 litre tanks on cultch are transferred to the field, approximately one month after set. Cultch is transferred to green collector bags and held in a container filled with ambient saltwater for transport to grow-out sites (see Sarkis and Lovatelli, 2007 for details). Bags are suspended on long-lines using scallop trays. Transfer to trays and securing trays is done quickly on grow-out site to minimize the time period in which spat are exposed to air. Trays are left for a period of six weeks in the field. At this time, spat are returned to the nursery, to remove from cultch, and distributed by weight to 3 mm pearl nets. A total of 150 spat are distributed per net, averaging at this time 7 mm shell height. Nets are suspended on long-lines (Figure 8).

FIGURE 8
Sub-surface long-line system used in Bermuda



Source: taken from Sarkis and Lovatelli, 2007.

FIGURE 9
Shell growth of calico scallop juveniles reared on long-lines in Bermuda



Source: taken from Sarkis and Lovatelli, 2007.

Spat set in raceway can be transferred to sea, once they reach 2–4 mm. However, as these are not attached to cultch, and too small for 3 mm pearl nets, they are transferred to pouches, made of window fly screen material. These pouches are inserted in the same scallop trays as described above. Spat are weighed to ensure that stocking density in pouches is suitable, averaging 400 spat per pouch (see Sarkis and Lovatelli, 2007).

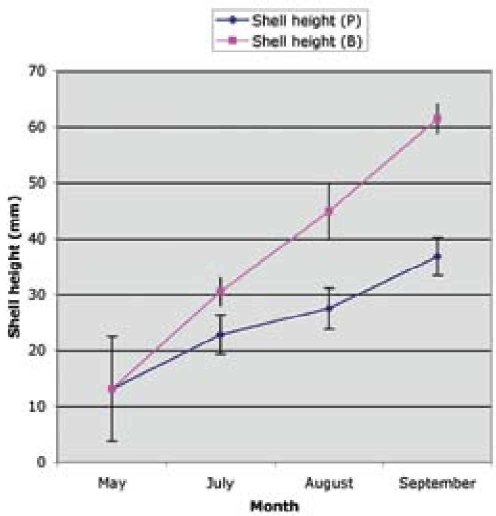
Spat reared in secondary nursery system attain shell heights greater than 4 mm, and can be directly transferred to 3 mm pearl nets for grow-out. They are easy to collect, and more tolerant to handling. Sub-samples of 150 spat are distributed per net.

Once spat are transferred to pearl nets, monthly checks are made thereafter, assessing survival and growth. During the first six months, growth is rapid and scallops are gradually transferred to 6, 9 and 12 mm pearl nets, reducing densities to 75, 40 and 30 individuals per net, respectively, during the first six months; thereafter scallops are maintained in 12 mm nets, checked for wear and tear on a monthly basis, and transferring nets if fouling is too high. Fouling was also controlled through a gentle saltwater power wash of nets and scallops on site. Scallops did not suffer any mortality following this treatment, provided that it is gentle and not too frequent.

Calico scallops are grown until market size in suspended cultures. Shell growth of calico scallops is shown in Figure 9; market size is attained within 18 months of grow-out.

Zigzag scallops are treated in a similar manner to calico scallops until 25 mm shell height. The recessive nature of this species favours bottom rather than suspended culture techniques. For this reason, at 25 mm shell height and above, juvenile zigzag scallops are reared directly on the sandy bottom, enclosed by a cage, protecting scallops from predation. This is a very labour intensive method; all labour is conducted by SCUBA.

FIGURE 10
Comparative growth between zigzag scallops cultured directly on the sandy bottom (B) and suspended in pearl nets (P)



Source: taken from Sarkis and Lovatelli, 2007.

Space requirement for optimal grow-out of zigzag is high; for 25 mm juveniles, initial density is 400 juveniles per 4 m^2 cage. As for calico scallops, growth is rapid in the first few months, and monthly checks are made, where density is adjusted according to growth. Juveniles are re-distributed to 200 and 100 per cage; mesh size on cage is increased from the initial 15 mm to 25 mm, in order to ensure adequate water flow. Routine cleaning of cages is necessary to control fouling. Although growth rates of zigzag are excellent using this technique (see Figure 10, where growth of animals in suspended and bottom cultures is compared), the difficulty in commercializing bottom culture lies in developing a time efficient and cost efficient system. To the author's knowledge, such a system for large scale rearing of the sand scallop has not been developed to date. An alternative may be the use of queen conch "parks" developed in the Turks and Caicos Islands for grow-out; these are situated in shallow bays, enclosed on the sides, yet of easy access by snorkel.

CONCLUSIONS

A summary of the setup and running costs of the 4-year operation in Bermuda is detailed in Sarkis and Lovatelli (2007). These costs are specific to Bermuda, but the percentage contributions of each aspect of hatchery operation are relevant. The larval rearing section requires the most labour and highest running costs for spat production; this is based on static rearing system, and can be reduced by the use of flow-through systems. Nursery costs are dependent on the size required for spat at transfer to sea; the quicker spat are transferred, the less costly in the nursery. Finally, grow-out is an important component, based in great part on the time achieved to market size, and type of system used.

This work demonstrates the feasibility of large scale subtropical scallop culture; market demand can be easily created, as the final product is considered a seafood delicacy, and much appreciated in the tourism sector. The work was conducted in a module hatchery, housed in mobile containers resulting in a relatively inexpensive facility for the rearing of bivalves; in addition, due to the flexible nature of the facility, species-specific requirements can easily be accommodated, and/or expanded as production increases. Details on the installation of the hatchery itself were beyond the scope of this paper but are given in Sarkis and Lovatelli (2007).

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The cultivation of marine invertebrates indigenous to the Wider Caribbean Region: established culture techniques and research needs for crustacean

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Creswell, R.L. 2011. The Cultivation of marine invertebrates indigenous to the Wider Caribbean Region: established culture techniques and research needs for crustaceans. In A. Lovatelli and S. Sarkis (eds). A regional shellfish hatchery for the Wider Caribbean: Assessing its feasibility and sustainability. FAO Regional Technical Workshop. 18–21 October 2010, Kingston, Jamaica. *FAO Fisheries and Aquaculture Proceedings*. No. 19. Rome, FAO. 2011. pp. 105–117.

ABSTRACT

Crustacean fisheries in the Caribbean Region are limited primarily to spiny lobster, *Panulirus argus* (the most valuable marine fishery throughout the Region), trawl fisheries for penaeid shrimp along the continental shelf of Latin America and the Greater Antilles and some minor local fisheries for callinectid crabs. Spiny lobster is a highly valued seafood product with large existing markets and, as a result, the development of aquaculture technology for this species has met with enthusiasm over the years. Penaeid shrimp culture is well established throughout the world with captive reproduction, larval rearing and pond grow-out practiced in commercial operations globally. Penaeid shrimp farming has been attempted in several island nations in the Caribbean, but with few commercial-scale shrimp farms currently in production, while Latin America with extensive acreage of estuaries and coastal wetlands, has realized significant development of shrimp aquaculture. Another crustacean that has been the focus of aquaculture research is the West Indian red spider crab, *Mithrax spinosissimus*, also called the Caribbean king crab. This paper will review the aquaculture potential for spiny lobsters, *Mithrax spinosissimus*, and penaeid shrimp indigenous to the Caribbean Region and how they can be incorporated into a regional hatchery model.

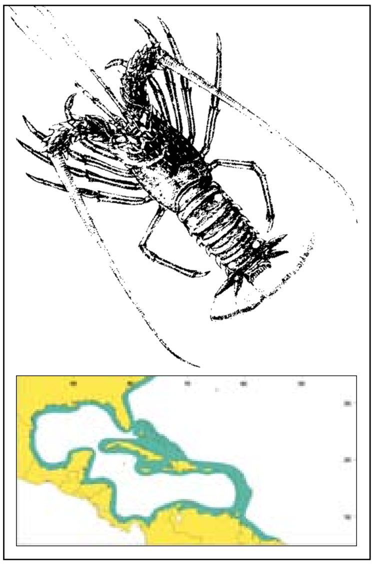
RESUMEN

Las pesquerías de crustáceos en la Región del Caribe se limitan principalmente a la langosta espinosa, *Panulirus argus* (la pesquería marina más valiosa en toda la Región), la pesca de arrastre de camarones peneidos a lo largo de la plataforma continental de América Latina y las Antillas Mayores y en menor grado algunas pesquerías locales para cangrejos calinéctidos (jaibas). La langosta espinosa es un producto marino altamente

valorado y con un amplio mercado y, en consecuencia, a lo largo de los años se ha generado gran interés en el desarrollo de tecnologías para el cultivo de esta especie. El cultivo de camarones peneidos está bien establecido en todo el mundo con reproducción en cautiverio, cultivo larvario y engorda en estanques que se practican en operaciones comerciales a nivel mundial. En varias naciones insulares del Caribe, se ha intentado el cultivo de camarones peneidos pero actualmente sólo unas cuantas granjas mantienen una producción a escala comercial, mientras que en América Latina se ha generado un desarrollo significativo de la camaricultura con una extensa superficie cultivada sobre estuarios y humedales costeros. Otro crustáceo que ha sido el centro de investigaciones acuícolas es el cangrejo rojo, *Mithrax spinosissimus*, también llamado cangrejo rey del Caribe. Este documento revisa el potencial acuícola para la langosta espinosa, *Mithrax spinosissimus* y camarones peneidos nativos de la Región del Caribe y cómo se puede incorporar en un modelo de criadero regional.

INTRODUCTION

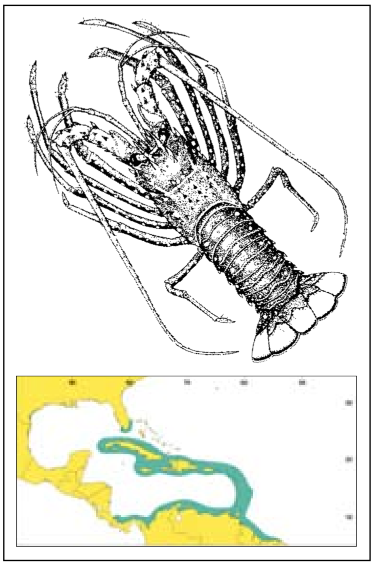
The native species of crustaceans in the Wider Caribbean Region are discussed in the current document. A brief synopsis for each is given, providing scientific and recorded common names, maximum size, and a summary of their distribution and habitat. For each species, a schematic diagram, along with a sketch of their current area of occupancy is given. Where available, a history of culture efforts is provided as background information for the species or groups of species, as well as available culture techniques and factors to be considered for aquaculture.



PALINURIDAE – spiny lobsters

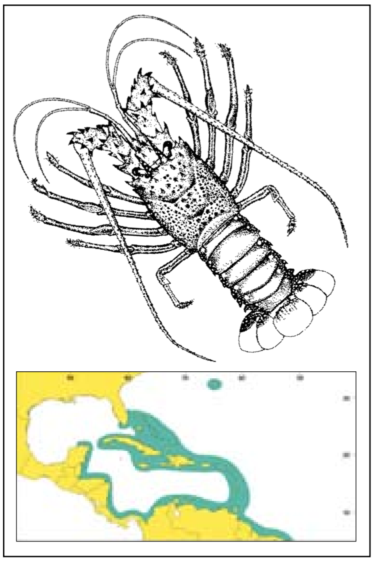
Panulirus argus
FAO names: **En**: Caribbean spiny lobster;
Fr: Langouste blanch; **Sp**: Langosta común del Caribe
Size: To 450 mm (commonly 250)
Distribution/habitat: Bermuda, North Carolina (United States of America), southward through the Gulf of Mexico, Antilles, and the coasts of Central and South America to the Federative Republic of Brazil. Lives in shallow water to 90 m; associated with coral reefs, seagrass beds as juveniles or in any habitat affording shelter.

Panulirus guttatus



FAO names: **En**: Spotted spiny lobster; **Fr**: Langouste brésilienne; **Sp**: Langosta moteado
Size: To 150–200 mm
Distribution/habitat: Bermuda, the Commonwealth of the Bahamas, southern Florida (United States of America), Belize, the Republic of Panama to the Republic of Suriname and the Federative Republic of Brazil, the Caribbean arc from the Republic of Cuba to the Republic of Trinidad and Tobago, Netherland Antilles, and Los Roques (Bolivarian Republic of Venezuela). Lives in shallow rocky areas, found mainly in crevices.

Panulirus laevicauda



FAO names: **En**: Spotted spiny lobster; **Fr**: Langouste brésilienne; **Sp**: Langosta moteado
Size: To 200–300 mm
Distribution/habitat: Bermuda, southern Florida (United States of America), the Caribbean and the coasts of Central and South America from Yucatán, (United Mexican States) to the Federative Republic of Brazil. Coastal waters to 50 m; on rock, gravel and coral substrates.

Culturing the Caribbean spiny lobster

The spiny lobster, *Panulirus argus*, is the most economically important fishery product in the Caribbean Region. Of the dozen species of tropical lobsters around the world, the available aquaculture information and strongest interest focuses on *P. argus*, but should include the congeneric palinurids indigenous to the Caribbean, *P. guttatus* and *P. laevicuda* (Ingle and Witham, 1968; Tamm, 1980; Miller, 1983; Ryther, Creswell and Alston, 1984; D'Abramo and Conklin, 1985; Ryther *et al*.,1988; Lellis, 1991; Lellis and Russell, 1990; Sandifer, 1991; Jeffs and Davis, 2003). The spiny lobster has an extensive natural range from North Carolina (USA) to the Federative Republic of Brazil and is found throughout the Caribbean. This paper reviews the existing research related to aquaculture of *P. argus* and identify those aspects requiring further research and development to expedite the commercial aquaculture of this lobster.

Until recently, it was generally conceded that "the potential for culture of spiny lobsters is very low" (Oesterling and Provenzano, 1985); this less than optimistic assessment was based upon: i) the lack of a hatchery technology and low probability of development in the near future; ii) difficulties in acquiring large numbers of juveniles from the wild for grow-out; iii) a long grow-out period; iv) the aggressive behaviour of lobsters; v) lack of suitable diets; and vi) lack of well-developed grow-out systems. However, recent work conducted by the Harbor Branch Oceanographic Institution in Florida (USA), Darden Industries in Belize and others, suggests that the potential for spiny lobster cultivation may be greater than previously believed. Some specific considerations follow.

Different populations of Caribbean spiny lobsters spawn at different times of the year, depending upon water temperature (Cobb and Wang, 1985). In very warm areas, such as around Honduras, spawning may take place year-round. The time of spawning may be related to the size of females (Cox and Hunt, 2005). One study reports that Caribbean spiny lobsters produce 1–2 million eggs per spawning (Lyons, 1981). For *Panulirus* spp., reported fecundities ranged from 50 000 to 900 000 eggs per spawning, while a more recent study found 300 000–800 000 eggs per spawning, depending on the size of the female (Bertelson and Matthews, 2001). Larger females produce considerably more eggs than smaller ones; 60 percent of eggs in the Upper Keys were produced by the largest females (85 mm carapace length or larger), which were less than 20 percent of the female population (Lyons, 1981). When the eggs are laid, they are attached to the setae (fine hairs) on the abdominal swimmerets of the females. Females carrying eggs are called "berried" because the appearance of the developing eggs is similar to that of berries. Depending on the species, the eggs are incubated in the mother's care for a relatively short period – 18 days to three months – depending on water temperature, with warmer water being related to faster embryonic development (Lyons, 1981). While she does this, the eggs become gradually hard and black and she continually grooms the eggs while aerating them with the pumping motion of her pleopods. Once the eggs hatch, they drift away with no further maternal care.

The Caribbean spiny lobster, like most Palinurids, has a long and complex larval development (Kittaka, 2000), which proceeds through 11 or 12 larval stages and is poorly understood (Yeung and McGowan, 1991). The figure below illustrates a typical life cycle for Palinurids. For over 50 years, researchers have tried to raise the phyllosoma larvae of many species of Palinurids lobsters. The fragile, slow developing phyllosoma

Life cycle of *Panulirus* spp.

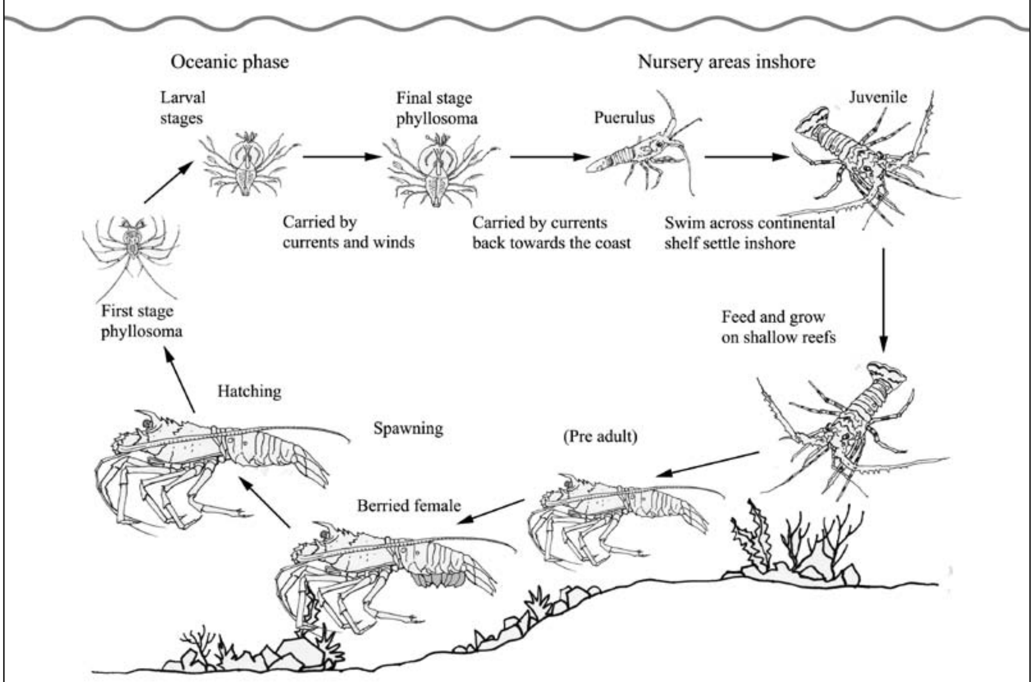


Illustration by: Federico Gemma.

(four months to 15 months depending on species, feed, temperature and water quality) has become legendary among aquaculturists – the Mount Everest of commercial larval rearing (Robertson, 1968; Provenzano, 1968; Ingle and Witham, 1968; Moe, 1991; Booth and Kittaka, 2000). There has been some success in a number of palinurid species where the phyllosoma has been reared through its entire eleven stages to post-larvae or pueruli. However, there has been such low survival in these experiments that commercially applicable technology is yet to evolve from the experimentation.

The Japanese had some success rearing *Panulirus japonicas* and then several other species of Palinurid lobster. During their experiments over the past ten years, they have been able to reduce the larval rearing time down from 417 days to as little as 231 in one *P. japonicus* and as short as 65 days in another (Kittaka *et al.*, 2001). Even with their success, they note that the phyllosoma larvae molted from 21–31 times to pass through the 11 phyllosoma stages (Sekine *et al.*, 2000). In other species of crustacean larval culture, molting without morphological or stage changes can imply that the larvae are under extreme stress – usually dietary or water quality – or both (Tong *et al.*, 1997). This might mean that even though this culture technique was able to contract phyllosoma larval development time nearly in half from previous efforts - it is still far from the optimum protocol, and there is much more progress that can be made in shortening the larval cycle and increasing their survival. Much progress could be made by simply examining variations among spiny lobster species, as in this case *P. guttatus* and *P. laevicauda*.

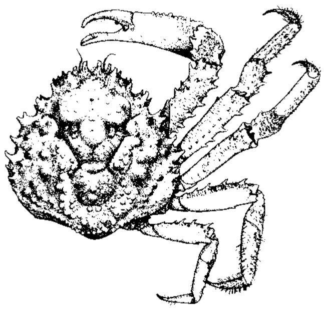
One of the alternatives to larval rearing and closing the life cycle of the spiny lobster has been the collection of pueruli from wild stocks adrift in the oceans and along coastal shores. It has been documented that a large and accessible supply of *P. argus* pueruli and early juveniles can be harvested from the wild. Unfortunately, commercial harvest of the early stages of *P. argus* for aquaculture is currently not permitted throughout most of the natural range of the species. It should be noted that such a harvest would be sustainable, as ecological research indicates that pueruli collection removes only a small portion of those available, the vast majority being lost to the fishery through natural predation (Butler and Herrnkind, 1988; Bannerot, Ryther and Clarke, 1988; Ryther *et al.*, 1988; Butler and Herrnkind 1989; Forcucci, Butler and Hunt, 1994).

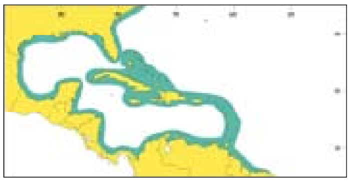
A variety of collection devices have been used to collect lobster post-larvae for research purposes including floating and submerged habitats, and suspended and towed nets (Witham, Ingle and Sims, 1964; Calinski and Lyons, 1983; Field and Butler, 1994; Phillips and Booth, 1994); suction dredges and bottom trawls have been shown to be ineffective methods for collecting post-larval and early juveniles lobsters (Sweat, 1968). Floating and submerged artificial habitats which provide an abundance of fine-scale structural complexity have provided reliable catches of pueruli; these include folded sheets of fibrous material (Witham, Ingle and Joyce, 1968), tassels of synthetic fibers (Gutierrez-Carbonell, Simonin-Diaz and Briones-Fourzan, 1992), and polyvinyl chloride (PVC) frames holding artificial seaweed (Cruz *et al.*, 1991; Cruz, León and Puga, 1995).

Although spiny lobsters, including *P. argus*, are naturally gregarious, high tank or cage stocking rates have been shown to inhibit growth; it has been shown that in the presence of inadequate or poor quality food, high stocking rates can result in extensive cannibalism, particularly among early captive juveniles (Childress and Herrnkind, 1994; Geddes *et al.*, 2001). Pardee and Foster (1992) suggest that improvements in food availability, attractiveness and nutritional quality will be necessary prerequisites for establishing high-density grow-out systems. Very rapid growth rates are achievable in culture; for example, male lobsters have been grown from first instar juveniles to 450 g in 12 months and 1.4 kg in two years (Lellis and Russell, 1990; Lellis, 1991).

Although hatchery production of spiny lobster seed for commercial aquaculture production is unlikely for the foreseeable future, optimizing techniques for collecting, holding, and nursery culture of juvenile *P. argus* is a research and extension activity consistent with a regional facility. In particular, previous studies have indicated that development of cost-effective formulated diets is likely the single most important obstacle to large-scale commercial aquaculture development for this species (Jeffs and Hooker, 2000).

M. spinosissimus





WEST INDIAN RED SPIDER CRAB

The West Indian red spider crab, *Mithrax spinosissimus*, is a large majid crab that inhabits coral reefs, rocky outcrops and man-made canals throughout the tropical Atlantic Ocean from the Carolinas on the East Coast of the United States of America, the Commonwealth of Bahamas, the islands of the eastern Caribbean and along the continental shelf of Latin America as far south as the Bolivarian Republic of Venezuela. As with most members of the family Majidae, these crabs remain in hiding during the day and venture out at night to forage on benthic algae and associated epifauna; they can be found in shallow waters of depths of 180 m. The sexes are dimorphic, the males attaining a larger mean size (133.4 mm carapace length) than females (122 mm) and typically weighing twice as much. Despite its large size, this crab is taken only occasionally by fishermen for home consumption or local markets, in large part due to their paucity and sporadic distribution. The only commercial fishery is recorded in the Republic of Panama, where they are locally abundant along the walls of the Panama Canal.

Culturing the West Indian red spider crab

Interest in the mariculture potential of the West Indian red spider crab began in the early 1970s in the Bolivarian Republic of Venezuela with initial trials conducted at a small marine laboratory in at Los Roques, with the researchers' preliminary results published in the Journal of the World Aquaculture Society (Brownell, Provenzano and Martinez, 1977). In 1983, the Marine Systems Laboratory of the Smithsonian Institution, funded by the US Agency for International Development (USAID) began research on full-scale *Mithrax* aquaculture using low-technology in several Caribbean countries (e.g. Turks and Caicos, the Dominican Republic and Antigua) utilizing floating cages and algal turf as a food source (Adey and Steneck, 1984; Adey, 1985).

Despite substantial resources dedicated to the project, positive results were not forthcoming due to some fundamental flaws in the production concept: i) production of algal turf on floating screens was insufficient to support the biomass of crabs housed in the floating cages; ii) *Mithrax* crabs are not docile, obligatory herbivores, as the investigators purported, but rather they are omnivorous, cannibalistic and highly aggressive crustaceans; and iii) *Mithrax* crabs undergo a terminal molt at puberty, after which no additional growth occurs. Therefore, the marketable size of crabs, 1 kg (2.2 lb), used for an economic analysis by the Smithsonian (Rubino, Epler and Wilson, 1985), would be achieved by only a small fraction of the crabs that were progeny of wild-caught broodstock. Only through selective breeding over several generations would a significant proportion of the population (exclusively males) reach 1 kg prior to terminal molt.

In 1984, the Harbor Branch Oceanographic Institution (HBOI) initiated a research programme to evaluate the potential for *Mithrax* culture which included the algal turf/cage culture system, as well as alternative methods (Ryther *et al.*, 1988). Larviculture, early juvenile growth, nutrition, infection and disease, and grow-out to harvest are described further in this volume (Creswell and Tunberg, 2000).

Interest in the culture of the West Indian red spider crab has waned since the late 1980s, in large part due to constraints related to the crabs aggressive behaviour. Unprotected open area systems, such as cages, raceways or ponds and simple, two-dimensional structures afford little protection against aggressive behaviour and are inappropriate for large-scale production of *Mithrax* crabs. One commercial venture, West Indies Mariculture Inc. (WIM), operated in the 1990s on North Caicos, in the Turks & Caicos Islands. The project was managed by alumni from an earlier Smithsonian Institution project on Grand Turk Island and employed a hybrid of methods using algal turf screens and those developed by HBOI. WIM produced soft shell *Mithrax* crabs and marketed them directly to restaurants throughout the Turks and Caicos Islands. Research into the mariculture of the West Indian red spider crab continued at the Universidad de Oriente, the Bolivarian Republic of Venezuela (Rengel *et al*., 2000), but to the authors' knowledge no ongoing research or commercial production exists today.

Culture techniques for Mithrax crabs

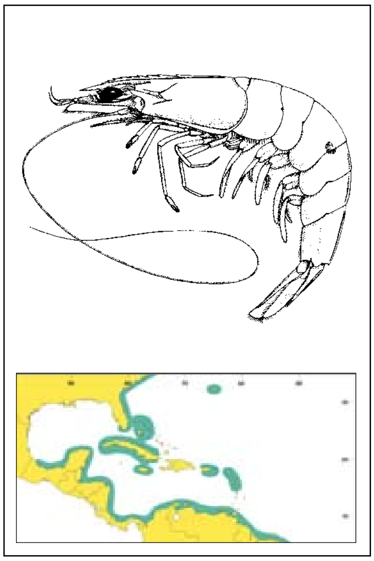
Female crabs undergo terminal molt at about 75 mm CL (carapace length) and will copulate after molting – a soft shell condition is not required – and the female will produce successive egg masses for extended periods (although the number and viability of ova declines over time). Fecundity estimates vary widely from "tens of thousands" (Brownell, Provenzano and Martinez, 1977) to up to 100 000. Creswell, Tunberg and Winfree (1986) reported 18 826 $\pm$ 3.3 ova/female, each approximately 1 mm diameter. Newly fertilized eggs are deposited on the pleopods, appearing bright orange and turning red, burgundy and finally tan or grey at hatching (at 18 days). The larvae hatch as swimming *first zoeae* and molt within 12 hours, again in 36–48 hours; during the zoeal stages the larvae are lecithotrophic. They then metamorphose into feeding megalopa (post-larvae), and within three to four days molt again to the first crab stage (six-eight days post hatch). Megalopa feed on benthic diatoms, epiphytes or finely blended macroalgae.

Early attempts to culture *Mithrax* larvae in fiberglass tank resulted in discouraging results (<4 percent survival to megalopa); an alternative larviculture systems, utilizing screen-bottomed floating trays resulted in 85 percent survival and could be stocked at densities of 25 000/m^2 (apparently the zoeae required a substrate to successfully molt to megalopa post-larvae).

Early growth for 2^{nd} and 3^{rd} stage crabs was 1–20 days and 25–30 days respectively, with crabs reaching a mean carapace length of 30 mm and weight 7 g in 180 days, but only about 20 percent of the crabs survived throughout the period. Small crabs consume macroalgae, but larger crabs are truly omnivorous and exhibit a strong tendency to supplement their diet with meat. They also will accept a range of commercially available dry feeds, including lobster, shrimp, tropical fish and guinea pig pellets. However, *Mithrax* crabs tolerate a narrow range of environmental parameters, a fact that has practical implications for commercial production, particularly for site and stock selection.

From post-larvae to large juveniles, *Mithrax* are aggressive and highly cannibalistic with females exhibiting more aggressive behaviour, suggesting that slower growing females should be eliminated from the population. Providing protective cover and/or complex, three-dimensional habitats may improve survival by reducing cannibalistic encounters, but it also complicates feeding, cleaning and harvesting. Systems that provide shelter and also allow for harvesting soft-shelled crabs, as well as a method to identify pre-molt crabs, may be economically viable if value-added markets can be established (similar to callinectid crabs).

PENAEIDAE – Penaeid shrimp

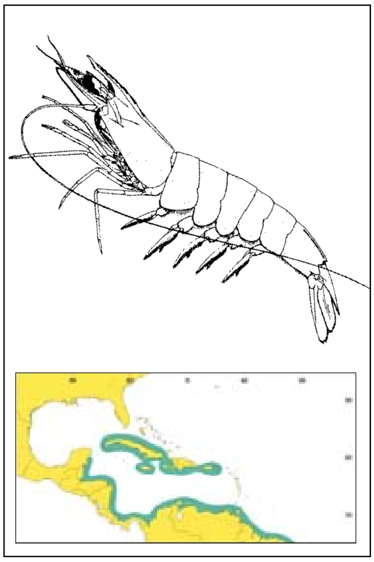


Farfantepenaeus brasiliensis

FAO names: **En**: Redspotted shrimp; **Fr**: Crevette royale rose; **Sp**: Camarón rosado sureño

Size: Females 250 mm; males 191 mm

Distribution/habitat: Off Cape Hatteras to Florida Keys (United States of America), off Campeche and Yucatán (United Mexican States); off Bermuda, through the Caribbean Sea and West Indies to Rio Grande do Sul (the Federative Republic of Brazil). Caught mainly with bottom trawls; juveniles are taken in estuaries and near shore waters with seines, cast nets, push nets and dip nets. Marketed mostly frozen; also fresh, dried, or canned; juveniles are mainly used as bait. This species has been farm-raised on a small scale.

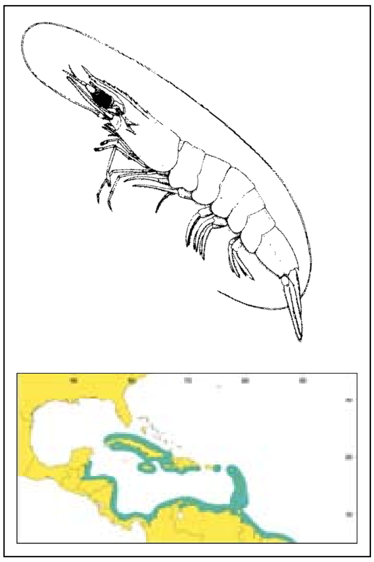


Farfantepenaeus notialis

FAO names: **En**: Southern pink shrimp; **Fr**: Crevette rose du Sud; **Sp**: Camarón rosado con manchas

Size: Females 200 mm; males 175 mm

Distribution/habitat: Caribbean Sea, including the greater Antilles, the Virgin Islands, and the continental shelf from Ascension Bay, Quintana Roo, to the south; along the South American coast, it extends down to Rio de Janeiro, the Federative Republic of Brazil. Inhabits shelf areas from the coastline to depths of about 100 m, rarely to 700 m; the largest concentrations are found between 3 and 50 m. Bottom mud or sandy mud and sandy patches among rocks. Caught mainly with bottom trawls; juveniles are taken in estuaries and near-shore waters with seines, cast nets, push nets and dip nets. Marketed mostly fresh.



Litopenaeus schmitti

FAO names: **En** Southern white shrimp; **Fr**: Crevette ligubam du sud; **Sp**: Camarón blanco sureño

Size: Females 235 mm; males 175 mm

Distribution/habitat: Greater Antilles from the Republic of Cuba to the Republic of Trinidad and Tobago; Atlantic coast of Central and South America, from Belize to the Federative Republic of Brazil (from Amapá to Rio Grande do Sul). Inhabits coastal waters to depths of 47 m, most abundant between 15 and 30 m, mainly on mud and muddy sand, of considerable importance in the Republic of Cuba, Belize, the Republic of Honduras, the Republic of Nicaragua, the Republic of Colombia, the Bolivarian Republic of Venezuela, the Republic of Guyana, the Republic of Suriname and French Guiana; outside the area all along the Brazilian coast. Consumed locally and exported. Aquaculture experiments have been undertaken in the Republic of Cuba.

Culturing penaeid shrimp

The evolution of shrimp farming began with collection of wild post-larvae from the surf zone along beaches and stocked into coastal ponds. Early hatcheries collected gravid females, or purchased them from fishermen (termed as "sourcing") and hatched the larvae (nauplii) directly in the culture tank (Lee and Wickins, 1992; Mock and Murphy, 1971). Although most hatcheries prefer this method, gravid females are often in short supply and some operations opt for the alternative of inducing gonad development and spawning of captive shrimp. Penaeid shrimp can be grouped into two broad categories, the open-thelycum (white shrimp such as *L. setiferus* and *L. schmitti*) and closed-thelycum (brown shrimp such as *F. brasiliensis* and *F. notialis*). While the open-thelycum shrimp follow the sequence of molt-mature-mate-spawn, the closed-thelycum shrimp follow the sequence of molt-mate-mature-spawn. Females of open-thelycum species require insemination prior to each spawn and are often artificially inseminated (manual application of the sperm mass to the thelycum), but most maturation units continue to rely on natural impregnation occurring in the maturation tanks (less labour, lower mortality and more consistent fertilization rates). For a detailed description of shrimp reproduction and the design of a maturation and larval rearing facility the reader is referred to Treece and Fox (1993).

Indoor facilities are usually favoured for maturation systems since they permit greater environmental control. Temperature, light intensity and photoperiod, tank colour and design and low noise levels all influence ovarian development and spawning. The design of broodstock maturation facility, methods and diet can vary greatly between different species, and even under very controlled conditions, some species will not mature with any regularity. For many species this can be overcome through a process of surgically removing the eyestalks (call ablation) which contain a complex of glands that inhibit gonad development (Liao and Chen, 1983).

Some hatcheries prefer to purchase nauplii from outside sources, which are sometimes traded internationally and are relatively easy to transport. For example, 300 000 nauplii can be held in a 30 litre plastic bag containing 15 litre of seawater and 15 litre of oxygen for up to 24 hours at 18–24 °C (Lee and Wickins, 1992). Larvae are typically stocked at 50–200/litre with water exchanges of 50–200 percent/day to maintain water quality. Hatcheries rear shrimp through three larval sub-stages (nauplius, protozoea and mysis); the entire process may take place in a single tank (20 tonnes) or in a two-phase approach where a smaller tank (5–10 tonnes) is used for nauplius through mysis and then transferred to a larger tank (10–30 tonnes) for culture from mysis to post-larvae.

Nauplii hatch around 14 hours after fertilization and go through five stages (each for seven hours); nutrition is provided by the yolk sac. The protozoeal stage follows with three molts (each for approximately 36 hours); the larvae swim continuously and now consume phytoplankton (at 150 000 cells/ml). The final three mysis stages last approximately 24 hours each; at this stage the larvae are slightly over 3 mm shell length and now feed on *Artemia* nauplii (2–5/ml) and phytoplankton (120 000 cells/ml). There are also a variety of formulated (encapsulated) artificial diets that are used to supplement live feeds, as well as enrichment formulas used to improve the nutritional quality of the *Artemia*. Manuals and other relevant publication covering penaeid larvae culture in more detail include: McVey (1983); SEAFDEC (1985); NACA (1986); JICA (1987); Chavez (1990); Treece and Yates (1990); and Treece and Fox (1993).

Post-larvae (PL) are usually harvested at PL_{10} (10 days post-metamorphosis) weighing 0.5–2.5 mg; stocked at 75–100/litre and fed *Artemia* (7–9 nauplii/ml), phytoplankton (at 10 000 cells/ml) and formulated supplements. The age that post-larvae are shipped varies depending on species and individual hatchery methods; typically PL 10–25 stocked at 50–2 000/ml (depending on size) and placed in 10–20 litre plastic bags with oxygen and often ice in the shipping container. The nursery phase can be conducted in tanks, raceways, concrete-walled or earthen ponds with sand bottoms, staked net pens and floating cages, usually stocked at 50–100 post-larvae/m^2. Fixed or floating cages (sometimes known as "hapas") are made from fine mesh netting (0.5 mm) (3.7 x 2.7 x 1.3 m deep) stocked at 30 000 PL_5/cage. The juveniles are transferred for on-growing after 15–25 days (Beveridge, 1987).

Grow-out techniques can be categorized into four groups, based primarily on the expected yield at harvest. These include extensive (low density, mixed species stocked in large, fertilized ponds), semi-intensive (moderate density, natural productivity supplemented by feed), intensive (high density monoculture, continuous water exchange and formulated feeds) and super-intensive (very high density monocultures in controlled environments, recirculating systems and formulated feeds) (see Lee and Wickins, 1992).

In the wake of devastating epidemics of viral diseases in outdoor, pond-based shrimp farming, some shrimp farm managers are considering switching to super-intensive, tank-based productions systems because of the additional biosecurity and reduced risks these systems provide. In addition, year-round, continuous production improves the economic potential of the enterprise through higher productivity and facilitates direct marketing to retail markets which generates higher value for the product (Van Wyk *et al*., 1999).

Shrimp release programmes to enhance fishery stocks have been undertaken in several Asian countries with reasonable success. In most cases, post-larvae (PL_{20}) or juveniles are liberated in fenced enclosures, man-made lagoons and artificial tidelands (Kurata, 1981). Shrimp releases in embayments in China have been particularly successful; in the mid-1980s an estimated 350 million hatchery-reared juveniles were released in the semi-enclosed Jiaozhou Bay, increasing stocks by factors of 4.7 and 7.3 over a three year period. Estimated average survival was an impressive 32 percent (Liu, 1990). In Taiwan PC, sea ranching is used to increase the supply of gravid females, with recapture rates estimated at 15 percent (Chaing and Liao, 1985). Similar programmes, appropriately sited in the Caribbean, could contribute greatly to modest local fisheries.

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State of shellfish aquaculture on the Caribbean coast of Colombia and potential site for a regional hatchery facility

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ABSTRACT

Despite the fact that there is considerable knowledge on the ecology, seed collection and culture of various native commercially important shellfish species in the Colombian Caribbean, culture of these species is only conducted at the experimental level. In this paper a description of the national production and commercialization of native shellfish is given and local knowledge on seed production and culture technologies summarized. An analysis of the advantages and problems for the culture of each species is presented and suggestions are made on the main actions considered necessary to develop marine aquaculture in the near future. Finally, the existing molluscs hatchery of the University of Magdalena is proposed as the site for the regional shellfish hatchery for the Wider Caribbean.

RESUMEN

A pesar de que existe un considerable conocimiento de la ecología, la colecta de semilla y el cultivo de diferentes especies de mariscos nativos de importancia comercial en el Caribe colombiano, el cultivo de estas especies se ha realizado únicamente a nivel experimental. En este documento se ofrece una descripción de la producción y la comercialización de mariscos a nivel nacional. Se resume el conocimiento local sobre la producción de semilla y las tecnologías de cultivo de las especies nativas. Por último, se presenta un análisis de las ventajas y la problemática para el cultivo de cada especie y se hacen sugerencias sobre las principales acciones que se consideran necesarias para el desarrollo de la acuicultura marina en un futuro próximo. Finalmente, se propone el criadero de moluscos de la Universidad del Magdalena para ser usado como el criadero regional de mariscos nativos para el Gran Caribe.

INTRODUCTION

The Colombian Caribbean has a coast line of 1 937 km and territorial waters totalling 532 162 km^2. These waters are associated with a large biodiversity of shellfish represented by 1 090 molluscs species (Díaz, Cantera and Puyana, 1998), 530 crustacean decapods species (Ardila, Navas and Reye, 2002) and 289 echinoderms species (Benavides, *pers. com.*).

Between 2006 and 2008, production of shellfish in the Colombian Caribbean averaged 31 825 tonnes/year, equivalent to 75 percent of the total production of marine resources in this area (CCI, 2006, 2007, 2008). This production resulted mainly from the farming of the introduced shrimp, *Penaeus vannamei* (90 percent), and contributed to in small part by the fishing of native species (10 percent). The fishing of shellfish in the Colombian Caribbean is mostly artisanal (75 percent) and targets mainly crustaceans (70 percent); the rest of the harvest consists of molluscs (29 percent), and a minority of echinoderms (1 percent). The main species reported for capture fisheries are presented in Table 1.

TABLE 1
Commercial shellfish species in the Colombian Caribbean

Group	Common name	Species
Molluscs	Clam	*Polymesoda solida* (Philippi, 1846)
	Clam	*Chione cancellata* (Linné, 1767)
	Clam	*Protothaca pectorina* (Lamarck, 1818)
	Chipi-chipi	*Anomalocardia brasiliana* (Gmelin, 1791)
	Chipi-chipi	*Donax* spp. (Linné , 1758)
	Mangrove oyster	*Crassostrea rhizophorae* (Güilding, 1828)
	Scallops	*Amusium* spp. (Gmelin, 1791)
	Queen conch	*Strombus gigas* (Linné, 1758)
	West Indian top shell	*Cittarium pica* (Linné, 1758)
	Copey snail	*Melongena melongena* (Linné, 1758)
	Octopus	*Octopus* spp.
	Squids	*Loligo pealei* (LeSueur, 1873)
		Loligo roperi (Cohen, 1976)
		Illex coindetii (Verany, 1839)
Decapods crustaceans	Blue crab	*Callinectes sapidus* (Rathbun, 1896)
	Swimming crab	*Callinectes bocourti* (A. Milne Edwards, 1879)
	Spiny lobster	*Panulirus argus* (Latreille, 1804)
	White shrimp	*Litopenaeus schmitti* (Burkenroad, 1936)
	Tití shrimp	*Xiphopenaeus kroyeri* (Heller, 1862)
	White shrimp	*Litopenaeus vannamei* (Boone, 1931)
	Pink shrimp	*Farfantepenaeus subtilis* (Pérez Farfante, 1967)
Echinoderms	Sea cucumber	*Holothuria occidentalis* (Ludwig, 1874)
	Sea urchin	*Lytechinus variegatus* (Lamarck, 1816)

AQUACULTURE SHELLFISH PRODUCTION

Production of shellfish by aquaculture in the Colombian Caribbean has been restricted to the shrimp *Penaeus vannamei*. This species was introduced from the Pacific Ocean in 1983, with a well-developed culture technology. This sector was successful for many years (especially between 1985 and 1990), but also incurred several problems associated with the shortage and low growth of imported seed (between 1991 and 1994), as well as with the introduction of disease (white spot and taura between 1994 and 1996 and necrotizing hepatopancreatitis in 2003). Additionally, since 2008, shrimp overproduction coupled with the world economic crisis (and devaluation of the US dollar by 11 percent), led to the closure of many shrimp farms, or to their reconversion to tilapia and/or cobia production (Erazo, *pers. comm.*). As a consequence, shrimp monthly production decreased from 2 387 tonnes during 2006 and 2008, to 8 tonnes at the present time (CCI, 2010).

Production of other shellfish species by aquaculture has been restricted to projects with little or no continuity. Between 1996 and 2002 mangrove oyster production reached 6 to 18 tonnes/year (Salazar, 1999; Barreto, *pers. comm.*) and during 2002 and 2003 pearl oysters, pen shell and scallops productions averaged 80 kg/year (INVEMAR, 2003).

TRADE OF SHELLFISH IN COLOMBIA

The seafood per capita consumption in the Republic of Colombia has been 6.5 kg/year in the last ten years (ANDI, 2009). This low seafood consumption can be attributed to several factors such as low market supply, high prices, poor presentation, low sanitary quality, limited awareness on products and their preparation forms.

Between 2006 and 2008, the highest proportion of shellfish produced in the Republic of Colombia was exported leaving approximately 40 percent for the domestic consumption. This was a result of the higher prices obtained in the external market for cultured shrimp and for the bivalve *Anadara* produced in the Colombian Pacific. Although, internal shellfish demand was reduced (17 932 tonnes/year), supply from national production was not sufficient. This forced the importation of shellfish to satisfy 28 percent of the total demand (CCI, 2006; 2007; 2008). At present, shellfish exports have decreased associated with the reduced shrimp industry; current limited production is mainly for internal consumption (Zúñiga, *pers. comm.*).

The price of the shellfish in the Republic of Colombia varies according to the group, its source and presentation (Table 2). Scallops, lobster, shrimps, octopus and mussels are the most expensive shellfish, while oysters and other local clam species fetch a much lower price.

TABLE 2
Shellfish prices in Colombia in 2009 and 2010

Shellfish	Source	Product form	Price (USD/kg)
Clams	National	With shell	1–2.5
		Without shell	4.5–8
	Imported	Without shell	2.8
Small clams	National	Without shell	2.5–5
Mussels	Imported	With half shell	8.8–9.5
Oysters	National	Without shell	2.8
Scallops	Imported	Muscles	10–30
Copey snail	National	Without shell	5.5–8.5
Octopus	National	Whole	8.5–10.5
Squids	National	Whole	2–4
Shrimp	National		8.5–16
Lobster	National	Whole	20–23

TECHNOLOGY AND PERSPECTIVES OF NATIVE SHELLFISH FARMING

In the Republic of Colombia, native shellfish farming has been carried out at an experimental level for some species. At present, there are no functional aquaculture farms due to various problems, such as the availability of seed supply, adequate planning, financial viability, communities and/or enterprises support, marketing and/or commercialization. In the following sections, the technology used in the Colombian Caribbean for seed production and/or culture of nine native shellfish species is described.

MOLLUSCS

Mangrove oyster, *Crassostrea rhizophorae*

This bivalve species is distributed from the Antilles, south of the Caribbean, Suriname to the Federative Republic of Brazil (Díaz and Puyana, 1994). It can be considered a bivalve species of medium size attaining 120 mm in length. Mangrove oysters are found attached to the red mangrove roots, to other shells and to hard substrata in intertidal zones of coastal lagoons and estuarine areas (Wedler, 1998). The species is a protandric hermaphrodite, reproducing through external fecundation and without external sexual dimorphism (Vélez, 1982). First maturity occurs between two and four months old at 10–20 mm shell length (Vélez, 1982). The reproductive cycle of mangrove oysters is continuous, with a higher proportion of spawning animals in the rainy season, between April and September (Velasco *et al*., in press). Fecundity averages 2.9 x 10^6 oocytes/female/spawn (Velasco *et al*., in press). This species has been traditionally used locally as food, with its populations being very abundant in some areas; however, water pollution and loss of habitat are factors currently leading to a decrease in their abundance and fishery.

Wild seed can be obtained using collectors made of asbestos plates, flexible plastic plates, rubber tires, mangrove terminal branches, aluminum wire coated by sand, lime and cement, or necklaces of oyster shells (Wedler, 1980; 1998, Arias *et al*., 1995; Rodríguez and Lagos, 2000; Lagos-Bayona *et al*., 2007). Collectors are suspended at depths between 0 and 50 cm under the shade of mangroves, in areas protected from currents and with natural populations. Collectors are left untouched for one or two months. Maximum settlement coincides with the rainy season between April and December. Collectors showing optimum settlement are those made of aluminum oscillate, with collection of 247 to 321 spats/collector.

Hatchery seed production has been carried out experimentally (Wedler *et al*., 2003; Velasco *et al*., in press). Oysters greater than 50 mm of length are collected from natural populations during the rainy season. They are induced to spawn using exposure to air at 16 °C for 1 hr, after that, they are immersed in a warm water bath of low salinity (32 °C and 25 ppt). Fertilization is not controlled, and males and females spawn freely in one tank at a ratio of 1:4. Incubation and larval rearing is conducted in cylinder-conical tanks (100 to 500 litre), at densities of 1–10 larvae/ml. Cultures are reared in micro-filtered seawater (1 µm), UV-irradiated and aerated. Temperature is maintained at 25 °C and salinity at 25 ppt. Diet consists of *Isochrysis galbana* and *Chaetoceros calcitrans* at rations between 30 and 70 cells/µl/day. Full water exchange is done every 48 hr. Pediveligers with eyespots and a creeping foot, appear 17–21 days after fertilization. Collectors made of oyster shell necklaces are submerged in the tanks at this time, and after 50 days they are transferred to sea.

Mangrove oyster culture has been carried out on the bottom and in suspension using a system of stakes (Wedler, 1980, Arias *et al*., 1995, Rodríguez and Lagos, 2000, Lagos-Bayona *et al*., 2007). Best results have been obtained using suspended cultures. For seed attached to aluminum collectors, densities of 250 to 350 spat prevent overcrowding and subsequent loss from the collectors. Spat can also be cultured, unattached, inside plastic boxes (90 x 90 cm) at densities as high as 500 oysters. Oysters should be exposed weekly to sun and air for 24 hr to control competitors, predators (*Thais haemastoma*, *Melongena melongena*, *Callinectes sapidus* and *Panopeus menippe*) and fouling (bivalves, polychaetes, barnacles, tunicates and sponges). After six to eight months of culture, juveniles reach marketable sizes of 55 to 70 mm in length (23 g body weight) with a survival rate of 91–98 percent. The meat yield is about 10 percent of the total weight.

Given the low infrastructure cost required for mangrove oyster culture, and the abundance of wild seed, it is suggested that this species be produced at a small-scale to ensure food security. Although this species has a considerable market demand, its price is relatively low (Table 2); for this reason, a commercial culture with the purpose of generating employment and income is recommended only for areas with very high availability of wild seed, as the use of seed from hatchery is not economically viable. Additionally, due to environmental degradation in estuarine areas, caused by mangrove deforestation, coastal erosion and/or water pollution, the identification of suitable farming areas for this activity is necessary.

Scallops – *Argopecten nucleus* and *Nodipecten nodosus*

Argopecten nucleus is a small bivalve species (50 mm in length) and *Nodipecten nodosus*, one of the largest scallop species (150 mm in length). Both are epibenthic, but while *A. nucleus* is a free-living species, *N. nodosus* attaches to hard substrates. *A. nucleus* is distributed in South Florida (United States of America), southern Gulf of Mexico, the Caribbean and Suriname, while *N. nodosus* has a wider distribution, extending northerly to North Carolina (United States of America) and southerly to the southern reaches of the Federative Republic of Brazil (Díaz and Puyana, 1994). *A. nucleus* is a short-lived species (one to two years), attaining sexual maturity early (three months), while *N. nodosus* is longer lived (>2 years), taking six months to reach sexual maturity. Both species are simultaneous hermaphrodites, producing 0.24–47 x 10^5 oocytes/animal/spawn (Velasco, Barros and Costa, 2007). Both species coexist on sandy bottoms at depths of 10–50 m; *N. nodosus* can be found to 120 m depth (Díaz and Puyana, 1994). Both species have not been harvested, due to the lack of information on the location of their natural banks. Small artificial populations were generated since 1996 from wild seed collected for the purpose of research.

Wild scallop seed can be obtained using artificial collectors made with onion polypropylene bags covered by mosquito net mesh (Borrero, 1995; Urban, 1999, INVEMAR, 2003, Castellanos and Campos, 2007). These collectors are kept in suspension at depths between 5 and 25 m for ten weeks. Settlement of *A. nucleus* is relatively constant throughout the year, while that of *N. nodosus* is greater between the months of January and June. Total number of seed settled is very low, with maximum values reported between 1 and 77 spats/collector (4 and 29 spats/m^2). Hatchery supplied seed is an alternative to natural collection (De la Roche *et al.*, 2002; Velasco, Barros and Acosta, 2007; Velasco and Barros, 2008, 2009; Velasco, 2008; Gomez-Leon *et al.*, 2009, 2010). The reproductive conditioning of completely immature animals is achieved between 16 and 77 days in *A. nucleus* and *N. nodosus*, respectively. Animals are kept in rectangular tanks (300 litre) with micro-filtered water (1 µm) at 25 °C, 35 ppt and aerated. The food is supplied through a continuous drip, maintaining food level within the tank, at constant concentrations of 40 *I. galbana* cells/µl. Daily, bio-deposits are siphoned and water is changed (80 percent). Changes of temperature combined with exposure to air, and high supply of microalgae, are the stimuli used to induce the spawning of mature animals. Eggs are cross-fertilized using a ratio of 50:1 or 100:1 oocytes:sperm. Zygotes are incubated at densities lower than 15 zygotes/ml using flat-bottomed conical tanks (200–2 000 litre) with micro-filtered sea water (1 µm), UV irradiated, aerated, with the same temperature and salinity used during reproductive conditioning. Larval and post-larval rearing is carried out at densities of 1 larva/ml under the same conditions described for incubation. Larvae are fed 20 to 60 cells/litre/day of *I. galbana* and *C. calcitrans*. The water volume is fully exchanged every 24 or 48 h. Pediveliger larvae appear after 11 to 15 days of culture. For settlement, onion bag collectors are immersed into the larval rearing tanks and water temperature is reduced (20 °C x 48 hr) in order to induce metamorphosis. After 15 days of settlement, collectors are placed into mosquito nets bags and are transferred to sea. They remain suspended for one month, when spat reach an average of 10 mm in length.

Scallops are grown in suspension, using long lines systems (Urban, 1999; INVEMAR, 2003; Velasco, 2008; Velasco, Barros and Guerrero, 2009; Gómez-León *et al*., 2010). Juveniles are placed in pearl or lantern nets at densities between 25 and 40 percent coverage of the bottom of the net and at depths of 5–15 m. Nets are changed each month to adjust the density and to remove predators (cimatid snails and portunid crabs) and fouling. Market size of *A. nucleus* (45 mm length; 23 g total weight) and *N. nodosus* (80 mm length; 87 g total weight) are obtained after 10 to 12 months of culture. Final survival approximates 65 percent. Muscle yield in relation to total weight is 13 percent for both species.

Due to the high price of scallops (see Table 2), preliminary financial analysis of seed production and culture of scallops, gives very encouraging results for both, with rates of return between 23 and 48 percent (Velasco, 2008; Gómez-León *et al*., 2010). Currently, there is a pilot project for commercial production using hatchery-produced seed in order to verify economic viability. Once the production model for these species is complete, it will be necessary to seek investors and transfer the technology to the private sector, namely fishing communities and/or companies.

Pearl oysters – *Pinctada imbricata* and *Pteria colymbus*

Pinctada imbricata is the smaller species of the two pearl oysters attaining 50 mm in length, whereas *Pteria colymbus* can grow up to 75 mm in length (Díaz and Puyana, 1994). Both of these marine species live subtidally; *P. colymbus* is found attached to octocorals, while *P. imbricata* adheres to rocks (Borrero, Diaz and Seczon, 1996). Both species have a similar distribution, occurring in the western Atlantic, from North Carolina (United States of America) to the south of the Federative Republic of Brazil (Díaz and Puyana, 1994). They are protandrics species (Borrero, Diaz and Seczon, 1996), with a continuous reproductive cycle peaking between May and June (Urban, 1999). Pearl oysters were highly exploited for their pearls during conquest times, but their abundance decreased and collection was stopped. Currently, there is no domestic market for these species.

Wild oyster seed can be collected using onion bags (Velasco and Borrero, 1996; Urban, 1999; INVEMAR, 2003; Velasco and Barros, 2010). Collectors are suspended at depths between 5–10 m for 8–10 weeks. Maximum settlement for *P. imbricata* (292 to 583 spats/m^2) is recorded between February and June, and for *P. colymbus* (58 at 333 spats/m^2) between February and May, coinciding with water changes in temperature. *P. imbricata* oyster seed has been successfully produced in hatchery conditions (Hernández, 1999; Hernández and Gómez, 2000). Conditioning of 70 mm individuals is achieved with temperatures of 24 °C and a daily ration of *Chaetoceros gracilis* and *Isochrysis galbana* (60 cells/µl/d). Mature specimens are induced to spawn by thermal shock. Larval rearing is carried out in cylindrical tanks (500 litre), filled with micro-filtered seawater (1 µm), irradiated with UV, at a temperature of 27 °C and salinity of 35 ppt. Larval density is maintained at 2–6 larvae/ml, and fed a mixed diet of *I. galbana* and *C. gracilis* (50 and 60 cells/µl/d). Larvae reach the pediveligers stage 16 days after fertilization. Settlement is carried out at densities of 1 larva/ml, fed an algal ration of 100 cells/µl/d; onion bag collectors are submerged in larval rearing tanks as a settlement substrate. Seed of 10 mm are obtained in three months under hatchery conditions.

Pearl oyster are grown in both suspended and bottom cultures (Velasco and Borrero, 1996; Urban, 1999; INVEMAR, 2003; Velasco and Barros, 2010). Suspended culture technology is similar to that described above for scallops. For bottom culture, boxes are used, and oysters are grown at densities of 30 percent cover of the bottom of the net. Pearl production is feasible in both species, where a single nucleus (diameter <11 mm) is implanted in animals greater than 60 mm length. Commercial size for both species (50 mm length and 20 g for *P. imbricata*; 75 mm length and 35 g for *P. colymbus*) is reached between 9–12 months of cultivation, with approximately 50 percent survival. The yield of the meat in relation to the total weight of the animal is approximately 30 percent.

There has been pilot-scale operations carried out by fishermen's associations and indigenous communities using wild seed. Due to the low infrastructure requirements for grow-out, results have been successful for a production used as a supplement for local food demand. These species are not recommended for large-scale aquaculture because the quantity of wild seed is too low. Hatchery-seed is required for increased production; however, this is not believed to be economically feasible given the lack of a pearl oyster domestic market (for both pearl and meat). Nevertheless, if it is possible to adapt successfully the technology for pearl production; culture of pearl oyster species could target the more lucrative pearl market and the local meat market contributing to food security.

Pen shell, *Pinna carnea*

Pinna carnea is a large bivalve species (300 mm) that lives semi-buried, vertically, in soft bottoms with gravel. It inhabits shallow waters of the marine subtidal, up to 25 m depth. It is distributed along the western Atlantic from the south of Florida (United States of America) to the Federative Republic of Brazil (Díaz and Puyana, 1994). This pen shell is a simultaneous hermaphrodite species, their populations have a continuous reproductive cycle with a period of higher proportion of animals spawning between July and November (García, 1997). The small populations of this species are not currently subjected to exploitation.

Wild seed collection of pen shells has been carried using the same technology described for pearl oysters and scallops (Urban, 1999; INVEMAR; 2003; Velasco and Borrero, 2004). Maximum settlement in *P. carnea* (6–100 spats/collector or 25 to 417 spats/m^2 of collector) occurs between September and December, associated with an increase in water temperature. This species can be cultured using similar suspended or bottom technology described for scallops and pearl oysters (Borrero 1995; García, 1997; INVEMAR; 2003, Velasco and Borrero, 2004). Survival at the end of cultivation is typically over 55 percent. Commercial size (160 mm length and 15 g total weight) is reached in 11 months in suspended culture with approximately a survival of 57 percent and a meat yield of 30 percent total weight.

Due to the moderate availability of pen shell wild seed, the absence of a market and its low costs (see Table 2) of production, it is suggested that this species is cultured as a food complement by coastal communities; additionally, the meat of *P. carnea* could be marketed as that of oysters and/or clams. The development of hatchery-seed technology is not recommended for this species, but should be focused on *Atrina seminude*, another less abundant species of pen shell with a larger adductor muscle.

West Indian top shell, *Cittarium pica*

The West Indian top shell, *Cittarium pica*, also known as burgao or cigua, is an archaeogastropod of large size (180 mm of width shell) (Figure 1). It lives on exposed rocky intertidal shores, with a distribution extending from Bermuda to the north coast of South America. It is nocturnal in its behaviour and feeds on macroalgae, diatoms and organic detritus (Díaz and Puyana, 1994). This is a gonocoric species, with external fertilization and without external sexual dimorphism. The minimum size of sexual maturity is between 33–40 mm of width shell (Randall, 1964). Populations in the Republic of Colombia have a continuous reproductive cycle; with a higher percentage of animals spawning between August and October (Osorno and Díaz, 2009). Fecundity of this species ranges from 1–1.3 x 10^6 oocytes/spawn. Conservation status of the species populations are considered vulnerable due to high overexploitation (Ardila, Navas and Reye, 2002).

Hatchery seed has been experimentally produced in the Republic of Colombia. The spawning coincides with the high tides in new moon periods. Animals larger than 70 mm are exposed to air for 24 hr and thereafter, placed in tanks with a continuous open flow of 50 µm filtered and UV-irradiated seawater. Egg incubation is carried out in rectangular plastic tanks (12 litre) at densities ranging between 8–88 zygotes/ml. Seawater is filtered to 1 µm, UV-irradiated and maintained at 25 °C and 35 ppt. Cultures are kept under low illumination without air injection and changing the supernatant water every 15 minutes for the first 2 hr. Once trochophore larvae develop (7.5 hr following fertilization), dead and lethargic larvae are decanted on the bottom and eliminated; culture water is replaced entirely every 12 hr maintaining densities between 0.2–1 larva/ml. After three to four days, when competent veligers are developed (with visible tubules in the epipodial tentacles), PVC plates covered with biofilm (diatoms) are introduced in the tanks. Once settlement is verified (two days), seawater system is changed to open flow with an air supply. Spat reach a shell width of 2 mm in three months. Juveniles are cultured on biofilm plates placed in holders, inside cages suspended in outdoor raceways. Macroalgae such as *Laurencia* sp. and *Padina gymnospora* are used to complement biofilm feeding. Biofilm plates and macroalga are renewed every two days. The supply of a continuous open water flow is required to avoid ammonia reaching toxic levels (Hawkins and Velasco, 2009). Time required to attain commercial size (70 mm width shell; 170 g weight) is unknown. Meat yield for this species is 20 percent of the total weight.

The West Indian top shell has a high market demand and commands a high price (see Table 2); however, production costs are also high, due to hatchery and raceway requirements used for culture. For this reason, culture of this species for food sustenance purpose is not viable. It is necessary to optimize techniques for seed production and culture, as well as to carry out a financial evaluation of the activity assessing commercial viability or stock enhancement efforts.

Queen conch, *Strombus gigas*

The queen conch is a gastropod of large size (320 mm of length) (Figure 2). It lives in subtidal bottoms with coralline sands, algae and *Thalassia*, at 2–30 m depth from Bermuda to the northern shores of South America (Díaz and Puyana, 1994). They are herbivorous and detritivores (Lagos-Bayona *et al*., 1996), gonocorics, with internal fecundation and external sexual dimorphism marked by the presence of a conspicuous penis in the males. First maturity occurs at three/four years of age, when individuals reach lengths of 22–24 cm. They mate and spawn along the whole year, with more reproductive activity between April and November (when water temperature starts increasing). The females spawn after mating on the sand. The eggs are inside of a continuous jellied tube that can measure up to 37 m. Fecundity averages 300 000 eggs/spawn (Lagos-Bayona *et al.*, 1996). This species has been exploited for its meat, shell and pearls. In spite of the fact that since 1991 there are restrictions on harvest (in terms of seasons, fishing areas, size and quotas), in practice, enforcement has not been efficient and conch populations are currently in a vulnerable state of conservation (Ardila, Navas and Reye, 2002).

Obtaining hatchery-produced seed has been possible through the collection of eggs masses from natural habitats (Lagos-Bayona *et al.*, 1996) or inside marine corrals where adult animals are confined. Egg masses are gathered in polyethylene bags by diving. These are washed with micro-filtrate water (0.5 µm) and disinfected (chlorine 0.5 percent x 60 s), and placed in upwellers systems with an open flow of filtered (0.5 µm) UV-irradiated seawater. In four days, the intracapsular veliger larvae have two velar lobes, and are ready to hatch. Egg masses are placed in a sieve inside the superior portion of cylindroconical tanks (1 000 litre), in a closed system with treated seawater. Once developed, veliger larvae are reared in this type of tanks at densities of 20–60 larvae/litre with continuous water flow. Larvae are fed with *I. galbana* at rations of 17–22 cells/µl/day. After 18 or 21 days, competent larvae appear (SEPESCA/CIQRO, 1994). In order to stimulate settlement and metamorphosis, larvae are placed on trays with open flow of filtered (5 µm) seawater, containing biofilms of *I. galbana* and hydrogen peroxide (50 µmoles x 10 hr). Juveniles are maintained in these trays or in tanks (400 litre) at densities of 15 juveniles/m^2. They are fed with biofilm plates and liquefied macroalgae *Dictyota* sp. Biofilms are composed of diatoms, such as *Thalassionema*, *Cylindrotheca*, *Bacillaria* and *Navicula*. Biofilm plates are changed daily and biodeposits are removed by siphoning. Young juveniles of 2 mm shell length attain 18 mm in two months, and older juveniles of 65 mm reach 100 mm in five months. These animals can be transferred to corrals in the sea or used for repopulation. In the Republic of Colombia the time of culture required to reach commercial size (200 mm length; 1 400 g weight) is unknown. Meat yield is between 6.5–9.6 percent in weight (SEPESCA/CIQRO, 1994).

Although it has been possible to produce hatchery seed of queen conch, mortality is very high, and there remain unknown aspects on culture techniques and more specifically, successful transfer to sea for stock enhancement. It is necessary to optimize technology for seed production and culture, as well as to evaluate their adaptation to the natural habitat. This species commands a high market price (see Table 2), but the production costs are high due to hatchery requirements and the long culture period to attain market size (SEPESCA/CIQRO, 1994). The authors suggest the culture of this species for repopulation and/or for production of pearls.

CRUSTACEANS

Spiny lobster, *Panulirus argus*

The Caribbean spiny lobster is a large decapod crustacean (180 mm of cephalothorax length and 990 g total weight). It is a benthic organism, associated with seagrass, corals and sandy bottoms at depths of up to 100 m. The species is known to undergo long migrations. Spiny lobsters are distributed from Bermuda to the Janeiro River in the Federative Republic of Brazil, embracing part of the coastal area of North America, all of Central America, the Antilles of the Great Caribbean and part of South America, being rare in the Gulf of Mexico (Cruz *et al*., 1990). This is a carnivorous and omnivorous species. They are gonocorics, with external sexual dimorphism, the females present large birramia pleopods and their gonopores are in the third base of the treadmills paws, while the males have small monorramia pleopods and their gonopores are in the fifth base of the treadmills paws. The reproductive cycle is continuous, but the largest proportion of mature individuals is found between September and November (CCI, 2006). Fecundity oscillates between 100 000 and 2 500 000 eggs/spawns (Briones *et al*., 1997). Larval life is long, lasting between 6–12 months and very complex, consisting of 11 larval stages, from the phyllosoma to the pueruli stage (Kittaka, 1994). In the Republic of Colombia, spiny lobsters have been exploited intensely; with recorded captures of 1 087 tonnes/year (Cruz *et al*., 2007). In spite of the size limits defined by capture regulations, it is common to find juvenile lobsters in the market. In the Republic of Colombia, the conservation status for this species is considered vulnerable (Ardila, Navas and Reye, 2002).

Pueruli and wild juveniles can be collected between mangrove roots (Eslava, 1986), or using artificial collectors, such as onion bags (Córdoba, 1997) and shredded polypropylene rope (Arango *et al.*, 1999; Jaimes, Pinzon and Trujillo, 2004; Cruz, *et al.*, 2007; Jaimes and Nieto, 2008). The most efficient collectors are polypropylene ropes, collecting between 14 and 251 juveniles and pueruli/collector. Collectors are suspended at depths between 1–15 m and must be checked every month to remove settled lobsters. Although there are settlements throughout the year, peak numbers are recorded between January and April and from September to November.

Juveniles have been cultured in cages placed in outdoor tanks (Córdoba, 1997) or suspended in the sea (Eslava, 1986; Jaimes *et al.*, 2009). Best results have been obtained using floating cages (9 m^3), made of four mesh levels, and with approximately ten shredded polypropylene rope collectors on each level. Grow-out density is approximately 30 animals/m^3. Organisms settled on the collectors inside the floating cages serve as food to the cultured lobsters; for animals greater than 40 mm cephalothorax length, a daily supplement of fresh fish viscera and small fish from commercial fishery discards is necessary. Fouling organisms and predators (*Callinectes* spp., *Mithrax* sp. and *Muraena* sp.) are eliminated regularly from the cages. Juveniles with an initial cephalothorax length of 8 mm reach 60 mm in one year of culture. Culture time required to reach commercial size (70 mm cephalothorax length or 385 g total weight) is unknown. Meat yield (by weight) of the tail is 30 percent of the total weight.

Continued efforts in optimizing culture techniques for spiny lobsters are recommended; more specifically, developing artificial diets for juvenile grow-out would alleviate costs incurred on an environmental and economic scale, as compared to the current use of fresh fish. On the other hand, considering the high availability of wild juveniles and the long duration of the larval phase, continued efforts in hatchery production are not advisable. Due to the high costs of the exogenous food, culturing spiny lobster as an alternative food source for small communities is not recommended. A financial analysis on spiny lobster culture is required to determine its viability as a commercial operation, including using a portion of production for the purpose of natural population enhancement. Another alternative is to promote the wide deployment of collectors to favour natural recruitment and in parallel develop a fishery for harvest, as done in the Republic of Cuba.

COLOMBIA AS THE POTENTIAL SITE FOR A REGIONAL SHELLFISH HATCHERY FACILITY

Since the 1980s, the Colombian Government has supported the development of native shellfish culture along its Caribbean coast through the funding of several research and development projects that led to the acquisition of technical farming knowledge described above. Starting from 2005, a number of national and international entities such as the Institute on Marine and Coastal Research (Instituto de Investigaciones Marinas y Costeras – INVEMAR), the University of Magdalena, the Japan International Cooperation Agency (JICA), the International Cooperation Agency of Chile (Agencia de Cooperación Internacional – AGCI), as well as a number of private companies (including Hidrocultivos de la Costa, Asociación de Pescadores Chinchorreros de Taganga, Coopestaganga and Genemaca Committee), have been promoting the culture of native scallops species.

Thanks to this support, the Republic of Colombia currently operates a functional shellfish hatchery at the University of Magdalena in Taganga, Santa Marta, Colombian Caribbean, and the first marine scallop farming concession of two hectares in the Bay of Taganga. The hatchery, with its total area of 400 m^2, has a seawater supply of 15 m^3/hr and a seawater cooling system by means of a chiller. The water filtration system is made up of a sand filter (50 µm), four bag filters (25, 10, 5 and 1 µm) and a UV sterilization system (four lamps of 4 W). The entire facility can also be cooled by means of airs conditioning. The hatchery includes a pump room, a water treatment room, a mollusk culture section, a microalgae section, a dry laboratory for microscopy and physical-chemical analysis, a material cleaning and sterilization room, an office and a meeting room. In addition, the facility has an outdoor quarantine area and a sedimentation pond for hatchery effluent waters before they are returned to the sea.

The hatchery, has access to the use and service of other facilities of the University of Magdalena such as the restaurant, communication facilities (internet access, phone), bathrooms, training facilities (classrooms, auditoriums), microbiology and water quality laboratories, as well as a small but functional fish processing facility. The area of the hatchery may allow an expansion of approximately 1 000 m^2. The hatchery is located in an area not affected by natural storms or hurricanes and easily accessible. Taganga is ten minutes from Santa Marta, 30 minutes from the local airport and 1.5 hr flight from Bogota. There are direct flights from Bogota to most of the countries of the Caribbean.

For the operation of the hatchery, there are five qualified professionals in molluscs reproduction, microalgae production, scallop grow-out, administration and aquaculture engineering. In addition, university students and undergraduates provide an additional helping hand when needed.

In the Colombian Caribbean, there is good broodstock availability for all the native shellfish species mentioned above. The seawater temperature and salinity are within the ranges of these species (20–22 °C; 29–37 ppt). At presence there is no evidence of the presence of harmful chemicals, diseases, toxic blooms or microbiological contamination in the local waters. The hatchery is currently producing about 8 million scallop larvae (with survivals of 30–60 percent) and 100 000 spat of 10 mm every 2.5 months (one month in the hatchery and 1.5 in the sea). However, due to the proximity of urban populations to the hatchery, a detailed study of the quality of the water in the area should be carried out.

The use of this facility as the regional hatchery for the Wider Caribbean imply financial savings, as well as savings in time and a reduced level of risks as the hatchery works well. The facility could be enlarged according to the production requirements.

CONCLUSIONS

At present, a wealth of knowledge exists on the culture and/or production of seed for some native species from the Colombian Caribbean; however, aquaculture production has not been conducted in a regular manner for any of these species. Based on this information, a number of actions are suggested in the short-term, in order encourage sustained production of native shellfish from the Colombian Caribbean. It is recommended for resources like the mangrove oyster, pearl oysters and pen shell whose market and price are reduced, but with a considerable availability of wild seed and low infrastructure requirements, that their cultivation be implemented to guarantee food security of the coastal populations of the Colombian Caribbean.

For scallop species, which command a high price and high production costs, but a reduced domestic market, a financial analysis of a pilot-scale operation is recommended; this would allow the development of a production model which potentially generates income and employment. On the other hand, when considering species facing ecological risk, such as the queen conch, the West Indian top shell and the spiny lobster, culture activity for the purpose of stock enhancement is an option. In addition, considering an existing substantial market demand, high price and high cost of production, continued research into culture techniques for hatchery-seed production is recommended for these three species, as well as a financial analysis assessing commercial viability. On the other hand, considering favourable prices and markets for octopus the authors suggest investigating the development and/or adaptation of culture technology for commercial purpose. Finally, considering the availability of infrastructure, equipment, qualified staff, availability and access to bivalve broodstock, the existing molluscs hatchery of the University of Magdalena could be developed into a regional facility for the benefit of all interested Caribbean countries.

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Status of shellfish fisheries and farming in Panama

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ABSTRACT

Commercial fisheries in the Republic of Panama are mostly developed on the Pacific Ocean, however, shellfish fisheries are more common in the Caribbean Sea. These extractive activities are seriously affecting the population of some commercially valuable species such as lobsters, crabs and a number of species of bivalves, gastropods and sea cucumbers. Conservation measures are applied to minimize the impact on the marine ecosystems, such as prohibiting the capture of egg-bearing lobsters and banning queen conch and sea cucumber harvest. There are currently a number of aquaculture projects on bivalve molluscs and other valuable marine species; these projects are successfully conducted in marine coastal areas and ponds. However, operational limitations due to poor infrastructure have restrained the expansion of many aquaculture activities from becoming truly commercial. It is anticipated that commercial seafood culture will develop in the near future with the collaboration of artisanal fishing communities and private investors.

RESUMEN

La pesca comercial en República de Panamá se desarrolla principalmente en el Océano Pacífico, sin embargo, la extracción de mariscos es más común en el Mar Caribe. Estas actividades extractivas están afectando seriamente a la población de algunas especies de valor comercial como langostas, caracoles, cangrejos y numerosas especies de bivalvos, gasterópodos y pepinos de mar. Para reducir al mínimo el impacto en los ecosistemas marinos se aplican medidas de conservación, tales como la prohibición de captura de langostas con huevos, veda de caracol gigante o pala y prohibición de la extracción del pepino de mar. Actualmente hay varios proyectos de cultivos de moluscos bivalvos y otras valiosas especies marinas; Estos proyectos se realizan con éxito en estanques y zonas costeras marinas. Sin embargo, las limitaciones operacionales debido a infraestructuras deficientes han restringido la expansión de muchas actividades acuícolas a niveles comerciales. Se prevé que el cultivo de mariscos comerciales se desarrollará en un futuro próximo con la colaboración de las comunidades pesqueras artesanales y los inversores privados.

INTRODUCTION

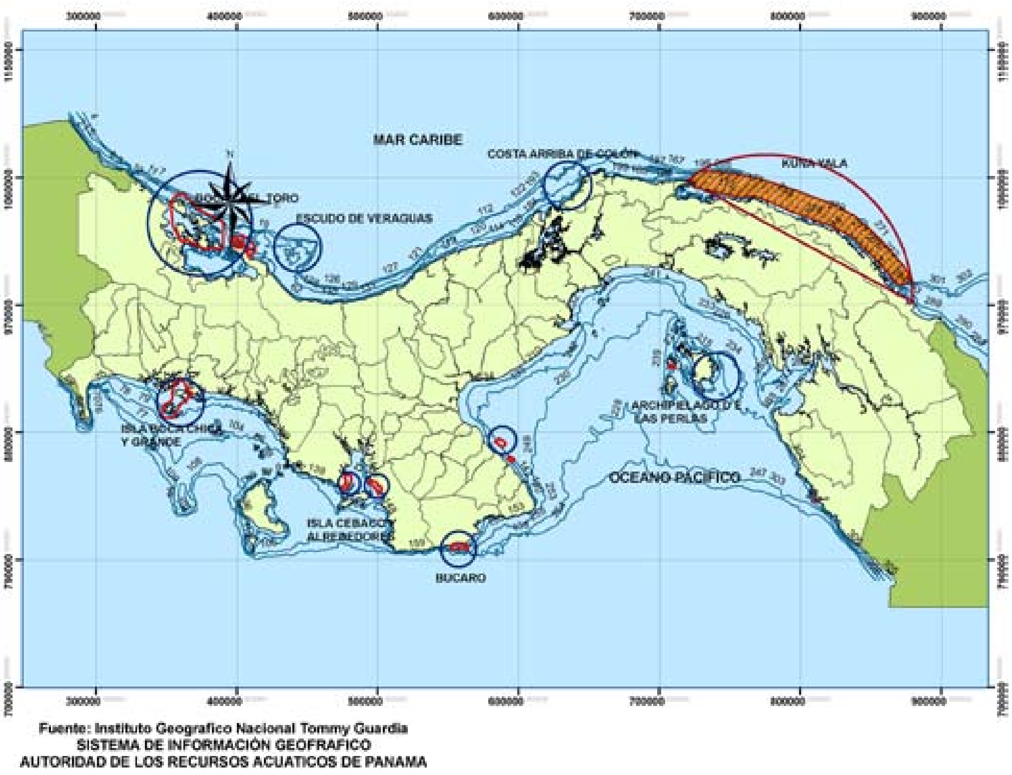
The Republic of Panama has a continental platform of 3 983 km^2, the majority of which is coastal (2 988 km^2). Almost half of the coastal platform lies on the Caribbean side.

Most of the artisanal and industrial fishing activity (95 percent) targets tunas, sardines, herrings and shrimp and is carried out in the Pacific Ocean. The Caribbean coast supports artisanal fishing of spider crabs, bivalve molluscs, queen conch and lobster; the latter being the most important product on the east and west coasts. Industrial fishing is not developed in the Caribbean Sea and for the most part does not compete with artisanal fishing; the only exception relates to lobster fishing, where approximately five fishing boats move from the Pacific coast on a yearly basis to fish this commodity.

Lobster fishery

There are strong indications, supported by export values and reduced harvest size, that overfishing of lobster is occurring. For this reason, conservation measures have been implemented since 1981 in the Republic of Panama; namely, minimal harvest size, and prohibition on harvest of egg-bearing lobsters. In addition, the Republic of Panama has adopted the regional closure of the fishing season for the Caribbean spiny lobster (*Panulirus argus*) since 2010. This regional measure was promoted by the Organization of Fishing and Aquaculture in Central America (Organización del Sector Pesquero y Acuícola de Centroamerica – OSPESCA), advocating for lobster fishing season to be closed between 1 February and 30 June and followed by all Central American countries. Figure 1 illustrates lobster fishing areas on both the Caribbean and Pacific coasts, with the majority found on the Caribbean side.

FIGURE 1
Lobster fishing zone; red circles indicate zone



Source: Araúz, 2008.

Sea cucumber harvest

As a precautionary principle, the extraction of sea cucumber has been permanently prohibited since 2003; this was based on a study indicating the critical reduction of the species' population in certain areas of Bocas del Toro, due to the extraction of sea cucumbers for the Asian market. Recently, the prohibition has been lifted for research purposes; this was made possible to support the interest in investigating sea cucumber culture – namely reproduction under controlled conditions – and thus, potentially reducing clandestine fishing activities.

Queen conch

In a presentation to OSPESCA, Martinez (2006) gave a preliminary statistical analysis on queen conch (*Strombus gigas*) landings from capture fishing. The results clearly indicate a reduction in size and quantity of the queen conch harvested (Tewfik and Guzman, 2003). This prompted action for conservation, leading to a moratorium of five years.

AQUACULTURE PERSPECTIVE

In 2009, the state policy on Panama's Aquatic Resources was adopted in order to achieve an optimal and rational exploitation of its aquatic resources, through regulation and monitoring. This was developed in order to secure the conservation, renewal and sustainability of aquatic resources and ensure the long-term continuity of fishing and aquatic farming activities; hence, also ensuring social, environmental and economic sustainability of these activities.

This official document promotes the cultivation of aquatic organisms especially molluscs, fish and macroalgae. In order to achieve this goal, mechanisms to support such development, including the provision of low-interest loans or non-reimbursable funds for community projects and for small commercial ventures, will be established.

Furthermore, a mariculture development strategy is currently being adopted by the authorities. Its objective is to set the conditions to enable and encourage cooperation between government experts and the private sector in supporting the growth of a truly competitive seafarming in the Republic of Panama. This strategy aims at: i) establishing norms, regulations and standard procedures for the development of sea farming; ii) creating and promoting a business environment that would allow competitive production; and iii) providing specialized technical training and develop locally applicable farming technologies.

Culture trials for crustacean and molluscan species

The Province of Bocas del Toro presents favourable conditions for the cultivation of diverse sea species of a high commercial value, among them are lobsters (*Panulirus* sp.), spider crabs *(Mithrax spinossissimus*), the mangrove oysters (*Crassostrea rhizophorae*), the queen conch or "cambute" (*S. gigas*) and the pearl oyster (*Pinctada imbricata*).

Population structure, distribution and abundance of three commercial sea cucumbers, *Holothuria mexicana*, *Isostichopus badionotus* and *Astichopus multifidus*, studied by Guzmán and Guevara (2002), suggests the need for an adequate management plan for these echinoderms in order to avoid illegal extraction. The production of bivalves through aquaculture has been restricted to research and development (R&D) projects on different native species of the Pacific Ocean and on the introduced Japanese oyster species, *Crassostrea gigas*.

The first experiments on the culture of molluscs were conducted in the 1970s by González-Muñoz (1975); results on grow-out of *Mitella speciosa* and *Ostrea palmula* in selected areas of the Gulf of Panama were not very encouraging. At this time a number of potential areas were identified in Bocas del Toro on the Caribbean coast for the culture of the mangrove oyster, *Crassostrea rhizophorae.* This led to further investigation on the settlement and culture of these oysters in Bocas del Toro by Muñoz in 1979 (Morales,

FIGURE 2
Hatchery crops and selection of conchuela, *Argopecten ventricosus*, seed

PHOTO: J.M. MAZÓN-SUÁSTEGUI, CIBNOR-MÉXICO

FIGURE 3
Preparing hatchery-reared *A. ventricosus* seed for transport and to grow-out sites

PHOTO: J.M. MAZÓN-SUÁSTEGUI, CIBNOR-MÉXICO

1990). Using asbestos cement collectors over a period of eight months, it was determined that peak spat settlement occurred in February, March and September. Spat grew to 68 mm in seven months.

Aside from *C. rhizophorae* in the area of Bocas del Toro, other species of commercial interest are *Anadara notabilis*, *Anadara chemnitzi*, *Nodipecten nodosus*, *Argopecten gibbus, Euvola ziczac* and *Arca zebra.* All of these have been recorded in the database of the Smithsonian Institute of Tropical Research (SITR).

In the past few years, collaboration has been initiated with the Mexican Northwest Biological Research Center (Centro de Investigaciones Biológicas del Noroeste – CIBNOR) on the reproduction technology of several species of Pacific bivalve molluscs. This has led to the successful reproduction of the Pacific calico scallop, *Argopecten ventricosus*, in one of the state research laboratories. Unfortunately however, due to inadequate infrastructure and facilities available, the production of this valuable species has been temporarily halted. In the meantime, the artificial reproduction of the large *Crassostrea gigas* was achieved by a private enterprise.

In 2004, in conjunction with the association of artisanal fishers, a pilot project was implemented focusing on the grow-out of *Argopecten ventricosus* (Figures 2 and 3). The technique involved a 55 x 55 x 7.5 cm mik pyramid, made of stowable plastic oyster farming baskets; these were tied with a nylon rope, forming modules of four culture baskets and one used as a cover fitted with a foam floating plate. This technique has been used in other oyster grow-out projects. Although this led to the successful growth of oysters, the technology has not been adopted by fishers, mainly due to socio-economic factors, which forces them to attend to more immediate needs and neglect grow-out operations.

In the Pacific coast, culture initiatives for *Crassostrea corteziensis* and *Crassostrea gigas* have been implemented. Seed supply was either imported from the United Mexican States or produced in the Republic of Panama. Several experiments have been carried out, including the adaptation of grow-out techniques for the Japanese oyster, *C. gigas*, in a shrimp farm reservoir. Seed, averaging 2.4 mm, was placed in mosquito bags at a density of 2 000 seed/bag. Following 56 days of growth, the experimental densities were established; oysters reached 6–7 cm in length within a period of seven to ten months.

Pilot grow-out of *C. corteziensis* oyster was conducted in an inlet of Isla Cañas in the southern part of the Peninsula de Azuero on the Pacific coast. Adequate density for culture of the species was determined at this time. In addition, the importance of frequent cleaning in order to prevent mortality caused by perforating snails (mainly of the *Cymatium* genus) and the effect of fouling on grow-out enclosures was identified. At present, the fishing community of Isla Cañas has adopted this technology, pursuing a third trial in oyster grow-out. The community's aim is to sell cultured product to hotels in the area targeting the tourism sector.

REPOPULATION OF OVEREXPLOITED NATURAL STOCKS

Projects have been implemented, both in the Pacific and Atlantic coasts of the Republic of Panama, aiming towards stock enhancement of natural populations of overexploited species. An outline is given below on the species targeted and the approach taken for each.

Culture trials for *Anadara tuberculosa* have been initiated by communities along the Pacific coast. The goal is to grow individuals to commercial size in the natural environment, allowing them to spawn prior harvesting and removal from the population. Daily harvest is classified by size using collectors; individuals smaller than commercial size are transferred to suitable sites for further on-growing.

Three projects have been carried out with fishing communities on the Caribbean coast. Two of these are based on the cultivation and repopulation of lobster and spider crabs following experiments conducted using cages in other Caribbean countries and in the United Mexican States. The third project involves the culture of the algae *Euchema cottonii* which has been produced in the Republic of Panama on a commercial-scale for the past 50 years (Figure 4). Techniques for this type of culture have been adopted by fishing communities in part due to a short production time frame required for the algae to reach commercial size.

FIGURE 4
Artisanal farming of the marine algae, *E. cottoni*

PHOTO: JORGE ABADÍA, ARAP-PANAMÁ

FIGURE 5
First stage red spider crab cages

PHOTO: JORGE ABADÍA, ARAP-PANAMÁ

Trials for the grow-out of the spider crab, *Mithrax spinosissimus,* have also been initiated. Egg-bearing females were captured and kept in oxygenated recipients until the hatching of zoeae larvae. Once the first crab stage was reached (approximately four to six days after hatching), individuals were put in 3 x 1.5 m (w x h) cages at a density of 150 crabs/cage (Figure 5). This method is labour intensive, requiring routine cleaning of the cages and maintenance of density through size selection of the growing crabs.

For all of the farming trials described above, success is directly related to the interest and commitment of the fishing communities; for this reason, continuous training and technical follow-through is needed for the successful adaptation of culture techniques.

SHORT-TERM PROJECTIONS

Based on the state policy and the national strategy, the following short-term actions are planned for the development of mariculture activities:

- Investments in mariculture R&D programmes will be increased.
- Increase training opportunities for technical staff in large-scale mollusc reproduction.
- Renovation and expansion of existing facilities for molluscs and sea cucumber reproduction.
- Establishment of pilot farm operations for *Anadara*, *Pinctada* and *C. rhizophorae* along the Caribbean coast.
- Reproduction of sea cucumber for farming and repopulation of natural stocks.

CONCLUSION

There are several factors favouring the development of aquaculture in the Republic of Panama. The country has a strong fishing tradition due to its strategic position, a stable economy, and its shores are relatively unaffected by the impacts of adverse weather phenomena. The country has generated basic technology for the development of commercial shellfish aquaculture and has well-trained technical staff. In addition, Panama has signed cooperation agreements with agencies such as the Smithsonian Institute of Tropical Research, the United Nations Development Programme (UNDP), the Government of the United Mexican States and is an active partner of the OSPESCA Central American Cooperation framework.

Existing strategies and policies encourage actions necessary to strengthen human resources and infrastructure aiming towards aquaculture in general. This enables the implementation of shellfish aquaculture and its sustainable management with the overarching goal of providing commercial alternatives to coastal communities.

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Developing echinoderm culture for consumption and stock enhancement in the Caribbean

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ABSTRACT

Echinoderm culture refers to the cultivation of both sea urchins (Echinoidea) and to a lesser extent sea cucumbers (Holothuroidae) – sea urchins are more valuable and more widely marketed than sea cucumbers. The sea egg, *Tripneustes ventricosus*, is widely harvested throughout the Lesser Antilles and is restricted from harvest in several countries. The variegated sea urchin, *Lytechinus* sp., is also harvested and exported to Japan and other Asian countries where its roe is highly valued. Echinoderms, particularly sea urchins, also occupy an important ecological niche in tropical coral reef environments. As benthic grazers of macroalgae, they mitigate the proliferation of fouling algae that occurs as nutrient loading increases (eutrophication) due to anthropogenic pollution. In the Caribbean, this problem has been exacerbated by the dramatic declines in *Tripneustes* populations due to overexploitation and the collapse of *Diadema antillarum* populations as a result of a devastating plague, unprecedented in marine history, that occurred in 1983 and affected only this species and almost wiped out these urchins that lived on the Caribbean coral reefs all the way north to Bermuda. It was the *Diadema* that grazed algae from the reefs allowing this species and other invertebrates to settle and grow and maintained the ecological balance of a healthy coral reef. Stock enhancement of natural sea urchin populations from hatchery-reared seed stock has been a well documented success in Japan, the People's Republic of China, the Republic of the Philippines and other Asian countries. Induction of spawning, larviculture, nursery grow-out and release have been highly successful in restoring stocks decimated by overexploitation and disease. Hatchery and nursery techniques, as well as several release and on-growing methods are discussed.

RESUMEN

El cultivo de equinodermos se refiere al cultivo de erizos de mar (Echinoidea) y en menor medida al cultivo de pepinos de mar (Holothuroidae). Los erizos de mar son más valiosos y más ampliamente comercializados que los pepinos de mar. El huevo de mar, *Tripneustes ventricosus*, se extrae ampliamente a lo largo de las Antillas Menores y su colecta está restringida en varios países. El erizo de mar verdiblanco, *Lytechinus* sp., también es capturado y exportado a Japón y otros países asiáticos, donde sus huevos son altamente valoradas. Los equinodermos, particularmente los erizos de mar, también ocupan un nicho ecológicamente importante de los ambientes de arrecife de coral tropical. Por ser herbívoros de macroalgas bentónicos, mitigan la proliferación de algas epibiontes que se producen a medida que aumenta la carga de nutrientes (eutrofización) originada por la contaminación antropogénica. En el Caribe, este problema se ha agravado por los descensos dramáticos en las poblaciones de *Tripneustes* debido a la sobreexplotación y al colapso de las poblaciones de *Diadema* como resultado de una plaga devastadora, sin precedentes en la historia marina, que ocurrió en 1983 y afectó sólo a esta especie, aniquilándo casi totalmente sus poblaciones que se extendían hasta el norte de las Bermudas. El pastoreo de algas que llevaba a cabo *Diadema* en los arrecifes permitía el establecimiento y crecimiento de esta especie y otros invertebrados manteniendo el equilibrio ecológico de un arrecife de coral saludable. El incremento de las poblaciones naturales de erizo de mar mediante las repoblaciones de semillas provenientes de criaderos ha sido un hecho exitoso bien documentado en Japón, la República Popular China, la República de las Filipinas y otros países asiáticos. La inducción al desove, larvicultura, levante en vivero y liberación han sido muy exitosas en la restauración de las poblaciones diezmadas por sobreexplotación y enfermedad. Se discuten las técnicas de reproducción y levante así como varios métodos de liberación y cultivo.

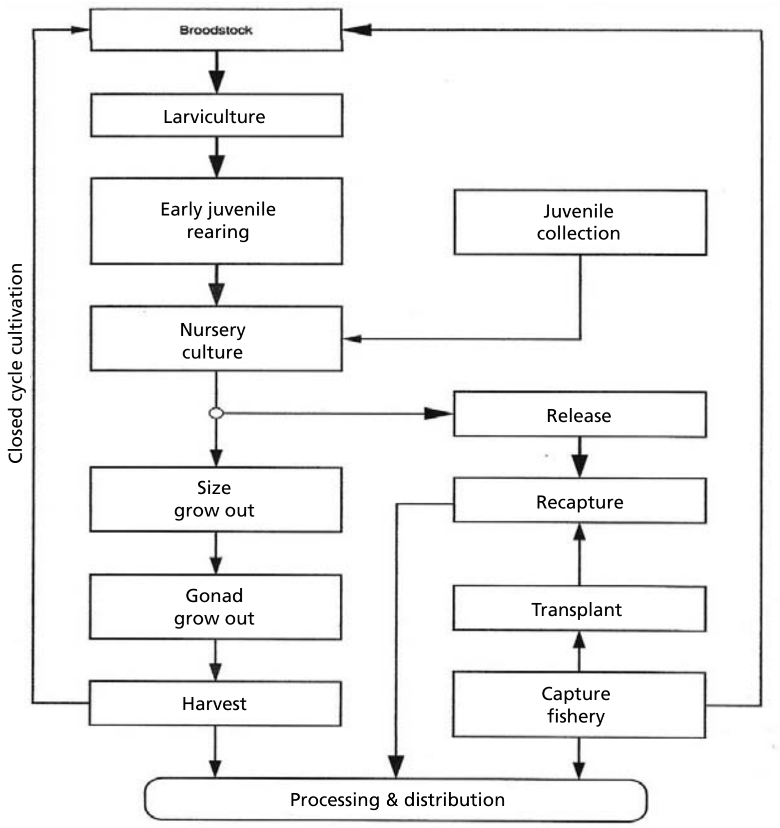
INTRODUCTION

Echinoderm culture refers to the cultivation of both sea urchins (Echinoidea) and to a lesser extent sea cucumbers (Holothuroidae) – sea urchins are more valuable and more widely marketed than sea cucumbers. The sea egg, *Tripneustes ventricosus*, is widely harvested throughout the Lesser Antilles and is restricted from harvest in several countries (Pena *et al.*, 2010). The variegated sea urchin, *Lytechinus* sp., is also harvested and exported to Japan and other Asian countries where its roe (“uni”) is highly valued.

Echinoderms, particularly sea urchins, also occupy an important ecological niche in tropical coral reef environments. As benthic grazers of macroalgae, they mitigate the proliferation of fouling algae that occurs as nutrient loading increases (eutrophication) due to anthropogenic pollution. It was the *Diadema antillarum*, or lime urchin, that grazed algae from the reefs and maintained the clean rock substrates that allowed corals, *Diadema* and other invertebrates to settle and grow and maintained the ecological balance of a healthy coral reef. In 1983, a pandemic disease of unknown origin decimated *Diadema* populations throughout its range with subsequent negative impacts on coral reef health.

Two species of sea urchins under consideration as target species for culture are high value seafood commodities that have been heavily exploited, and the third species (*Diadema*) is a demonstrated keystone species for Caribbean coral reef habitats. Sea urchin culture is a well-established industry in Japan, the People’s Republic of China and other Asian countries, Australia, New Zealand, Scandinavia, the United Kingdom of Great Britain and Northern Ireland, and Canada (Pearce, 2010). In most cases sea urchin cultivation is based on spawning of wild broodstock, with the availability of mature sea urchins restricted to the annual spawning season once or perhaps twice a year (Figure 1). Nonetheless, the largest sea urchin nursery in Japan, located in southeastern Hokkaido, obtains broodstock from source populations twice annually (spring and fall) to produce over 11 million juvenile *Strongylocentrous intermedius* per year (Saito, 1992). The factors that control reproductive maturation have been established for a few species and spawning is usually possible with well-fed broodstock cultivated in warm water and in darkness.

FIGURE 1
Principal sea urchin cultivation techniques

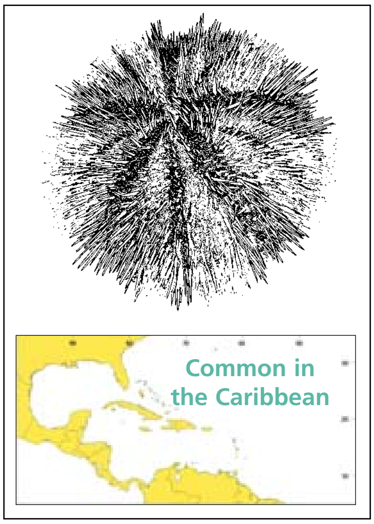


Source: from Hagan, 2000.

Mature sea urchins are induced to spawn by air exposure for two hours followed by injecting 1–2 ml of a 0.53 M KCl solution into the coelom (Liu, Zhu and Kelly, 2010). After mixing the gametes, excess sperm is rinsed off, and the fertilized eggs hatch after approximately 20 hours. After three to four days, the pluteus larvae require phytoplankton and are usually fed a combination of the diatom *Chaetoceros gracilis* and the green flagellate *Dunaliella tertiolecta* at a density of 5 000 cells/ml and increased to 50 000 cells/ml for late stage larvae (Strathmann, 1987; Chang and Gao, 2004). Continuous flow systems are employed, initially at 15 percent exchange/day, increasing to 100 percent daily exchange at time of settlement (16–30 days post-fertilization). Initial larval density is approximately 2 larvae/ml, but decreases to 0.8 ml at the time of settlement (Saito *et al*., 1985).

Settlement is induced by introducing plates covered with benthic algae, primarily diatoms that are cultured in tanks supplied nutrient enrichment similar to that used for phytoplankton culture for the larvae. The benthic algae is a primary food source until the juveniles reach 3–4 mm test diameter, at which time they are provided soft macroalgae such as *Ulva* spp. After a few months when the juveniles have grown to 7–10 mm test diameter, they can be placed in floating cages and provided a natural diet, fed commercially available formulated feeds, or released into the environment for restocking. Some months of additional nursery cultivation produces larger juveniles (15–20 mm test diameter) and result in higher survival at recapture, 16–40 percent has been reported (Saito, 1992). *Tripneustes gratilla* reared in a hatchery in the Philippines reached sexual maturity in six to seven months; natural mortality exceeded 90 percent in unprotected sites, but survival improved to 60–87 percent in seagrass cages. It is widely viewed that the hatchery-reared urchins, provided predation control, played a significant role in the recovery of this recruitment-limited fishery (Juinio-Meñez, Macawaris and Bangi, 1998).

Closed-cycle cultivation of sea urchins is being conducted in several countries with temperate climates and cooler water temperatures, but it is capital intensive and has high operational costs. Closed-cycle cultivation, however, may offer the opportunity for growth acceleration, improved survivorship and gonadal indices through systematic broodstock selection and breeding. Currently, development of hatchery production of juvenile sea urchins for fishery enhancement appears to be the best first step. Scheibling and Mladenov (1987) spoke to this in the Marine Fisheries Review...... "An alternative approach [in addition to fisheries management programmes] would be to artificially enhance *T. ventricosus* recruitment by aquaculture techniques. Larvae and early juvenile stages could be reared in the laboratory, and juveniles could be released in large numbers in selected natural habitats or protective enclosures in the field (e.g. cages or rafts). Techniques for rearing *T. ventricosus* larvae are being developed, and juveniles have been grown in the laboratory and in field enclosures on a variety of algal foods. Moreover, fishermen claim to have successfully restocked areas by transplanting breeding adults. Therefore, in our view, artificial stock enhancement through aquaculture presents a feasible and promising means of rehabilitating the fishery in areas where pollution and food supply are not limiting factors." (Scheibling and Mladenov, 1987).



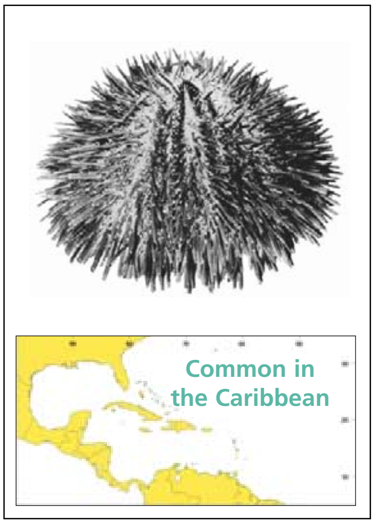
CLASS ECHINOIDAE – Sea urchins

Tripnuestes ventricosus

FAO names: **En**: Sea egg; **Fr**: Oeuf de la mer; **Sp**: Erizo de mar

Size: To 130 mm test diameter

Distribution/habitat: Uncommon throughout much of the Caribbean from US Virgin Islands, Puerto Rico, and Jamaica to the Bolivarian Republic of Venezuela; most common in the Lesser Antilles, Saint Lucia, Barbados, Grenadines (Figure 2). Lives on coral rubble, rocky areas, or sand near *T. testudinum* beds between depths of 2 and 5 m. Heavily exploited and now protected through much of the island of the eastern Caribbean.



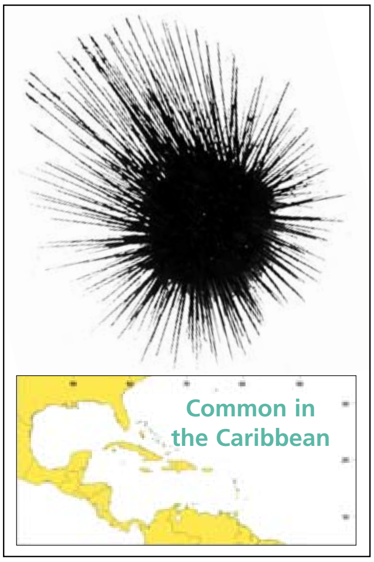
Lytechinus variegates

FAO names: **En**: Variegated sea urchin; **Fr**: Oursins de mer panachés; **Sp**: Erizo de mar variegado

Size: To 80 mm test diameter

Distribution/habitat: North Carolina (USA) and Bermuda to Santos Brazil (Figure 3). Although it may occur on rocky bottoms or open sand, it is most commonly associated with seagrass beds (*T. testudinum*, *Halimeda* spp. and *Cymadacea manatarum*) at depths of low water to depths of 2 to 3 m. This sea urchin tends to attach shell and debris to its test, a behaviour termed "masking", which is pronounced during high illumination, is associated with clustering within denser seagrass beds, presumably for predator avoidance.

Larviculture: The variegated sea urchin is a protandrous hermaphrodite that becomes reproductively active at approximately one year of age and a test diameter of around 40 mm. Reproductive output increases exponentially as the urchins grow, with a decline in fecundity at the larger sizes (75–80 mm test diameter).



Diadema antillarum

FAO names: **En**: Long-spined sea urchin

Size: To 40 mm test diameter

Distribution/habitat: North Carolina (USA) and Bermuda throughout the Caribbean (Figure 4). These urchins have no commercial importance, and their presence on the reefs was usually viewed as detrimental since their long sharp spines often caused injuries to SCUBA divers and complicated the activities of lobster divers. Once they were gone, however, and algae and coral disease decimated the reefs, it seems that only the reef ecologists have connected the loss of this keystone herbivore with the rapid decline of the tropical western Atlantic coral reefs.

Larviculture: Larviculture of *D. antillarum* has been successful at several laboratories (e.g. Mote Marine Laboratory, USA) utilizing techniques described in this paper. Metamorphosis occurred in approximately 30 days at densities of 0.5–1 larvae/ml. Transition to a post-larval benthic stage required an average of seven days with over 50 percent survival (Leber *et al.*, 2008).

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Hatchery design considerations

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ABSTRACT

The layout of hatcheries varies from site to site, with species produced, geographic location and available funds. Considerations taken for the design of a regional molluscan hatchery are outlined and include the two basic parts of such a facility: the seawater system and the physical plant. Volume and quality of seawater supply required defines the size of pumps and diameters of pipes used. All surfaces coming into contact with seawater need to be non-toxic. A hatchery needs to have the capacity to: 1) filter parts of its system to 1µm; 2) have access to ultra violet (UV) sterilized seawater; and 3) control water temperature – chilling and/or heating – for selected parts. There are several seawater systems used in hatcheries: 1) open flow-through systems; 2) recirculating or semi-recirculating systems; and 3) storing systems. Discharge of the effluent should be controlled, especially for a regional hatchery importing broodstock from various populations across a wide geographical area. The physical plant should be designed for efficiency and flexibility, allowing the production of a range of molluscan species. It should consist of: 1) an algal culture room; 2) a broodstock quarantine area; 3) a broodstock conditioning and spawning area; 4) a larval rearing unit; 5) a post-larval rearing unit; 6) a juvenile culture unit; 7) a dry laboratory; and 8) a storage area. Various areas of the hatchery should have the capacity to operate independently and be isolated in the event of disease outbreak.

RESUMEN

El diseño de un criadero varía de un sitio a otro dependiendo de las especies producidas, ubicación geográfica y los fondos disponibles. Se describen las consideraciones adoptadas para el diseño de un criadero de moluscos regional y se incluyen las dos partes básicas de una instalación: el sistema de agua de mar y la planta física. El volumen y calidad del suministro de agua de mar requerida define el tamaño de las bombas y diámetro de las tuberías a utilizar. Todas las superficies que entren en contacto con el agua del mar no deben ser tóxicas. Un criadero debe tener la capacidad de: 1) filtrar partículas del sistema a 1 µm; 2) tener acceso a agua de mar esterilizada con luz ultravioleta (UV); y 3) controlar la temperatura del agua mediante refrigeración o calefacción para las áreas seleccionadas. Hay varios sistemas de agua de mar utilizados en un criadero: 1) sistemas de flujo abierto, 2) sistemas de recirculación o semi-recirculación; y 3) sistemas de almacenamiento. La descarga de los efluentes debe ser controlada, especialmente para un criadero regional que importará reproductores de diversas poblaciones desde una extensa área geográfica. La planta física debe estar diseñada con eficiencia y flexibilidad, de manera tal que permita la producción de una amplia gama de especies de moluscos. Esta planta deberá consistir en: 1) una sala de cultivo de algas; 2) un área de cuarentena para reproductores; 3) un área de acondicionamiento de reproductores y desove; 4) una unidad de cultivo larvario; 5) una unidad de levante de postlarvas; 6) una unidad de cultivo de organismos juveniles; 7) un laboratorio seco; y 8) un área de almacenamiento. Las diversas áreas del criadero deberán tener la capacidad para operar de forma independiente y aislada en caso de brote de una enfermedad.

INTRODUCTION

There is no rigid design for a shellfish hatchery. The layout of hatcheries varies from site to site, with species produced, geographic location and available funds. In order to avoid limitations and problems in the long-term, careful thought needs to be given to the design of the hatchery, based on well-defined long-term goals. The end result should be an efficient facility with the capacity to be flexible, allowing for changes in culture techniques and species produced. Most importantly, the design must allow for thorough cleaning of all areas and part of the system and for isolating culture areas for the various life stages is valuable in the event of disease outbreak. Good husbandry and management of stock is essential to the success of an aquaculture operation. This paper provides a broad outline of the considerations to be taken when designing a regional shellfish hatchery and summarizes the requirements for such a facility. Further details are available in two FAO technical papers, written by Sarkis and Lovatelli (2007) and Helm, Bourne and Lovatelli (2004).

HATCHERY ACTIVITIES

In order to design an efficient hatchery, it is advisable to have both short-term and long-term activities of the facility well-defined. A full hatchery cycle will consist of spawning adults under controlled conditions and rearing larvae until such time that they can be transferred to the natural environment. The size and timing at which the latter occurs varies from remote setting of mature eyed-larvae for bivalves (at least 14 days old), to the grow-out of settled juveniles or spat (at least ten days after settling or 30-days old).

The hatchery cycle is usually short relative to the grow-out phase; however, rearing larvae or young juveniles is very labour intensive, requiring technical skills, excellent husbandry protocols, and a basic understanding of the biology of the species, thus providing optimal conditions for rearing particularly in terms of water quality and nutrition.

HATCHERY COMPONENTS

There are essentially two basic parts to a bivalve hatchery: i) the seawater system; and ii) the physical plant.

Seawater system

One of the most important criteria for an efficient and productive hatchery is the access to high quality seawater. The volume of seawater supplied and the level of treatment (filtration and temperature control) is dependent on the scale of the operation and the target species produced. This defines the size of pumps and the diameter of pipes required. All materials should be selected to ensure that surfaces coming into contact with seawater are non toxic; these include most plastics, cast iron and certain grades of stainless steel. All piping must be non-toxic, usually PVC (polyvinylchloride). The diameter of the pipes depends on water demand. In most hatcheries the main distribution lines within the hatchery are 50 mm (4”) diameter or less, although the main intake pipes may be up to 150 mm (6") diameter. Cleanliness throughout the system is critical to successful hatchery production, and thought must be given to ease of cleaning during piping installation; clean-out ports and/or unions should be located at critical points throughout the line for ease of flushing and dismantling.

Selection of the intake requires an analysis of the seawater and if an accurate assessment of the seasonal fluctuations is not possible, a good understanding is required. The equivalent of a roof drain filter should be adapted to the intake pipe, in order to avoid large animals – i.e. fish – from entering the pipe. It is advisable to install a secondary intake system in the event of clogging and/or pump failure. Seawater pumped directly from the ocean is first passed through sand filters that filter out most particulate material greater than 40 µm in size potentially fouling pipes and inhibiting larval rearing; Jacuzzi and swimming pool filters are commonly used for this first coarse filtration. Routine backwash is necessary to optimize the efficiency of the sand filter. Finer filtration (10–1 µm) is thereafter achieved through the in-line installation of cartridge or bag filters.

In-line UV (ultra-violet) or ozone sterilizing units are advisable as sterilized or disinfected seawater is required for the initial stages of algal culture, or if disease problems arise. Water must be filtered to about 1 µm prior to sterilization since UV-light is readily absorbed by particles in the water reducing the efficiency of the unit.

In most hatcheries, there needs to be the capability to heat and sometimes to chill part of the seawater supply whether it is for broodstock conditioning, increased rate of larval growth, post-larval acclimation to the natural environment, etc. The method of chilling or heating also depends on the volume of water to be treated and on the cost of electricity. For larger volumes of seawater, titanium heat exchangers or digitally controlled titanium heaters can be installed and treated seawater is pumped to the required areas. For smaller volumes, for example, as may be required for spawning induction, aquarium heaters immersed directly into the required tank, or independent chilling units may be sufficient.

There are several seawater systems which may be used in hatcheries:
Open flow-through systems – this ensures a continuous supply of well-oxygenated, filtered seawater throughout the hatchery; water is pumped in, passed through once and pumped out.

Recirculating or semi-recirculating systems – less costly than open systems, these systems are used for the entire facility if seawater is in short supply. However, a hatchery will often combine both open and semi-recirculating systems within the facility; where the latter are used for specific phases of growth, such as spat rearing. Recirculated water may be passed over biologically activated filters to remove metabolic wastes of the animals and held before it is reused. If the water has been heated or chilled it may be passed through heat exchangers to partially heat or chill incoming water and thus, reduce energy costs.

Storing system – some hatcheries pump filtered seawater to a storage tank, made of either concrete or fiberglass. Sufficient water is pumped into the storage tank so it can supply the hatchery until the tank can be refilled. The tank is located at height so that the effect of gravity maintains a sufficient water flow through the hatchery. Storage tanks are useful when water can only be obtained at a particular time, e.g. at high tide, or in areas where electrical power is unreliable to ensure a continuous supply of seawater.

For all seawater systems, discharge of the effluent must be considered carefully if broodstock are imported from other populations and countries. This is primarily to avoid the introduction of pathogens and diseases, as well as of exotic species to the natural environment. Government regulations of the country need to be reviewed and adhered to.

Physical plant

A hatchery consists of several areas which are inter-related. These are: i) an algal culture room; ii) broodstock quarantine; iii) broodstock conditioning and spawning; iv) larval rearing; v) post-larval rearing; vi) juvenile culture; vii) a dry laboratory; and viii) a storage area**.** Design of the physical plant should consider the sequence of operation for culture of the species; for example, a dry laboratory area should be in proximity to the algal room in order to facilitate the counting of algae for calculating food rations; similarly, counting of eggs during spawning is at times critical for successful cross-fertilization and requires a dry lab area (see schematic diagram in Creswell "Establishing operational protocols for a regional aquaculture facility" in this publication).

FIGURE 1
100 litre cylinders used in semi-continuous algal culture production

PHOTO: S. SARKIS

Algal culture facility – Hatcheries focusing on bivalve and gastropod production rely on the successful production of algae. An ideal algal culture facility will include: 1) a separate small room, or a temperature and light controlled chamber to maintain stock or master cultures of algae apart from the larger cultures; and 2) a main algal culture area for 4 litre, 20 litre and larger 100 litre cultures of algae. Temperature control (air conditioner), or ventilation, a bank of fluorescent lamps, air supply and carbon dioxide supply are required. Ideally, an adjacent room housing an autoclave for sterilizing seawater for medium and small cultures is installed. The size of the main algal culture area depends on the number of species being cultured and the amount of algae required. This area can occupy a substantial part of the hatchery.

Large scale algal culture has been well tested and well documented. It can be conducted as batch culture, using 3–4 m diameter, 2 m deep tanks, or as semi-continuous in 100 litre cylinders (Figure 1). Temperature in the algae room is maintained between 15 and 20 °C, dependent on the algal species cultured.

In many hatcheries, considerable portions of the algae, if not all, are raised in greenhouses. These can be stand-alone structures or attached to one side of the hatchery, receiving as much sunlight as possible. The size of the greenhouse depends on the method of culture and quantities of algae that need to be produced.

Broodstock quarantine – In the case of a regional facility, where a number of cultured species will not originate locally, it is primordial that installation of a quarantine facility is planned to ensure that pests, parasites and diseases are not introduced with the exotic species or larvae accidentally escape into the natural environment. This will require a separate drainage system in the area of the hatchery designated for quarantine that empties into special holding tanks where the effluent can be sterilized with a strong hypochlorite solution. The sterilized water can be treated before discharged back into the environment (e.g. using ozone for large volumes and sodium thiosulphate for small volumes) to neutralize any residual chlorine before it is discharged back into the environment. Quarantine facilities may require a separate room to hold condition and spawn adults. Drains from this room will also empty into the quarantine treatment tanks.

Broodstock holding and spawning area – The amount of space needed to hold and condition broodstock, depends in part on the number of species being held and whether some or most of the conditioning will be undertaken in the open environment rather than in the hatchery. Heated or chilled seawater may be required for this aspect of operation at certain times of the year. The ability to isolate tanks so that photoperiod can be adjusted is desirable since it has been shown that varying periods of light and dark can affect gonadal maturation.

Larval culture area – The larval rearing facility is a major component of the hatchery; its size is not only dependent on the scale of production, but on the culture requirements of the species (such as optimum larval density in culture tanks), duration of larval life and spawning frequency. Species with a more rapid turnover, attaining settlement in a shorter time, may be cultured in a smaller larval facility than those with a longer larval life, reared at lower densities, if the same scale of production wants to be achieved.

Optimal culture density varies greatly for bivalve larvae. Pectinid scallop species usually grow best at low densities (starting at 10 larvae/ml for Day-2 larvae, and finishing at 1 larva/ml for pediveligers); where oyster larvae in general fare well at high densities. Traditionally, larvae are reared in closed systems, where water is changed every other day; flow-through systems have been tested and yield good results for certain species (see Sarkis, Helm and Hohn, 2006 for *A. gibbus* culture in flow-through). Size of larval tanks required are dependent on optimal density range for species, and type of culture, ranging from 200 litre conical tanks for flow-through systems to 50 000 litre for static systems.

FIGURE 2
Typical fiberglass larval tanks

PHOTO: S. SARKIS

Larval rearing tanks are generally made of fibreglass or of a suitable plastic and should be thoroughly leached prior to use (Figure 2). Regardless of the size of tanks used, there should be large sunken floor drains to handle large volumes of water when the tanks are drained. A preparation area in the larvae culture room is required for washing, grading, counting and measuring larvae and for accommodating the equipment used for these purposes. This area requires cupboards and shelves for the storage of equipment when not in use.

Post-larvae and juvenile culture area – This “nursery” area may accommodate both larval settlement phase and rearing of post-larvae to young juvenile size (or “spat”). Settlement of larvae may be conducted in various ways dependent on the species’ requirements; settlement may occur in round fiberglass tanks similar to larval tanks or in raceways.

Spat may be reared under controlled conditions in a variety of systems, such as upwellers, downwellers, tray systems or raceways until they exceed 2 mm shell length. At this point, they are usually transferred to the natural environment, as the rearing of larger juveniles is found to be uneconomic due mainly to increased food and space requirements. The size of transfer at sea is dependent on the species; methods have been investigated and well tested for scallop species, as well as for the transfer of eyed pediveligers (pre-settlement) from the hatchery to remote sites for the Pacific oyster (Henderson, 1982; Sarkis and Lovatelli, 2007).

Other space requirements – The dry laboratory is where master algal transfers can be made, chemicals weighed and mixed, microscopes kept for examining cultures, samples collected for the assessment of reproductive status, larval and post-larval growth, and all others required for monitoring of cultured animals, records maintained and scientific equipment stored.

Static machinery such as the main pumps, sand filters and pre-filters (to remove particles down to 10 µm), seawater heating/chilling units, furnaces, the air ventilation system, air blowers/compressors, a standby generator for emergency power supply, together with electrical panels and control equipment, are housed in a sound proof machinery room. Duplication of essential equipment is preferred in the event of electrical or mechanical failure. Compressed air is required in all phases of culture and carbon dioxide is required for algal culture. In many hatcheries the seawater intake pumps and sand filters are located in a separate pump house close to the point of intake and the final filtration of seawater may take place at the point of use rather than at a central, fine filtration unit.

Since storage is always an issue in a hatchery, it is useful to have a large general-purpose area that can be used for storing materials and equipment, packing seed and as a workshop. Most of the working areas should be fitted with benches and sinks. Access to freshwater at all points of the hatchery is necessary for cleaning.

In addition, as mentioned previously, it is always advantageous to have the capacity for outdoor holding tanks, and for suspending enclosures in the natural environment. This facilitates transfers of animals, holding of individuals in-between various phases of culture and for demonstration/training purposes.

Finally, assessing production level, product type and target species will guide the design of a cost-efficient hatchery.

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Establishing operational protocols for a regional aquaculture facility: encouraging industry development and sustained use through best management practices to ensure resource and environmental preservation

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ABSTRACT

The establishment of a regional shellfish aquaculture facility for the Caribbean provides a unique opportunity to stimulate nascent aquaculture industries and markets to further economic development, to bring scientists of the developed and developing countries together to advance the technology resulting from aquaculture research to the point of application as an economically viable industry, and to transfer the scientific, engineering and economic knowledge to local entrepreneurs. A regional aquaculture facility (RAF) concept embraces these opportunities, as well as challenges related to biogeographic, genetic and political boundaries. An aquaculture facility that receives wild harvested broodstock and distributes cultured seed stock will be under regulatory and public scrutiny that will require the development, adoption and promotion of best management practices (BMP) or environmental codes of practice. This paper is intended to identify important environmental considerations of shellfish hatchery operations (i.e. molluscs, crustaceans and echinoderms) on the environment and to provide background information and guidance to hatchery staff and clients so that they can utilize BMP in their activities. Attentive detail to these practices will serve to minimize potential negative effects to the environment while maximizing the positive environmental effects associated with shellfish culture and enhancement. The author recommends that the Caribbean regional aquaculture facility, from the outset, drafts a document that establishes and codifies protocols for BMP that address the requirements for all stakeholder participants.

Additionally, a training programme for shellfish culturists from stakeholder countries should be implemented to ensure proper transport and handling of broodstock and seed stock and as a means to transfer hatchery technology for establishment of, if desirable, satellite facilities in participating countries.

RESUMEN

El establecimiento de un centro regional de acuicultura de mariscos para el Caribe, ofrece una oportunidad única para estimular un mayor desarrollo económico en la emergente industria acuícola y de mercados; para que los científicos de los países desarrollados y en vías de desarrollo coadyuven en el avance de tecnologías resultantes de investigaciones acuícolas hasta el punto de lograr su aplicación en una industria económicamente viable; así como para transferir conocimientos en temas de ingeniería, económicos y científicos a los empresarios locales. El concepto de un centro regional de acuicultura abarca estas oportunidades, así como los desafíos relacionados con límites biogeográficos, genéticos y políticos. Una instalación de acuicultura que reciba reproductores de origen silvestre y distribuya semilla producida en laboratorio estará bajo el escrutinio público y de los entes normativos, por lo que requerirá el desarrollo, la adopción y la promoción de buenas prácticas de manejo (BPM) o códigos de práctica ambiental. Este documento tiene la intención de identificar consideraciones ambientales importantes en las operaciones de un criadero de mariscos (moluscos, crustáceos y equinodermos) y proporcionar información de referencia y orientación para el personal del criadero, así como para los clientes para que puedan utilizar BPM en sus actividades. La atención en detalle a estas prácticas servirá para reducir al mínimo los efectos negativos al medio ambiente y elevar los efectos positivos asociados al cultivo de mariscos y su intensificación. El autor aconseja que el Centro Regional de Acuicultura para el Caribe, desde su inicio establezca y codifique protocolos para BPM y que cumplan los requerimientos de todos los países involucrados. Además, se debe implementar un programa de formación para cultivadores de mariscos de los países interesados con el objetivo de garantizar prácticas adecuadas en el transporte, manejo de reproductores y semilla así como ser un medio para la transferencia de tecnología del criadero, por si se considera establecer instalaciones satélites en los países participantes.

INTRODUCTION

An aquaculture facility that receives wild harvested broodstock and distributes cultured seed stock will be under regulatory and public scrutiny that is exacerbated by international transport and a host of agencies with different oversight responsibilities (e.g. customs, fisheries, environmental protection, agriculture); additionally, each require compliance with their specific regulatory instruments. The development, adoption and promotion of best management practices (environmental codes of practice) should provide the operational protocols for a regional shellfish aquaculture facility (PCSGA, 2002; FDACS, 2007; Creswell and McNevin, 2008). This document has identified six separate categories for consideration (Leavitt, 2004):

1. site selection;
2. water supply and discharge;
3. hatchery equipment requirements;
4. bio-secure hatchery facility requirements;
5. disease control and transfer prevention; and
6. regional transport and certification issues.

Development and construction of a regional shellfish aquaculture hatchery facility (RAF) will require thoughtful planning that addresses the environmental concerns of the host country, as well as each stakeholder nation that will take advantage of this aquaculture production facility. It will be incumbent upon the planners to develop production and transport protocols that will comply with all environmental regulatory requirements and ensure users that seed stock from the facility is consistent with their expectations with respect to product quality and documentation.

Public perception related to the environmental impact of shellfish culture includes a desire to maintain the genetic integrity of wild populations of shellfish, avoid the introduction of undesirable species and the potential public health risks associated with shellfish consumption. With respect to farming shellfish in public waters, concerns focus on displacement of benthic aquatic vegetation, discarded nets and equipment, displeasing aesthetics associated with plot markers and working vessels/platforms, and increasing turbidity and disruption of sediments during harvesting. In contrast, there also is public recognition of the positive effects of shellfish aquaculture through water quality enhancement and its role as essential habitat for other important marine species, such as nursery grounds for commercially harvested fish. The support for a Caribbean regional shellfish aquaculture facility, and the activities that will proliferate from its operation, will be firmly based on public perception of its societal and economic benefits and its environmental sustainability.

It should be a fundamental premise that the RAF will comply with all laws and permit requirements which apply to their operations and location, as well as required statutes from donor/recipient countries. These include:

- Ensure that the RAF operations meet or exceed regulatory and environmental standards; keep current on all rules, regulations, certification and permit requirements governing shellfish aquaculture operations.
- Incorporate environmental policies into employee training and orientation.
- Become involved in local watershed and water quality improvement activities of stakeholders and support legislation and regulatory policies that promote environmental protection, especially water quality.

SITE SELECTION

Appropriate environmental conditions that ensure high-quality seawater are critical in determining the site location for a shellfish hatchery. Best management practices dictate that the site has minimal environmental and social impacts, and economic considerations, such as labour and utility costs, and distance from international transport, should be evaluated. These include:

- Water exchange and tidal currents at the RAF site should be sufficient to provide an adequate supply of high quality seawater, including appropriate depth, salinity, oxygen and water flow characteristics.
- Pumping, intake and discharge systems must be designed to avoid current-borne sedimentation, scouring, turbidity or any other damaging impacts on the surrounding habitat.
- Avoid sites with submerged aquatic vegetation and minimize erosion during construction;
- The RAF should be located so as to minimize environmental impacts, risks to public health, should not present an impediment to navigation and is aesthetically consistent with adjacent properties.
- The facility should have easy public access and within reasonable transport distance to international air and land transport services.

WATER SUPPLY AND DISCHARGE

The aquaculture facility will require a primary salt water source, as well as a freshwater source for cleaning and to provide makeup water lost to evaporation or percolation. This water source can exist as saltwater intakes, ground wells or surface waters. Well water is a desirable water source because it is virtually free from bacterial, viral or parasitic pathogens. However, the water may have some undesirable chemical characteristics such as high hydrogen sulphide, carbon dioxide and ammonia and most likely be low in oxygen.

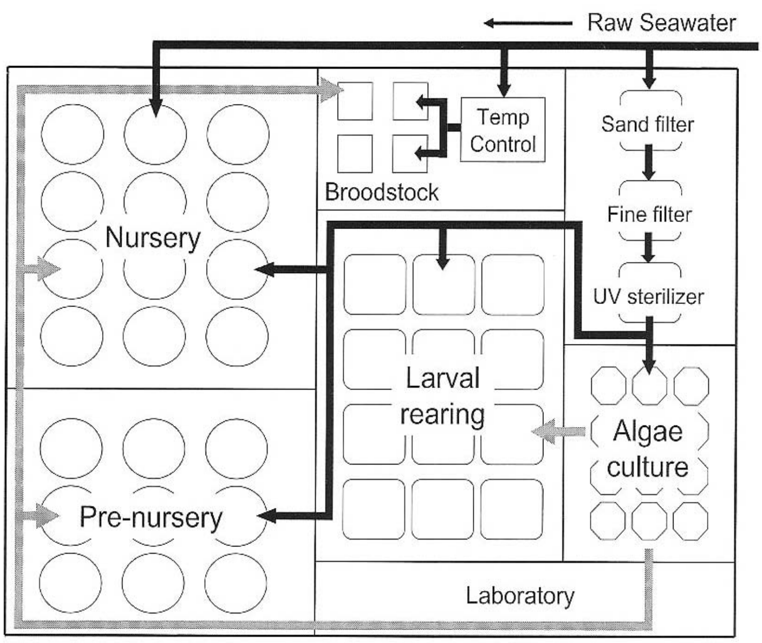
- The RAF should comply with all regulations and permitted water use criteria by the host government. A water or consumptive use permit may be required for a user to withdraw a specified amount of water from either a groundwater well or from an allowable surface water source.
- Water intake systems must be designed to avoid current-borne sedimentation, scouring, turbidity or any other damaging impacts on the surrounding habitat. They should not interfere with navigation and should be aesthetically benign.
- There should be no direct off-site discharge of production water. Saline water should not be discharged into freshwater environments (including well injection).
- Effluents must be treated and retained on-site or discharged to a permitted sanitary sewer system. Retention of all production unit effluent on site is considered proper management of effluent. In certain locations, where the soil is highly porous allowing for water infiltration, a treatment pond may be constructed to hold all required discharge and allow for percolation. The volume of the pond is determined by the expected quantity of discharge and the evaporation and percolation rate of the soil.

HATCHERY EQUIPMENT REQUIREMENTS

Although shellfish hatcheries are quite varied in size and design, they all share several key production components. These include a seawater source and pre-treatment system, and in the case of a bio-secure facility, will require isolated, recirculating systems, and effluent water treatment (Van Wyk *et al*., 1999). A phytoplankton (and perhaps zooplankton) culture area will also be required (Figure 1). A general list of these system components include:

- Pumps – Centrifugal, submersible, peristaltic.
- Fibreglass larviculture tanks (conical), settling troughs (upwelling systems), raceway.

FIGURE 1
A general schematic of a shellfish hatchery



- Sieves (various mesh sizes), artificial substrates.
- Plumbing supplies, standpipes and drain structures.
- Solids filtration – Sedimentation tanks, hydroclones, tube settlers, micro-screen filters, bead filters, sand filters, foam fractionators, ozone.
- Disinfection – Ultraviolet sterilization, ozonation, autoclaving, pasteurization, chlorination.
- Biofiltration – Submerged biofilters, trickling biofilters, rotating biological contactors, bead filters, sand filters, fluidized bed biofilters.
- Aeration – Regenerative blowers, venturi valves.
- Lighting – Fluorescent, metal halide, mercury vapour (phytoplankton culture).
- Illuminated, temperature controlled phytoplankton stock culture room and algae production tubes.

BIO-SECURE HATCHERY FACILITY REQUIREMENTS

Hatchery production of invertebrates (molluscs, crustaceans and echinoderms) may have fundamental differences in their larval development, environmental requirements, and dietary needs, but none of them change most of the basic hatchery facility requirements – other than perhaps the floor plan. However, the proposed RAF, by definition, will be culturing different species, from different locations and perhaps (if not likely) genetically distinct populations. Therefore, the facility will need to be designed as a bio-secure hatchery (not unlike a medical facility). Broodstock holding tanks, larviculture systems and nursery facilities should be separate and isolated from each other to minimize the likelihood of cross-contamination. The scope and complexity of the facility design will be a function of the number of species to be cultured and their biogeographic distribution. The basic requirements will include:

- A state-of-the-art phytoplankton culture that includes a temperature-controlled stock culture room and both indoor and greenhouse phytoplankton production culture facilities;
- A wet/dry laboratory equipped for microbiological analysis sufficient for culture assays, disease diagnosis and certification of seed stock in preparation for export.
- Broodstock shellfish should be handled in quarantine. Upon delivery they should be separated from all other stock in a separate holding facility, cleaned and transferred to a holding system isolated from others. All shipping materials should be immediately removed from the RAF and equipment, utensils and laboratory ware should be disinfected.
- The RAF larviculture systems should be of a modular design that precludes any transfer of veligers, bacteria or other contaminants from one culture unit to another. Although the water source and pre-treatment systems can serve the entire facility, each culture module – the tanks, sieves, containers, glassware, cleaning supplies, water-exchange containers, etc., should be specific to each module and not comingled with others.
- The RAF, as a bio-secure, quarantined facility should require either zero-discharge or extensive effluent treatment (e.g. ozonation, chlorination) prior to release into a holding reservoir.

DISEASE CONTROL AND TRANSFER PREVENTION

Over the past decades, the shellfish industry has experienced major disease outbreaks that have had significant adverse impacts on environmental quality, the value of natural resources and the economics of coastal communities. Diseases might be the result of genetic defects in the stock or infectious pathogens that prevail under stressful environmental conditions. Most genetic diseases can be avoided through broodstock selection practices, while pathogenic conditions are usually related to poor water quality, nutritional deficiencies, overcrowding or inappropriate handling procedures.

Therapeutic agents for disease control in the hatchery should be used as a last resort. Good housekeeping procedures, such as routine cleaning and sanitation of all hatchery components, are critical to maintaining quality production.

- Adhere to regulations regarding importation of broodstock or exportation of seed stock.
- Isolate the culture facility from sources of infection.
- Minimize stress through good husbandry practices.
- Prohibit wet-storage activities.
- Maintain good records and utilize them to identify potential problems when animal behaviour, poor growth or mortality exceeds pre-established limits.
- If pathogens are identified as a source of mortality in larviculture, infected animals should be moved to other areas of the facility and quarantined or discarded.
- Minimize drug and therapeutic use for disease control.

REGIONAL TRANSPORT AND CERTIFICATION ISSUES

Receiving broodstock from other countries will require a clearly defined protocol for delivery through custom authorities, as well as the appropriate agency for agriculture/fisheries/natural resources. In order to maintain the bio-security and genetic integrity of the RAF programme, a primary focus of operational protocol should be well-documented information regarding the source of broodstock, as well as all customs clearances and other required agriculture and/or environmental paperwork from the country of origin. Similarly, seed stock produced at the RAF and exported should be well documented for international transport, including health certification, customs documentation and any recipient country requirements.

- Every delivery of shell stock should have an aquaculture certificate or registration number which tracts the commodity from the point of origin that is clearly identified by tags or labels that are securely attached and clearly displayed on transport containers.
- Carefully inspect all shellfish broodstock and remove non-target species. Assure that all non-local organisms are non-viable when disposed.
- Properly quarantine or dispose of infected stock and contaminated materials.
- Do not store non-local shellfish or non-native aquatic species where there is potential for escapement into local waters (wet storage).
- Maintain detailed records of broodstock arrivals and seed stock departures. Detailed records of stock growth and survival at all stages of the production cycle, logged daily and evaluated frequently, can alert the culturist to imminent problems related to the spread of pathogens and activate further examination and immediate corrective action.
- Shellfish products shipped from the RAF should be certified by a licensed veterinarian that the stock is free of any clinical signs of disease pathogens that may pose a threat to natural shellfish populations.

CONCLUSIONS

The establishment of a regional shellfish aquaculture facility (RAF) for the Caribbean will be an evolving process, beginning with the current gathering of interested parties from throughout the islands of the Caribbean and Latin America. The objective of this paper is to provide an outline of general principles that should be considered to realize this goal. The site selection, facility design and size and a host of operational protocols will be thoughtfully determined based upon the interest and input of the stakeholders assembled at this Workshop.

Clearly, a regional approach to shellfish aquaculture development in the Caribbean can be facilitated by a centrally located production hatchery with the infrastructure, engineering and equipment and scientific expertise to provide seed stock and the technology transfer to further a successful aquaculture industry. As importantly, this facility should provide technical training and outreach to transfer the scientific, engineering and economic knowledge to local entrepreneurs and to provide continuing resources for the solution of problems and the improvement of aquaculture methods.

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Cultivation of bivalve molluscs in Venezuela: diversity, potential and infrastructure for seed production

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ABSTRACT

Aquaculture has become one of the most profitable agricultural businesses in the Bolivarian Republic of Venezuela with a global yearly production exceeding 14 000 tonnes. Bivalve culture is considered a potential industry for mass production of marine products, particularly in the northeastern region where upwelling promotes a high primary production in coastal waters. Aquaculture in the country began in the late 1930s following the introduction of the rainbow trout, *Oncorhynchus mykiss,* in the Andes. Marine shrimp culture started in 1987 and since then has grown to more than 30 businesses with a production close to 10 500 tonnes in 2009. Bivalve aquaculture began in the 1970s in the eastern region of the country with the involvement of few companies and a production estimated around 200–300 tonnes of oysters (*Crassostrea rhizophorae* and *Crassostrea virginica*) and the South American rock mussel (*Perna perna*). This latter subsector of the industry has been facing diverse problems related to seed availability, red tides and market issues. Numerous other molluscan species have been identified as potential candidates for aquaculture. The green mussel, *Perna viridis*, and the pearl oysters, *Pteria colymbus* and *Pinctada imbricata* (both for meat and pearl production) show acceptable natural seed abundance, as well as high growth and survival rates under culture conditions. The commercial hatchery production of scallops seed, *Euvola ziczac* and *Nodipecten nodosus*, has been demonstrated along with their culture techniques. The farming of these two scallop species (as well as of *Crassostrea rhizophorae*) could also contribute to the maintenance of wild populations since most natural banks have been overexploited. Several national institutions are involved in the promotion of bivalve aquaculture with coastal fisher communities. The use of the Turpialito Hydrobiological Station, with its 5 300 m^2 of infrastructure, is proposed as the regional hatchery site for large scale production and distribution of bivalve seed to the Greater Caribbean Region.

RESUMEN

La acuicultura se ha convertido en una de las actividades agrícolas con mayor rendimiento en la República Bolivariana de Venezuela, con una producción anual superior a 14 000 toneladas. Se considera al cultivo de bivalvos como una industria potencial para la producción masiva de productos marinos, particularmente en la región nororiental donde la surgencia promueve una alta producción primaria en las aguas costeras. La acuicultura en el país comenzó a finales de los años 30 luego que la trucha, *Oncorhynchus mykiss,* fue introducida en las tierras altas de los Andes, la cual aún persiste allí con significativos avances en la genética del cultivo. El cultivo del camarón marino comenzó en 1987 y desde entonces ha crecido hasta alcanzar más de 30 empresas con una producción anual cercana a 10 500 toneladas en 2009. La acuicultura de bivalvos comenzó en los años 70 en la región oriental en cuyo propósito se involucró un número reducido de empresas con una producción de 200–300 toneladas de ostras (*Crassostrea rhizophorae* y *Crassostrea virginica*) y un mejillón (*Perna perna*), pero confrontó diversos problemas relacionados con la disponibilidad de semillas, mareas rojas y mercadeo, y actualmente está siendo reconstruida. Se han identificado otras especies como candidatos potenciales para ser cultivados. El mejillón verde, *Perna viridis*, las ostras perlíferas, *Pteria colymbus* y *Pinctada imbricata* (tanto para consumo como para producción de perlas) muestran una abundancia aceptable de semillas en bancos naturales, así como altas tasas de crecimiento y sobrevivencia bajo condiciones de cultivo. Se ha demostrado la posibilidad de producir semillas comercialmente en laboratorios de las vieiras, *Euvola ziczac* y *Nodipecten nodosus*, así como sus técnicas de cultivo. El cultivo de estas dos especies de vieiras (y de la ostra *Crassostrea rhizophorae*) pudieran contribuir también al mantenimiento de las poblaciones naturales silvestres ya que la mayoría de los bancos naturales han sido sobreexplotados. Existe actualmente un programa permanente de monitoreo de PSP y bacterias en el agua de los principales bancos de extracción de moluscos bivalvos y áreas potenciales para la acuicultura. Diversas instituciones están actualmente asociadas a la promoción del cultivo de bivalvos entre las comunidades de pescadores en la costa. Se formula la propuesta del uso de la Estación Hidrobiológica de Turpialito, con 5 300 m^2 de infraestructura, como un laboratorio para la producción masiva de semillas de bivalvos que pudiera proveer semilla en la Región del Caribe.

AQUACULTURE DEVELOPMENT IN VENEZUELA – 70 YEARS OF EXPERIENCE

Aquaculture in the Bolivarian Republic of Venezuela, like in other countries of the Americas, may have been performed by indigenous people in coastal areas since ancient times. Ponds could form in coastal areas by wave action or as a consequence of tropical storms and hurricanes, still commonly observed in the Caribbean. These ponds fill with seawater along with planktonic larvae, which can grow to consumable size if conditions in the ponds last long enough to support biomass, and eventually harvested by local people. Such a process is common in the northeastern Bolivarian Republic of Venezuela, where shrimp and mullets can be observed growing under these conditions.

Commercial aquaculture started in 1937 with the introduction of the rainbow trout, *Oncorhynchus mykiss*, in the Andean high lands of the country (Martínez and Salaya, 1982). Yearly production in the last 20 years has ranged between 160 and 540 tonnes and seems to have stabilized around 230 tonnes during the last four years (INSOPESCA, 2010). Other introduced species are the Giant river prawn, *Macrobrachium rosembergii*; tilapias *Oreachromis niloticus* and *Oreachromis aureus*; and the Pacific white shrimps, *Litopenaeus vannamei* and *Litopenaeus stylirostris.* Culture of the Giant river prawn was initiated around 1984, reaching peak production of 25 tonnes in 1991; since then, farmers lost interest in this species, finding it difficult to compete with marine shrimp species. No production of this species has been reported since 1997. Similarly, the two species of tilapias introduced in 1989, reached a peak production of 2 298 tonnes in 1998, but declined to 46 tonnes by 2009. Since, a slight increase to 111 tonnes has been recorded.

Aquaculture of marine shrimps was initiated by farming the local white shrimp, *Litopenaeus schmitti* in 1986; however, reduction of growth rate for pellet-fed animals of 10 cm and above discouraged farmers in pursuing culture operations for this species and for the other four native penaeid species. By 1987, both *L. vannamei* and *L. stylirostris* had been successfully introduced and culture rapidly expanded, particularly for the former species; by 2004 production peaked at 23 000 tonnes, more than two-fold the landings of local marine shrimp species. Today, more than 30 businesses are involved in the cultivation of these species under semintensive or intensive farming conditions, encompassing more than 7 000 hectares of ponds. However, in 2005 the first problems as a result of the Taura syndrome, reduced production and in 2009 production dropped to 10 500 tonnes.

Development of tropical fish aquaculture has been slow, in spite of having resolved by 1975 major drawbacks with the reproduction of continental species held under laboratory conditions. Pacu, *Colossoma macropomum*, and a hybrid species (*C. macropomum* x *Piaractus brachipomum*) have been successfully grown in fish farms. Production has been growing since 2004 and reached 4 000 tonnes by 2009. However, market for these species is mainly in rural communities (i.e. away from mayor cities), limiting consumption volumes. Production of other freshwater species with a better market profile, such as coporo, *Prochilodus mariae*, is increasing, but numbers have remained low at approximating 44 tonnes in 2009. The initial goal of domesticating the large South American catfishes, like the barred sorubim, *Pseudoplatystoma fasciatum*, has been elusive as a result of cannibalism. The first steps towards a full commercial aquaculture production for marine finfish were made through the installation of a laboratory for large-scale juvenile production of the paguara (*Chaetodipterus faber*), as well as the development of several artisanal farms along the Gulf of Cariaco in the eastern Bolivarian Republic of Venezuela.

These examples show that aquaculture in general, and mariculture in particular, of native species has not successfully developed around the Caribbean Sea. Among the several factors associated with this situation, is the lack of in-depth studies to determine the biological and economic feasibility native marine species culture in the Region and the inadequacy in existing infrastructure for training and development of culture techniques.

With respect to bivalve molluscs, in the Bolivarian Republic of Venezuela there have been commercial experiences with the following three species: the brown mussel, *Perna perna*; the mangrove oyster, *Crassostrea rhizophorae*; and the American oyster, *Crassostrea virginica*. At present, efforts are focused on the development of culture techniques for *P. perna, P. viridis* (the green mussel) and *Pinctada imbricata* (the Atlantic pearl oyster) in collaboration with local fisher communities.

The Spanish heritage of mussel rearing

In the early 1970s, technicians in the Ministry of Agriculture and Livestock, previously employed as mussel growers in Galicia (the Kingdom of Spain), introduced mussel cultivation technique to the Bolivarian Republic of Venezuela. Seed material of 2–3 cm were collected from the rocky intertidal zones in the northern State of Sucre and induced to re-attach on artificial substrates (interlaced strings of rubber from old automobile tires); this was done by engulfing seed and substrate with rayon string. The cords, thus formed were suspended in the sea, from wood rafts fixed by poles hammered into the coastal substrate; cultures were left as such, for approximately ten months, when harvest size was attained. Competition on the market with wild mussels was not an issue during the closed fishing season for mussels (i.e. during the spawning period of the species) which lasted four months and enabled the selling of the farmed product. Toxic red tides episodes were occasional at the time, but have became a major problem since, which lead to the prohibition of selling shellfish products nationwide. The national market was reopened, once the levels of Paralytic Shellfish Poisoning toxin (PSP) became acceptably low in the harvesting areas. Since 1977, the National Institute of Agricultural Research conducts permanent seawater monitoring for red tides in the main bivalve extraction zones of the State of Sucre, including bacteriological counts since 2005 in order to certify water quality. These programmes provide a better platform for the culture and commerce of bivalve molluscs in the region.

Oysters

Rafts, similar to those used in mussel culture, were used for oysters with the spat settling directly on the rubber strings hanged from the rafts. Overfixing could become a problem and limited the growth size attained by the oysters. Other artificial substrates, such as clay tiles or discarded soft-drink plastic bottles were also used for spat collection. The plastic bottles had the advantage that small oysters could be easily detached by twisting the bottles causing less damage than when removing them from the tiles. The spat were then placed in plastic containers for grow-out in the natural environment, suspended from rafts or any other suitable structure, such as mangrove roots, until the commercial size was reached. Grow-out was generally attained in about 12 months for the mangrove oyster to six months for the America oyster.

The region where the American oyster thrives is located near the Orinoco river delta, an area with generally low seawater salinity and with a high suspended organic content. This reflects on the poor taste and high bacteria content of these oysters, compared to mangrove oysters grown in the high salinity and clear waters of the Caribbean Sea. Depuration of the American oyster was tested by keeping them under a high salinity and clean seawater environment for 12 to 24 hours. Volunteers were then used to test whether they could recognize the difference in taste between untreated mangrove oysters and depurated American oysters; the test showed no significant difference in taste between these two groups of oysters.

Predation by the snail, *Cymatium* spp. (Gastropoda: Ranellidae), was identified as a problem within the Gulf of Cariaco for *Crassostrea rhizophorae* grown in permanently submerged enclosures. This snail species entered the oyster enclosures as larvae, growing and predating within the nets and potentially causing 90 percent mortality of the oysters within two months (Núñez *et al.,* in press). However, the snail can be partly eliminated if the oyster containers are kept in the intertidal zone and become exposed to air during low tides. Exposure effectively kills the snail larvae, but not the adults. Oyster survival under this condition was higher than 90 percent.

HIGH DIVERSITY AND LOW BIOMASS

As a general rule, temperate regions are characterized by few species which, in terms of biomass, may reach high annual production. In contrast, tropical regions usually host a large variety of species with small abundance and low production per species, as can be observed within the general Caribbean Sea environment. Primary productivity in the latter zone and the Gulf of Mexico shows intermediate to low values. This pattern is interrupted in the vicinity of large rivers and along the path of their outflow (e.g. Orinoco, Amazon, Mississippi) and in coastal areas where upwelling brings nutrients to surface waters (as in the eastern and western Bolivarian Republic of Venezuela). These phenomena result in the presence of zones with very high primary production which hold major fisheries, particularly of filter feeders like bivalve molluscs and small pelagic fish (e.g. sardines).

In the Bolivarian Republic of Venezuela, fishery landings reached 219 000 tonnes in 2009, of which 27 percent were landed by the industrial sector (tuna and trawling vessels) and the rest by artisanal fishers. About 60 percent of the landings originate in the eastern region. A large portion of the landings is accounted for by filter feeders such as the ark shells (45 850 tonnes).

POTENTIAL FOR BIVALVE AQUACULTURE

The coastal geography of the eastern Bolivarian Republic of Venezuela, with many protected bays and coves, along with the physical and chemical conditions of its seawater, render the environment appropriate for marine aquaculture, particularly for bivalve molluscs. The publication "Catalogue of marine molluscs of the northeastern coasts of Venezuela: Class Bivalvia" (Lodeiros, Marin and Prieto, 1999) reflects the high biodiversity of the zone, which includes over 125 species. Based on this, it is estimated that at least 35 species (28 percent) already have commercial use or have potential for it.

Bivalve molluscs have been traditionally consumed in the region. Evidence used by anthropologist to report the presence of indigenous people in coastal areas has been the finding of "concheros", mounds of bivalve shells left behind after consumption. There are currently important local fisheries for at least 12 species of clams, mussels or scallops, while aquaculture of the green and brown mussels and of the mangrove and American oysters, remains in the growing phase. Until bivalve seed are made available in sufficient numbers and at a reasonable price, aquaculture facilities may remain at low profile, in spite of the growing interest among potential investors and artisanal fisher communities.

Seed supply can be obtained by natural fixation or by large-scale production under controlled conditions. The monthly variation of natural spat settlement has been evaluated in the southern coast of the Gulf of Cariaco at eight metres depth from the sea surface. Species that show a year-round settling occurrence are the pearl oysters, *Pteria colymbus* and *Pinctada imbricata*; while the amber pen shell, *Pinna carnea,* settles seasonally.

The pearl oysters (*P. colymbus* and *P. imbricata*), seeked by the Spanish colonists, are now fished for their mother-of-pearl and meat contents. *Pinctada imbricata* is currently fished although landings are still modest with approximately 21 tonnes landed in 2009. As indicated, both species recruit abundantly during almost the year, have a high growth and survival rates (almost 100 percent) in suspended culture and suffer relatively little from fouling and adverse environmental conditions. The estimated time to reach commercial size (i.e. 50–55 mm) is six to seven months for *P. imbricata* and eight to nine months for *P. colymbus*. There have been preliminary trials the for production of "mabe pearls" (i.e. half pearls) and free pearls.

Other potential aquaculture species

The amber pen shell, *Pinna carnea*, has moderate and periodical recruitment of seed by natural fixation and has shown a high growth and survival rates (almost 100 percent) in suspended culture. This species, furthermore, is not much disturbed by fouling and adverse environmental factors in general, however, growth of the seed tends not to be very uniform. The estimated time for this species to reach market size (i.e. around

150 mm) is five to seven months for a whole product and 14 months for a "muscle-only" product.

The scallop, *Euvola ziczac*, has been extensively worked over in experimental suspended and bottom cultures. There have been more than 30 publications dealing with seed production; cultivation at intermediate depth; suspended and bottom cultivation; effect of environmental parameters and farming conditions on growth and survival rate; genetic improvement and energetic metabolism. Major findings from these studies indicate that there is a reduced availability of seed through natural settlement, but there are adequate techniques available for seed production under controlled conditions (hatchery-nursery). Growth and survival of the juveniles is considered adequate from a farming stand point, but in suspended cultures this species suffers from adverse environmental and biotic factors, particularly fouling and strong wave activity. These conditions lead to stress and a drastic reduction of growth and survival rates. However, the effect of these negative factors can be minimized when suspended culture takes place during periods with reduced fouling and low wave action. Alternatively, bottom culture is also a solution as it is closer to the natural conditions of this scallop species.

A proposed strategy to cultivate this scallop species would be: i) production of seed under controlled conditions (30–45 days); ii) sea transfer of hatchery-produced seed when 1–5 mm in size for grow-out on long-lines until they reach a size of 30–40 mm (four to five months); iii) further grow-out on the sea bottom until individuals attain a commercial size (an additional culture period of five to six months). The final product would be scallops of 70 mm (12–13 months).

Another scallop species with a great interest for aquaculture in the region is the *Nodipecten* (*Lyropecten*) *nodosus.* This species recruits poorly in the wild, but it is easily reproduced under controlled hatchery conditions. In suspended cultures, adverse environmental factors does not impact the growth of this species dramatically as in the *Euvola ziczac*, hence, growth and survival rates makes it an interesting farming species. In contrast, this species showed poor growth rate when cultured in the bottom. It has been estimated that production of commercial size individuals (i.e. 80 mm) can be reached in one year.

Argopecten nucleus is a scallop species smaller than the two previously mentioned, but has some advantages, such as its moderate to low but continuous availability of seeds by natural settlement and ease of reproduction under controlled hatchery conditions. It is a hardy species that has a reduced response to negative influence of fouling and environmental factors in general, allowing an adequate growth in suspended culture. It has been estimated that production of commercial size individuals (i.e. 45–50 mm) can be reached in eight months.

Lima scabra, or the flame scallop, is a beautiful bivalve that lives on rocky and coral substrates. Growth experiments lasting three to four months in suspended culture conditions with individuals of different size have shown that, despite a 100 percent survival, growth rate was insignificant. It was hypothesized that it could be a species with very low growth rate, or that it requires interaction with the natural rocky habitat in order to develop.

Finally the Asian green mussel, *Perna viridis*, is a species that invaded the southern Caribbean Sea from the Indo-Pacific Ocean some years ago. It has currently spread widely in the region and seems to be somewhat outcompeting the endemic *P. perna* from its natural banks. In experimental suspended grow-out trials, it shows a smaller initial growth rate compared to the South American rock mussel in the Gulf of Cariaco, but its growth rate is higher when cultured closer to the bottom in high silt content water. Under the latter conditions, individual *P. viridis* specimen reached 70 mm in six months, while those of *P. perna* took seven months. There is a probable negative influence of environmental factors on the growth rate of this species.

There are other 23 species of bivalves on which rearing has not been experimentally tested, but that have potential for aquaculture in the general area of the Caribbean Sea.

Cephalopods

There have been experimental cultivation trials conducted by the University of Oriente (Universidad de Oriente – UDO), Margarita Island, with *Octopus vulgaris*, *Octopus briaroeus* and *Octopus joubini*. All species can attain relatively large sizes, grow fast and have short life spans. These cephalopods are able to spawn in captivity and development has been monitored until the juvenile stage for *O. briaroeus* and *O. joubini* (Robaina, 1983). There have also been recent studies on the grow-out of *O. vulgaris* fed with sardines (*Sardinella aurita*) and turkey wing mussel (*Arca zebra*) with initial promising results (700–1 000 g in one month). In spite of a large amount of larvae obtained in the laboratory, juveniles have not yet been produced due in part to the lack of knowledge of a specific diet for the different stages of the animal and the limited infrastructure available for larval rearing at the University. On the other hand, juveniles of *O. joubini* were obtained in the laboratory as this species does not have a larval stage.

Gastropods

There have been trials to cultivate *Strombus gigas* for restocking purposes in the National Park Archipelago Los Roques, in the central Venezuelan coast, since the species has been severely exploited even though this fishery has remained closed for the past ten years. Its reproductive period expands from April until November and seems to be controlled by water temperature (Weil and Launghlin, 1984).

Echinoderms

A variety of sea urchin species including the *Lytechinus variegatus*, *Echinometra lucunter*, *Tripneustes ventricosus* and *Arbacia punctulata*, have been considered for a while as potential aquaculture candidates (Lawrence and Balzhin, 1998; García *et al.*, 2005; Astudillo *et al.*, 2006). There is also interest in the use of their ova and larvae for bioassays to check for toxic and contaminant substances in the water (Sclapés, 1999) enforcing the importance of developing reproduction techniques for these echinoderms. The cycle from spawning to juvenile has been completed in the laboratory with all these species, demonstrating the feasibility for their commercial culture in the country.

In conclusion, it is biologically feasible to culture species such as the mussel *Perna perna*, the mangrove oyster, *Crassostrea rhizophorae*, and the American oyster, *Crassostrea virginica*, in specific zones along the coast of the Bolivarian Republic of Venezuela. However, it remains necessary to adequately define the technological packages to be recommended for use in different zones. Furthermore, technology transfer projects should be supported before physical installation of aquaculture infrastructure and prior to the promotion of cultured products for human consumption.

The availability of seed during almost the entire year and the rapid growth of the pearl oysters, *Pinctada imbricata* and *Pteria colymbus*, render these species advantageous candidates for cultivation. The possibility for pearls production is currently under evaluation. There are already established techniques for the production of seed under controlled conditions and for grow-out of *Euvola ziczac* and *Lyropecten nodosus,* which would enable large-scale production.

Pinna carnea and *Argopecten nucleus* can be included in cultivation activities as secondary species, due to their fast growth and moderate to small availability of seed. There is a need for in-depth studies to determine the biological feasibility of the culture of *Perna viridis* and *Lima scabra.* The culture testing of several other potential species remains a major challenge in the region.

The feasibility for the culture of several species of echinoderms has been demonstrated, but that for cephalopods and gastropods remain under evaluation.

There are currently several governmental institutions including the Foundation for the Development of Science and Technology in the State of Sucre (Fundación para el Desarollo de la Ciencia y Tecnología del Estado Sucre – FUNDACITE Sucre), the Socialist Institute for Fisheries and Aquaculture (Instituto Socialista de Pesca y Acuicultura – INSOPESCA) and mainly the Foundation for Research and Development of Aquaculture in Sucre State (Fundación para la Investigación y Desarrollo de la Acuicultura del Estado Sucre FIDAES) which, along with the Research Group on Mollusc Biology, University of Oriente, are working on the development of small aquaculture projects with local fisher communities, particularly with the mussels, *Perna perna* and *P. viridis* and the Atlantic pearl oyster, *Pinctada imbricata* (Lodeiros, 2010).

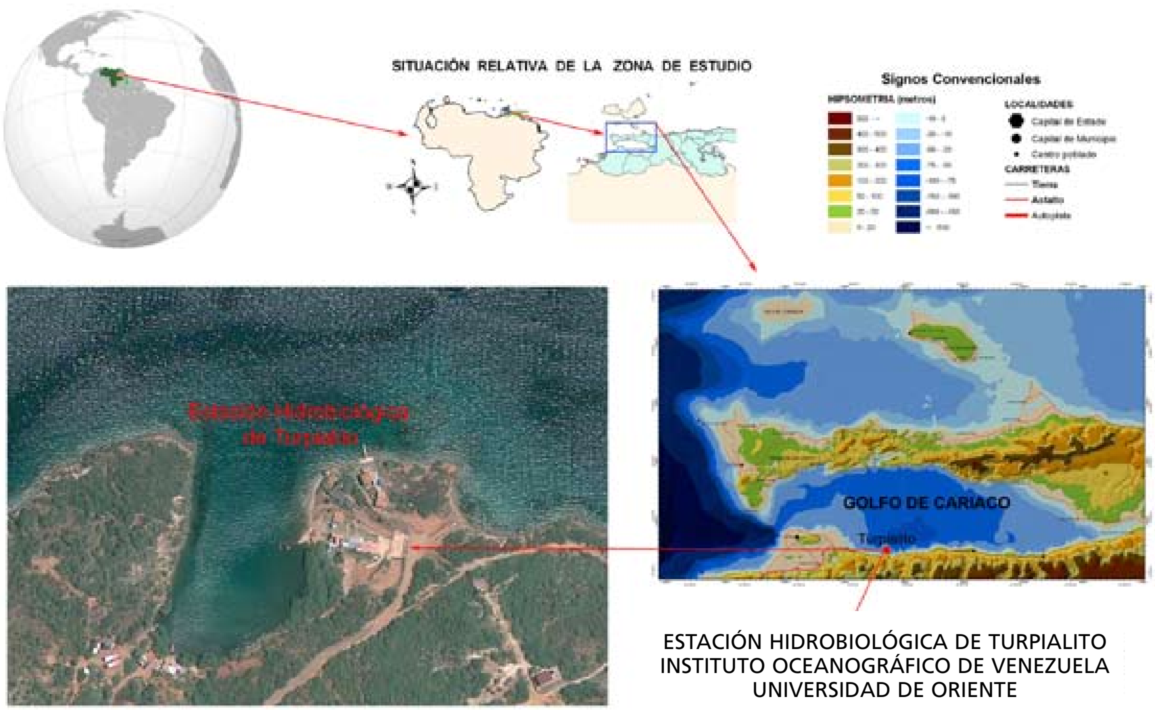
THE TURPIALITO HYDROBIOLOGICAL STATION - A REGIONAL FACILITY FOR LARGE-SCALE BIVALVE SEED PRODUCTION

The Turpialito Hydrobiological Station (THS) is located in the southern coast of the Gulf of Cariaco, between the cities of Cumaná and Mariguitar (10° 26,62' N; 64° 02,0' W; Figure 1). It was constructed in the late 1970s and since then the station has served as a platform for diverse research activities mainly pertaining to marine aquaculture.

Research activities on biology and aquaculture techniques have involved species such as the brown mussel, *Perna perna*, the mangrove oyster, *Crassostrea rhizophorae,* the scallops, *Euvola ziczac* and *Nodipecten nodosus* and the common pampano, *Trachinotus carolinus.* The resulting knowledge from such extensive research activities, particularly that on molluscs and their environment, makes it possible to commercially exploit some of these species in a rational manner.

FIGURE 1

Location of the Turpialito Hydrobiological Station in the Gulf of Cariaco, the Bolivarian Republic of Venezuela



The station has served as a laboratory for the training of diverse professionals. Examples of the scientific achievements associated with the work done at the THS can be found in the more than 250 publications among books, chapters in books, articles in scientific journals and publications for the general reader. A paramount effort has been placed in the strong impulse given to marine aquaculture, particularly that of bivalve molluscs in Latin America. In this respect, the Latin American Program for the Development of Science and Technology (Programa Iberoamericano de Ciencia y Tecnologia para el Desarrollo – CYTED) considers the station as an institution of international importance for development of aquaculture of marine bivalves.

Currently, researchers of the Oceanographic Institute and other entities of UDO, as well as those from other institutions and groups associated with marine sciences and aquaculture, show a growing interest not only in the field of marine aquaculture, but also in other economically productive areas.

In spite of the work done at the THS, its research and production infrastructure is still inadequate hence, limiting the proper execution of studies required to promote regional aquaculture development. On the other hand, the UDO and the Venezuelan Government are investing in training of its personnel, in different areas of marine sciences and aquaculture, in particular, which has lead to the availability of highly skilled professionals. However, the relatively poor infrastructure available somewhat limits the progress of applied research activities.

This situation provides a substantial case for upgrading and supporting the functioning of the THS. The station is suitably located close to the city of Cumaná (the capital of Sucre State) and its airport. It takes approximately 20 minutes to reach the airport and 30 minutes to reach the main campus of University of Oriente. The water quality in the vicinity of the station is good, since there are neither industries nor fixed sources of pollution in the vicinity and discharge of permanent rivers. Thus, salinity is high throughout the year. There is no need for antibiotics for bivalve larval production. Furthermore, the site location is geographically strategic in a protected zone within the Gulf of Cariaco, allowing rapid access to many locations in the Gulf. The land on which the facility emerges has a rocky substrate adequate for new constructions and facilities and it is serviced by the various utilities (phone, electricity and running freshwater). The site of the station is secure and minimum surveillance is required. Finally, the station is relatively well equipped with research and production equipment and operated by a number of researchers and technicians.

The THS is located on a plot of land closed to the coastline of approximately 15 060 m^2 owned by the University of Oriente (i.e. the Venezuelan Government). Of this area, about 5 300 m^2 are fully developed with 1 550 m^2 of covered infrastructures, a parking lot and internal roads and walking and approximately 950 m^2 of green space. The topography of the land together with a privileged position of the station in a protected bay with optimal environmental quality conditions provides a strong opportunity to further develop the facility and make it into a regional centre supporting shellfish aquaculture development in the Wider Caribbean.

In order to make the THS a truly regional facility, a project (and funds) will be required to recuperate the old infrastructure and existing facilities and for the construction of new laboratories, storage and external production facilities. A renovation project exists which currently includes five additional buildings each with a specific function. In 2001, the old THS station was partly demolished and the construction of new main buildings initiated, but stopped the following year and to resume only in 2006 when the National Fund for Science, Technology and Research (Fondo Nacional de Ciencia, Tecnología e Investigación – FONACIT) and the Chancellor's Office of the University of Oriente gave an impulse to the project. At present, the station continues to receive support from the Chancellor's Office of the UDO.

In conclusion, support is needed to complete the field station, in particular to finish the construction of the partly completed infrastructure; hiring of personnel; and for the provision of materials and equipment. A strong support on the value of the station has been given by the Research Group on Mollusc Biology of the University of Oriente, adding its voice to those of the university community as a whole and other interested institution, particularly the FUNDACITE of the State of Sucre. There have been a number of reasons for the regrettable delay in the construction process of the station during the period 2002–2005, but the local support situation has now changed. Today, it is generally hoped that a new THS will be established as a research and productive model for the Bolivarian Republic of Venezuela and other Latin America nations, supporting the development of aquaculture and general knowledge in marine sciences.

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Honduras as a potential site for the establishment of a small-scale shellfish hatchery facility

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ABSTRACT

The Republic of Honduras is one of the main fisheries and aquaculture countries in Central America. Together, both activities make up the third largest economic sector in the country. Annual commercial fisheries exports reach approximately 4 500 tonnes consisting mainly of lobster, shrimp, scale fish and queen conch. The United States of America is the main export market. Artisanal fishing is carried out on both the Pacific and Caribbean coasts. Artisanal fishing of molluscs on the Pacific coast target mainly the ark shells, *Anadara grandis*, *Anadara tuberculosa*, *Anadara similis*, the Guyana swamp mussel, *Mytella guayanenesis* and the bean clam, *Donax* sp. These species are sold on the national markets. On the Caribbean coast, the fishery industry targets three species of gastropods, i.e. the *Strombus gigas*, *Strombus pugilis* and *Cassis madagascariensis,* the first two for export, while the latter species for the local market. The aquaculture sector is based on shrimp and tilapia farming. Commercial shrimp culture farms are located on the Pacific coast and with annual outputs of around 20 000 tonnes; this production is exported to the United States of America and markets in the European Union. Artisanal shrimp culture is also conducted on the Pacific coast. Tilapia artisanal culture is carried out in 17 departments, by individual owners or associations and production is sold on the national market. Currently, consumption of fish products in Honduras averages 3.9 kg per person/year.

RESUMEN

La República de Honduras es uno de los países de Centroamérica con mayor importancia en pesca y acuicultura. En conjunto, ambas actividades conforman el sector económico más grande en el país. Las exportaciones anuales de pesca alcanzan aproximadamente 4 500 toneladas, consistiendo principalmente de langosta, camarones, pescado de escama y caracol gigante o pala. Los Estados Unidos de América es el principal mercado de exportación. La pesca artesanal se lleva a cabo en las costas del Pacífico y el Caribe. En la costa del Pacífico la pesca artesanal de moluscos está destinada principalmente a especies como las conchas arca, *Anadara grandis*, *Anadara tuberculosa*, *Anadara similis*, el mejillón de pantano de Guyana, *Mytella guayanenesis* y la almeja, *Donax* sp. Estas especies se venden en los mercados locales y nacionales. En la costa caribeña, la industria de la pesca está dirigida a tres especies de gasterópodos: el *Strombus gigas*, *S. pugilis* y *Cassis madagascariensis*, las dos primeras para exportación, mientras que la última especie se destina para el mercado local. La acuicultura se basa en el cultivo de tilapia y camarón. Las granjas de cultivo comercial de camarón están ubicadas en la costa del Pacífico con exportaciones anuales cercanas a las 20 000 toneladas; esta producción se exporta a la Unión Europea y Estados Unidos de América. El cultivo artesanal de camarón también se lleva a cabo en 17 departamentos de la costa del Pacífico, por propietarios individuales o asociaciones de productores y la producción se vende en el mercado nacional. En la actualidad, el consumo de productos de la pesca en Honduras tiene un promedio de 3,9 kg por persona al año.

INTRODUCTION

This paper provides background information on the Republic of Honduras, relevant to the development of aquaculture for native species of shellfish. More specifically, this is relevant to the proposed establishment of a regional shellfish hatchery for the Wider Caribbean. A summary of the geography of the country, oceanic circulation, occurrence of native species and previous culture work is given within this document, for the benefit of other Caribbean Governments and to assist the decision-making process in the selection of a site for the proposed regional facility.

The Republic of Honduras is located in the middle of Central America. It has terrestrial borders with three other countries, i.e. the Republic of Guatemala, the Republic of El Salvador and the Republic of Nicaragua, and maritime borders with the following eight countries: the Republic of Guatemala, Belize, the United Mexican States, the Republic of Cuba, Grand Cayman, Jamaica, the Republic of Colombia and the Republic of Nicaragua. It has two separate coasts: 1) the Caribbean coast extending 686 km; and 2) the Pacific coast (Gulf of Fonseca) of 164 km.

Total surface area for Honduras is 112 492 km^2 of which approximately 1 000 km^2 are wetlands. A substantial portion (35 percent) is situated in the departments of Valley and Choluteca in the Gulf of Fonseca, amounting to a total area of 6 025 km^2 (4 360 km^2 in Choluteca and 1 665 km^2 in Valley). The department of Gracias a Dios (La Mosquitia), totalling an area of 1 229 km^2, comprises 115 water bodies including coastal lagoons and ponds amounting to 78 percent of the aquatic surface area of the country. This department also includes the wetlands of Caratasca, Brus Laguna, Ibans and the Platano river biosphere. During the rainy season, the Republic of Honduras is strongly hit by hurricanes and rains, which often bring floods and landslides.

OCEANIC CHARACTERISTICS

The Gulf of Fonseca **–** The majority of the fishing zones used by fishermen are at less than 10 m depth. Water depth increases to 20 m, after Amapala, on the island of Meanguera (the Republic of El Salvador) and to 30 m outside the Gulf. Ocean circulation differs seasonally in the Gulf of Fonseca. During the rainy season, movement is typical of estuaries, where surface water is of low density (low salinity and high temperature), and flows out of the mouth of the Gulf inland coastal waters as surface waters. Incoming water from the Pacific enters the inland waters as deep water. In contrast, during the dry season, a reverse circulation occurs, due to the lack of low density inland waters. Waters from the Gulf coastal area are of higher density due to evaporation and concentration of salts, becoming deeper and flowing along the bottom out in the deep waters of the Pacific Ocean; whereas, surface waters from the Pacific Ocean moves towards the coast and into the Gulf.

CLIMATE

Although the Republic of Honduras lies within the tropics, climate varies according to the geography of the various regions. Three distinct regions are identified within the country: 1) the Caribbean lowlands, with a tropical wet climate due to a fairly even distribution of rainfall throughout the year, and consistently high temperatures and humidity; 2) the Pacific lowlands, with a tropical wet and dry climate, a dry season from November to April and high temperatures; 3) the interior highlands also characterized by a distinct dry season, but with temperatures decreasing as elevation increases, typical of a tropical highland climate.

Unlike more northerly latitudes, temperatures in the tropics vary primarily with elevation rather than with the season. Areas below 1 000 m in altitude are typically referred to as "tierra caliente" (hot land); between 1 000 and 2 000 m as "tierra templada" (temperate land); and above 2 000 m as "tierra fría" (cold land). Both the Caribbean and Pacific lowlands are "tierra caliente" with daytime temperature levels averaging between 28–32 °C throughout the year. In the Pacific lowlands, the warmest temperatures are recorded in April, i.e. the last month of the dry season; during the rainy season the climate is slightly cooler. In the Caribbean lowlands, the only relief from the year-round heat and humidity comes during December or January when an occasional strong cold front from the north typically brings several days of strong northwest winds and slightly cooler temperatures.

The interior highlands range from "tierra templada" to "tierra fría". Tegucigalpa, situated in a sheltered valley and at an elevation of 1 000 m, has a pleasant climate with an average high temperature ranging from 30 °C in April, the warmest month, to 25 °C in January, the coolest month. Above 2 000 m temperatures may fall to near freezing at night with severe frost events occurring occasionally.

Rain falls year round in the Caribbean lowlands but it is seasonal throughout the rest of the country. Amounts are copious along the north coast, especially in the Mosquitia where the average rainfall is 2 400 mm. Near San Pedro Sula rain fall levels are slightly less from November to April, but considerable precipitation is still recorded each month. The interior highlands and Pacific lowlands have a dry season, known locally as "summer" from November to April. Almost the entire rain in these regions falls during the winter months from May to September. Annual precipitation levels vary according to the regions and land topography, e.g. in Tegucigalpa, situated in a sheltered valley, annual precipitation averages 1 000 mm.

The Republic of Honduras lies within the hurricane belt, and the Caribbean coast is particularly vulnerable to hurricanes or tropical storms that travel inland from the Caribbean. Hurricane Francelia in 1969 and the tropical storm Alleta in 1982 affected thousands of people and caused extensive damage to crops. Hurricane Fifi in 1974 was the worst natural disaster in recent Honduran history; more than 8 000 people were killed and nearly the entire banana crop was destroyed. Hurricanes occasionally form over the Pacific and move north to affect southern Honduras, but Pacific storms are generally less severe.

SHELLFISH SPECIES IN THE GULF OF FONSECA

The main shellfish species occurring in the Gulf of Fonseca, are the following: *Anadara* sp. (ark shell), *Anadara grandis* (sangara ark shell), *Crassostrea* gigas (Portuguese oyster), *Crassostrea rhizophorae* (mangrove oyster), *Crassostrea corteziensis* (Cortez oyster), *Ostrea irisdescens* (stone oyster), *Argopecten ventricosus* (Pacific calico scallop), *Mytella* spp. (mussel), *Mytella guyanensis* (mangrove mussel), *Modiolux capax* (fat horsemussel), *Protothaca asperrima*, *Pinctada mazatlanica* (Calafia pearl oyster) and *Tagelus peruvianos* (barba de hacha).

THE GULF OF FONSECA MOLLUSC PROJECTS

The Gulf of Fonseca Mollusc Project was initiated in 1999 by a group of women in Venado Island. Growth of the sangara ark shell, *Anadara grandis*, under controlled conditions was investigated; unfortunately, only one year of sampling was completed, after which the project ceased to operate. A second initiative in 2001–2002 focused on a short research project with the collaboration of the University of Santiago de Compostela (the Kingdom of Spain) on farming the swamp or mangrove mussel, *Mytella guyanensis*. Following this, permission was granted in 2005 to establish a private project for the culture of this species; however, this has not yet led to a production level high enough for export. More recently, in 2010, a permit was given to another member of the private sector for the culture of the same species. To date the farmed species has not been exported but entirely consumed locally.

PERFORMANCE OF THE AQUACULTURE SECTOR

The aquaculture sector in the Republic of Honduras consists in the farming of two main species, i.e. shrimp and tilapia. Both species are farmed in large and small-scale facilities. Industrial aquaculture projects also operate their own hatcheries and processing plants.

The shrimp farms (both industrial and artisanal) are located on the Pacific coast and cover an overall area of approximately 16 000 hectares. The annual production from large shrimp farms averages 20 000 tonnes which is exported to the United States of America and the European Union. The annual output from smaller artisanal farms is around 500 tonnes and is sold on the national market.

Tilapia farming on the other hand has developed mainly in the central and northern regions of the country. All operation run their own hatchery and small processing plants. The annual production from large tilapia farms amounts to approximately 10 000 tonnes which is also exported to the United States of America and the European Union. Small-scale tilapia farming is conducted in 17 departments of the country by the private sector (individual owners or associations) and the production is sold on the national market. Artisanal aquaculture production of tilapia has been estimated at around 800 tonnes per year.

FUTURE PERSPECTIVE OF AQUACULTURE

According to a feasibility study on the potential of aquaculture development in the Republic of Honduras, recently commissioned by the government, the north coast of Honduras holds the highest developmental potential for this economic sector. This was deemed especially true for the region of La Mosquitia, characterized by a vast amount of water bodies, including coastal lagoons and inland waters. At present shrimp farming is carried out in this region but the current activity level is minimal compared to the estimated potential. The amount of available land for shrimp culture in the Gulf of Fonseca has been estimated at around 28 000 hectares. To date only 18 hectares have been developed.

In addition, the availability of coastal lagoons and their use for culture of bivalves, gastropods and other molluscs has not yet been exploited. The region of La Mosquitia has an extensive surface area, encompassing coastal and inland water bodies, yet no aquaculture has developed in this region to date.

There are two large commercial and two small artisanal finfish cage operations located in the Lake of Yojoa and in the dam of Francisco Morazán in El Cajon.

Overview of aquaculture in Belize

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ABSTRACT

The development of commercial aquaculture in Belize dates back to the early 1980s when the farming of the Pacific white shrimp (*Litopenaeus vannamei*) was established through commercial experimentation. The success of this endeavour during the early phases of the industry led to the rapid expansion of shrimp farming to a total of 18 farms with a total production area of 2 790 hectares in 2005. To date, seven farms remain operational with a production area of 1 247 hectares as a result of disease events and major decline in global market prices in 2000 which continues to impact the financial sustainability of these operations. By mid-2000, the species portfolio was expanded to the commercial production of tilapia (*Oreochromis niloticus*) and cobia (*Rachycentron canadum*). Other species that have been attempted in the past have been the culture of red fish (*Sciaenops ocellatus)*, a number of African cichlids for the aquarium trade, the Australian red claw (*Cherax quadricarinatus*), the Caribbean spiny lobster (*Panulirus argus*) and the queen conch (*Strombus gigas*). The most successful was the production of conchs juvenile between 1987 and 1992. The primary objective of the project was to develop laboratory techniques for the cultivation of queen conch larvae in an on-shore hatchery facility.

RESUMEN

El desarrollo de la acuicultura comercial en Belice se inició desde los años 80, cuando el cultivo de camarón blanco del Pacifico (*Litopenaeus vannamei*) fue establecido a través de la experimentación comercial. El éxito de este esfuerzo durante las primeras fases de la industria, llevó a la rápida expansión del cultivo de camarón a un total de 18 fincas con una superficie total de producción de 2 790 hectáreas en 2005. A la fecha, quedan siete fincas camaroneras con una superficie productiva total de 1 247 hectáreas. Esta reducción es resultado de eventos de enfermedades y principalmente con las caídas del precio internacional del camarón que empezaron en al año 2000 y siguen afectando la sostenibilidad financiera de esta industria. A mediados del año 2000, el portafolio de especies se extendió a la producción comercial de tilapia (*Oreochromis niloticus*) y cobia (*Rachycentron canadum*). En el pasado se ha intentado el cultivo de otras especies como la corvina roja (*Sciaenops ocellatus*), cíclidos africanos, la langosta australiana (*Cherax quadricarinatus*), la langosta espinosa (*Panulirus argus*) y el caracol gigante o pala (*Strombus gigas*). El intento más exitoso fue la producción de juveniles del caracol gigante o pala entre 1987 y 1992. El objetivo principal del proyecto fue desarrollar técnicas de laboratorio para su cultivo larvario en las instalaciones de un criadero.

INTRODUCTION

The first commercial aquaculture trials in Belize date back to 1982, when the farming of the Pacific white shrimp (*Litopenaeus vannamei*) was established. The successful farming of Penaeid shrimp led to the rapid expansion of the sector, leading to the establishment of 18 farms amounting to a production area of 2 790 hectares in 2005. During this period, the contributions from the sector accounted to USD 45 million which became the third largest foreign exchange earner to the Belizean economy. To date, seven farms remain operational with a production area of 1 247 hectares; this decrease in production was due to disease events, compounded with a major decline in global market prices in 2000. Both of these factors continue to impact the financial sustainability of these operations. By mid-2000, the species portfolio was expanded to the commercial production of tilapia (*Oreochromis niloticus*) and cobia (*Rachycentron canadum*). The existing aquaculture operations have been able to cope with the dwindling market prices by accessing niche markets and reducing production cost.

AQUACULTURE TRENDS

Shrimp aquaculture

Although shrimp aquaculture expanded rapidly, shrimp farming operations experienced significant economic losses in the mid-1990s and early 2000 as a result of diseases and declining market prices. The first recorded episode of a disease in Belize occurred in July 1995, with the Taura Syndrome Virus (TSV). Mortalities associated with this disease were as high as 80–90 percent in some locations. In the mid-2000 the shrimp farming sub-sector was also impacted by another viral disease, the Infectious Hypodermal and Hematopoietic Necrosis Virus (IHHN). In May 2001, the shrimp farms were again impacted by TSV (Myvett and Quintana, unpub.).

In addition to the economic losses as a direct result of diseases, there was a decline in the global market prices for farmed shrimp commodities in 2000 for the major market destinations, i.e. the United States of America, Japan and the European Union (EU) (Figure 1). Since then, prices have not been favorable for producing countries such as Belize. The decline in shrimp prices is directly associated with the larger volumes of farmed shrimp exported by the Asian countries at very low prices.

FIGURE 1
Farmed shrimp export and value trends in Belize

Given the various challenges in the shrimp farming sector, more than 50 percent of the production area has been out of production. In 2005, there were 18 shrimp farming operations with over 2 790 hectares in production ponds. Over the last decade, 11 shrimp farms have ceased operations. Currently (2010), there are seven operating farms with a cumulative production pond area of 1 247 hectares. Export volumes of farmed shrimp were reported at 2 280 tonnes valued at USD 9.25 million in 2009. The main market destination for shrimp commodities is the Mexican market, followed by the United States of America and the Caribbean Community (CARICOM).

Tilapia farming

Apart from shrimp farming, commercial production of tilapia was established in 2000 by one commercial farm (Fresh Catch Belize Ltd). First exports to the US market were made in mid-2004. By 2009, this tilapia farm had 121 hectares of production ponds in operation, and a total yield of 1 900 tonnes. The operation is vertically integrated with a hatchery and processing plant to compliment the pond production systems. It is currently being expanded by an additional 40 hectares of production ponds. It is estimated that this will increase the total annual production capacity of "Fresh Catch Belize Ltd." to 4 000 tonnes.

The portfolio of products from 'Fresh Catch Belize' includes both whole eviscerated fresh fish, as well as fresh frozen fillets. The fillets are destined for the US market, while the eviscerated fish is exported to United Mexican States and the Republic of Guatemala. Fresh Catch Belize Limited is part of the "Mountain Stream Tilapia Alliance", which is a conglomerate of fish farming companies from the Republic of Costa Rica, the Republic of Honduras and Belize exporting under one name brand.

Cobia farming

The other commercial aquaculture venture is "Marine Farms Belize Ltd". The facility is the only commercial cobia farming operation established in Belize. The operation is based on marine cage farming using Norwegian technology. Farming is conducted near Robinson Point Cays, using cage infrastructure ranging from 5 m circumference nursery cages to 40, 60 and 100 m grow-out cages. The farm was established in 2006, and started exporting by 2007 to the US market through AQUA GOLD, a marketing company. Exported products are "bullet" cuts, where the head is removed and the fish is gutted. The production capacity during phase I and II of the operations has been projected at 2 000 tonnes per annum. In 2008, cobia whole fish production was approximately 384 tonnes.

Marine Farms Belize Ltd. has fully established a hatchery operation near Dangriga. The broodstock in the hatchery have been sourced locally and the first spawns were realized in July, 2009. The production capacity of the hatchery has been estimated at one million fingerlings per annum.

Small-scale aquaculture

The history of the early phases of small-scale inland fish farming in Belize and its socio-economic contributions remains undocumented. Rural fish farming has been practiced in Belize on an experimental basis since the early 1990s. This has been mainly in the form of backyard farming operations with a focus on locally occurring cichlids species. These species include: the bay snook (*Petenia splendida*), crana (*Cichlasoma uropthalmus*), mus-mus (*Cichlasoma friedrichstali*), tuba (*Cichlasoma synspilum*) as well as the exotic tilapia (*Oreochromis niloticus*). Most recently, farmers have focused their interest in the farming of the red hybrid tilapia, given the growth performance and local market demand. In 2009, there were a total of 55 farmers engaged in small-scale tilapia farming with a total area of 5.6 hectares of production units ranging from 40 to 1 000 m^2.

Past attempts at farming other species

In the past, there has been several trials on other species including the freshwater Australian red claw lobster (*Cherax quadricarinatus*), the redfish (*Sciaenops ocellatus*) and a number of African Rift Lake ornamental finfish species such as *Haplochromis* sp., *Labeochromis* sp., *Melanochromis* sp., *Tropheus* sp., *Psuedotropheus* sp., *Awlenocara* sp. and the local queen conch (*Strombus gigas*). The most successful was the production of juvenile conch between 1987 and 1992. This initiative was funded by the United States Agency for International Development (USAID) and the Government of Belize.

The primary objectives of the project were to: i) develop laboratory techniques for the cultivation of queen conch larvae in land-based hatchery facility; ii) restock nearby conch habitats that have traditionally sustained viable conch populations; and iii) conduct field exercises to estimate survival rates of hatchery-reared juvenile conch.

Data on husbandry aspects from broodstock to juvenile stages was obtained through the Belize queen conch project. The hatchery process included the collection of egg masses from the wild, followed by laboratory rearing up to juvenile stages. Subsequently, juveniles were stocked in the wild and survival rates were monitored during a period of eight weeks. After a few years of experimentation, project funds were insufficient, leading to the closure of the project.

FUTURE TRENDS

The aquaculture sector continues to have its own challenges, in terms of the sustainability of various farmed commodities due to high cost of production inputs and unstable market prices. Shrimp producers are currently taking advantage of the high end markets, as well as of the existing whole shrimp market in the United Mexican States, and other niche markets in the EU and CARICOM. For the tilapia sector, the Mexican market is also available for whole fresh fish and the US market for fresh fillets. The future expansion of cobia aquaculture has been inhibited due to limited supplies of hatchery-reared fingerlings.

In terms of diversification from the traditional aquaculture activities in Belize, there has been a growing interest by investors in marine cage farming of cobia, tilapia cage culture, sea cucumber aquaculture, as well as the farming of seaweed.

With regards to investment opportunities, the Government of Belize continues to offer various development incentives for aquaculture. The competitive advantage of Belize is its proximity to the regional markets for supplying fresh products to the US markets.

REGIONAL COOPERATION PROJECTS IN AQUACULTURE

Through the Organization of Fisheries and Aquaculture in Central America (Organización del Sector Pesquero y Acuícola de Centroamerica – OSPESCA), funded by Taiwan, Province of the People's Republic of China, there are various activities, currently implemented to further strengthen sustainable development of aquaculture in the region. An aquaculture working group was established in early 2010 to coordinate various activities. Within this context, a regional forum on aquaculture, held in the Republic of Panama in April 2010, enabled member countries to present emerging trends on successful aquaculture projects. Through this initiative, some of the key issues affecting the development of aquaculture were discussed with the purpose of developing future plans, and in this way, advance the development of aquaculture in the region.

As part of their 4-year work plan, OSPESCA has a component for developing a mariculture programme for restocking depleted marine fish stocks. The project is in the process of being defined, namely for the identification of target species to be considered. Additionally, a project is currently being considered for funding to further improve the mollusc hatchery in the Republic of El Salvador; this facility would serve as a regional seedstock and training centre through cooperation from the Government of Spain.

The CARICOM Caribbean Regional Fisheries Mechanism (CRFM) is currently finalizing a Master Plan on sustainable use of fisheries resources for coastal communities with support from the Japanese International Cooperation Agency (JICA) (see www.caricom-fisheries.com). Within this initiative lies the implementation of various pilot projects. Results gathered during the study will be utilized in the finalization of the draft Master Plan to be completed in February 2011. One of the pilot projects, focusing on the development of low-cost feed for small-scale aquaculture, is being implemented in Belize.

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Selecting a site for a regional shellfish hatchery

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ABSTRACT

The selection of a suitable site for a regional shellfish hatchery is critical to its long-term sustainability and profitability. Costs for purchase of the site, construction, equipment and shipping if needed, utility overheads and trained staff need to be assessed. Government regulations with regards to building permit of a shellfish hatchery need to be supportive. Assessing the potential impact of the hatchery on the surrounding environment is good conduct practice. Good quality seawater is a primordial requirement to successful hatchery production; existing information or detailed sampling of water chemistry in water column needs to be understood over a 12-month period – namely, temperature, salinity and oxygen of intake water needs to be known. Areas potentially subjected to silt load and salinity fluctuations due to heavy rain falls and occurrence of algal blooms should be avoided as this may lead to reduction in survival and/or growth of larvae and juveniles. Heavy natural fouling will be problematic and cause clogging of the intake and of the seawater pipes. Impact from nearby industrial plants, agricultural lands, domestic sources of pollution are not completely understood, but are known to be extremely damaging to larvae. Potential encroachment of urbanization and exposure to natural disasters also need to be considered. Building the hatchery at sea level and close to the ocean facilitates plumbing. Alternatively, water may be supplied from a well. More general considerations are the availability of land for storage, expansion and accommodation of trainees from other countries, a supply of freshwater and a skilled labour force. The proximity of universities or laboratories is beneficial as technical support to a hatchery operation. More specific to a regional hatchery, the ease of access to a nearby airport facilitates broodstock import and shipping of spat. Local legislation needs to support the export of spat and the method of transport. Finally, a quarantine area for broodstock and proper discharge of effluent is a must to avoid introduction of pathogens and diseases and escape of exotic larvae to the natural environment.

RESUMEN

La selección de un sitio adecuado para un criadero regional de mariscos es fundamental para su sostenibilidad y rentabilidad a largo plazo. Es necesario evaluar los costos para la adquisición del sitio, construcción, equipamiento y gastos de envío si es necesario, gastos generales de servicios públicos y de personal capacitado. Las regulaciones gubernamentales con respecto a los permisos de construcción de un criadero regional deben ser de apoyo. La evaluación del impacto potencial del criadero sobre el medio ambiente es una práctica de buena conducta. El agua de mar de buena calidad es un requisito primordial para una exitosa producción del criadero. Es necesario contar con información existente de la calidad química de la columna de agua o llevar a cabo muestreos por un período de 12 meses (contemplando temperatura, salinidad y oxígeno de la fuente de agua). Deben evitarse las áreas que estén sometidas a fluctuaciones de la salinidad y carga de sedimentos debidas a las fuertes lluvias y a la aparición de afloraciones de algas, ya que esto puede conducir a la reducción de la supervivencia y/o el crecimiento de las larvas y juveniles. Las incrustaciones naturales serán un problema al causar la obstrucción en la toma de agua de mar y las tuberías. Los impactos de la cercanía de instalaciones industriales, tierras agrícolas y de fuentes de contaminación doméstica no se conocen con exactitud, pero se sabe que son extremadamente perjudiciales para las larvas. También es necesario considerar el potencial de ocupación de la zona por urbanización y la exposición a los desastres naturales. La construcción del criadero al nivel del mar y cerca del océano facilita la instalación de tuberías. De forma alternativa, el agua puede ser suministrada desde un pozo. Consideraciones más generales son la disponibilidad de tierras para almacenamiento, expansión y el alojamiento de alumnos de otros países, suministro de agua dulce y mano de obra calificada. La proximidad de las universidades o laboratorios es beneficiosa como apoyo técnico para el criadero. El acceso a un aeropuerto cercano específicamente para el criadero regional, facilita la importación de reproductores y envío de semilla. La legislación local tiene que facilitar la exportación de semilla y el método de transporte. Por último, es indispensable contar un área de cuarentena para reproductores y el adecuado manejo de los efluentes para evitar la introducción de agentes patógenos, enfermedades y fuga de larvas exóticas al medio ambiente.

INTRODUCTION

Culture of marine species consists of two major phases: i) hatchery phase, which is land-based and usually conducted under controlled conditions; and ii) grow-out phase, where juveniles are reared to adult or market size; for bivalves, gastropods and crustaceans, this is conducted in the natural environment in enclosures or on the seabed. This document concerns itself with the site selection criteria for the land-based hatchery facility.

In the case of a regional facility, such as the one proposed for shellfish culture in the Wider Caribbean, site selection involves both the selection of a country, strategically located within the region, and the selection of a site within this country. This document will, therefore, outline considerations to be made for assessing a best suited country and site.

First and foremost, as Helm and Bourne (2004) note, one must recognize that the installation and operation of hatchery is costly. Considerable initial capital is required to build a hatchery and finance its first years of operations. The goal is to generate income, in order to sustain running operations and make a profit. For this reason, before deciding to build a hatchery, all aspects of building and operating a hatchery need to be examined, and the level at which a hatchery will be economically viable must be determined. Many costs need to be considered including purchase/lease of the site, construction of the hatchery, installation of the seawater system, equipment needed for all phases of production, maintenance, supplies and utility overheads, loan repayments and the need for trained staff.

The initial selection of a suitable site on which to build the hatchery is of utmost importance to subsequent success for production of seed. A supply of high-quality seawater, free from pollution and organisms causing disease is essential. Other factors to be considered are land availability at reasonable cost, local availability of electricity and freshwater, a qualified or easy to train labour force and good communication to facilitate acquisition of materials and supplies.

GOVERNMENT REGULATIONS

The first consideration to be made in assessing the suitability of a country for a regional hatchery is to determine existing government regulations and political will for the development of aquaculture. Not all governments have legislation enabling and/or facilitating aquaculture; this may become a major hindrance, unless political will is strong and supports growth in this sector.

The first step is the verification of government regulations supporting permit construction of a shellfish hatchery at a desired site. Enquiries to local, state, provincial or federal authorities are critical. It is advisable to have more than one site evaluated as a potential hatchery site, and select the site most amenable to government regulations. In some cases, changing existing government regulations for hatchery construction permit may be an option, if there is government support for aquaculture development.

Many countries require a number of permits and licences to ensure compliance with local building codes and national and local environmental regulations before any construction is allowed. This can be a lengthy, costly and time consuming process. Whether it is required or not, good conduct practice should include the potential impact of the hatchery on the local environment before construction.

Some of the existing regulations in need to be in favour of aquaculture development are: i) aquaculture permit for hatchery operation; ii) duty on culture equipment and materials; iii) licensing for installing permanent structures on the seabed (seawater pipes for intake); iv) immigration laws for overseas staff/scientists; v) import of live shellfish for broodstock and export of spat; vi) licence to sell cultured species; vii) health inspection laws; viii) lease of seabed for grow-out systems; and ix) tourism and recreational regulations (potentially leading to multi-use conflicts).

ADDITIONAL CONSIDERATIONS FOR A REGIONAL FACILITY

In addition, a country selected for a regional facility should have sites amenable to the following considerations:

<u>Infrastructure</u> – Not all countries have land available suitable for the establishment of a land-based hatchery and in proximity to seawater. In some, such land may be earmarked for other residential or commercial uses. A hatchery may also be developed from an existing building suitable to required modifications. In some cases, this may prove less costly than building a hatchery on undeveloped land, depending on price of land, construction costs, etc. Countries offering a land area for a regional facility should ensure the availability of an adequate supply of electrical power to ensure smooth running of hatchery activities and access to freshwater for cleaning purposes. In addition, there should be scope for expansion at the selected site, enabling an increase in production, training, storage, etc.

<u>Transport</u> – The ease of access to a nearby airport is critical to facilitate broodstock import and adequate infrastructure allowing ease of shipping of spat to other countries in the region. Adequate infrastructures (e.g. roads) are needed for reliable shipments; this also includes the acquisition of materials and equipment needed for hatchery construction and operation.

The location of a hatchery may have important economic consequences for transport costs. Access to shipping lines is of major importance, as the majority of spat will be sold to other Caribbean countries; as a consequence, ready access to an efficient road system and airport offering direct and economic routes are required to ensure that the product reaches its destination quickly and with maximal survival and health status. Survivability is influenced by a number of factors, including the level of handling before the journey starts and environmental factors such as temperature and humidity during the journey. Some species of bivalves which normally live subtidally (e.g. scallops) are particularly vulnerable to journey times of more than 24 hr. Hatchery-reared spat or juveniles are shipped as air freight to reach their destination quickly. There are methods which have been well tested and documented for some of the target species (bivalve scallops; see Sarkis *et al*., 2005, for specific transport techniques). However, the hatchery needs to be at a site where there is availability of shipping materials and central to potential importing countries.

Local legislation – Legislation of the country needs to be verified to ensure that transport is conducted accordingly. In some countries, legislation requires that shellfish are transported under such conditions (with regard to space, ventilation, temperature and security) and with such supply of liquid and oxygen as are appropriate for the species concerned.

Target species – The occurrence and availability of target species for regional culture in the country selected for a regional facility is advisable. It would facilitate the supply of broodstock to the hatchery, mitigating potential transport of foreign disease and pathogen to the regional hatchery.

Quarantine – For a regional facility, a quarantine system to ensure that no pathogens or diseases are transferred via the broodstock to the hatchery is a must.

Human resources – Capacity to train personnel in adhering to strict protocols ensuring disease-free facility. The need for surveillance of the facility should also be considered.

Technical support – Established collaboration with a laboratory allowing for the testing of pathogens and larvae/spat health status prior to shipping. Additionally, the proximity of a university or research centre provides technical support for some aspects of culture work (for example, water quality analyses).

Protection from natural disasters – The occurrence, frequency and type of natural disasters should be assessed prior to selection. These can include storms and hurricanes, earthquakes, but also toxic algal blooms and diseases. Avoidance of exposure to such disasters is optimal, but difficult. However, the utmost needs to be done to select a site which is relatively protected (considering both country and specific location within the country), and to ensure that precautions are taken for survival of the stock in the event of such a disaster. For example, in case of power loss due to storms or hurricanes, a generator should be put in place to ensure a supply of seawater, temperature control, and lights for algal culture, until such time that power is restored.

Additionally, in some countries insurance against such losses is possible, now that aquaculture is recognized as an insurable risk and should be considered.

ENVIRONMENTAL PARAMETERS

Before committing to what is considered to be a suitable location for a hatchery, it is critical to ensure that good quality seawater exists year-round at the prospective site. If a good seawater source is not available, it will be difficult to develop an efficient and profitable hatchery operation. For this reason, every effort should be made to obtain as much information as possible on water quality throughout the year at a potential site or sites. Information is required not only for surface waters but also for the entire water column, since thermoclines may develop or upwelling may occur periodically.

Any previous data stemming from oceanographic surveys or environmental studies should be reviewed. If not, it is advised to undertake a detailed sampling of the waters at the proposed site for at least a year.

Environmental parameters of seawater that need to be examined will depend in part on geographic location and the intended species for culture. Molluscan larvae, as well as juveniles and adults have strict physiological requirements, such as water temperature, salinity and oxygen levels and these must be maintained in a hatchery operation. Although some of these can be controlled within the hatchery seawater system, it will be more reliable and less costly if environmental parameters of the incoming seawater resemble closely those required for larval rearing – namely with respect to temperature, salinity and oxygen. Dependent on the species produced, importance in range of fluctuations varies.

Other parameters, such as quantities of silt potentially increased during periods of heavy rainfall and associated runoff may lead to problems in a hatchery; these are difficult to predict and control and are best to be avoided from the onset by careful site selection. High incidence of boat traffic will entrain resuspension of sediments, increasing the need for routine maintenance of seawater filters to hatchery supply. Heavy rainfall can also cause periods of low salinity. Similarly, the occurrence of dense concentrations (blooms) of some marine algal and bacteria species may release toxic substances that may cause reductions in both the survival and growth of larvae or juveniles, or mass mortalities in extreme cases. For this reason, a site potentially exposed to such problems is not recommended. As much data should be collected prior to deciding on the suitability of a site for a shellfish hatchery. Remedial measures to improve inadequate quality seawater can be extremely costly and may adversely affect the profitability of a venture.

Areas with high levels of natural production may be problematic, as fouling of intake lines and pipes will occur more rapidly. Additionally, areas with excessive external input of nutrients can lead to increased phytoplankton blooms, causing a decrease in oxygen levels, which can potentially impact survival. It should be noted that, although a hatchery site concerns itself mostly with the land-based facility, there are times where a need arises to hold juveniles and/or adults within enclosures in the natural environment (for example, prior to transfer at sea, juveniles may be acclimated in nets off the dock; or grow-out enclosures may be tested or demonstrated). For this reason, natural seawater parameters favourable to growth of target species in proximity to the hatchery are ideal. Suitable levels of nitrate, phosphate and silicate are required for growth, as well as the presence of iron, manganese and other metals.

Locations possibly influenced by effluents discharged from industrial plants should be avoided. The lethal and sublethal effects of many industrial pollutants are not completely understood, nor are the additive effects they may exert when several industries are discharging a range of potentially toxic wastes in nearby waters. Effects of such effluents can be extremely damaging to bivalve larvae. For example, an anti-fouling ingredient added to marine paints, tributyltin (TBT) has been found to be highly lethal to bivalve larvae even at concentrations of a few parts per billion. More recently, Irgarol 1051 is also found toxic to larvae. Drawing a seawater supply from the vicinity of marinas and commercial docks needs to be avoided.

Agricultural (including forestry) and domestic sources of pollution should also be avoided. It has recently been shown that, runoff from some cultivated lands can carry concentrations of pesticides at levels deleterious to the growth and survival of bivalve larvae. Domestic pollution may not only contain pollutants that are toxic to bivalve larvae but the high organic content can cause depletion of oxygen levels and increased levels of bacteria that could also lead to reduced growth and mortalities of larvae.

Another consideration when deciding upon the location of a bivalve hatchery is that of potential impact due to adjacent development. Urbanization with its ancillary problems is one of the main concerns in bivalve culture. If it is anticipated that the site will be encompassed by urbanization then every effort must be made to ensure that sources of potential pollution will be kept to a minimum. This will require working closely with planners and developers. Alternatively, another site should be considered.

LOCATION

The hatchery should be located close to the ocean so that the distance required to pump water is kept to a minimum. This negates the necessity of having to maintain great lengths of pipe. It should also be located as close to sea level as possible to avoid problems of pumping water any great vertical distance. Intakes for the seawater should be as short as possible and conveniently located for easy service and maintenance. If fluctuations in surface seawater temperature and salinity occur regularly, the intakes for the pipes will need to be located at depth to maintain more constant water temperature and salinity. This will also reduce the number of organisms and amount of detritus entering and fouling the system, reducing water flow into the hatchery. Intakes at depth also help to avoid major phytoplankton blooms, some of which may be toxic to larvae. If the intake is in an area where thermoclines develop, the intake should be located below the thermocline.

Depending on the nature of the geological strata, it may be possible to drill wells close to the shore to access seawater aquifers. A water source of this nature will be at a more constant temperature and salinity year-round and will already be pre-filtered by percolation through the strata, resulting in high quality seawater. Because of this, it usually requires little further filtration. It may, however, require oxygenating before use. It is recommended that a full analysis of water be conducted prior to the drilling of such a well to ensure that it will be suitable; at times, well water can also be rich in certain minerals, such as iron, which may be problematic to the filtration system. Constructing seawater wells can be expensive initially, but the high capital cost is offset by reduced operating costs. It is advisable to consult with a suitably qualified engineer, if possible, when making decisions on the best methodology and technology to procure the water supply.

Other considerations are similar to those discussed above when evaluating most suitable countries as potential sites for a regional hatchery facility: i) sufficient area available to accommodate the hatchery and ancillary buildings and also to allow for any future expansion; ii) electrical power supply; iii) freshwater supply; iv) skilled labour force; v) good communications; and vi) proximity to research/technical institutions.

Site selection is critical to successful hatchery production, even more so within the scope of a regional facility. Concerned governments need to objectively evaluate proposed sites in consideration of target species, level of production and potential markets.

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CARICOM perspective and possible funding opportunities for establishment of a Caribbean regional shellfish hatchery

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ABSTRACT

This presentation provides a brief overview of the emerging policy framework for aquaculture development and a perspective on the development of a regional shellfish/mollusc hatchery within the Caribbean Community. It argues that although the aquaculture industry is still in its embryonic stages of development in the Region, governments are nevertheless interested in accelerating the development of the industry. In this regard, governments have taken steps in recent years to elaborate a long-term regional development policy and plan for sustainable expansion of aquaculture including mariculture. The paper also explores possible international and regional partners and sources of funding, appropriate technology and expertise to support aquaculture development generally and the shellfish hatchery in particular.

RESUMEN

Esta presentación ofrece un breve resumen de marco político emergente para el desarrollo de la acuicultura y una perspectiva sobre el desarrollo de un criadero regional de moluscos y/o mariscos dentro de la comunidad del Caribe. Se argumenta que, aunque la industria de la acuicultura está todavía en su etapa embrionaria de desarrollo en la Región, los gobiernos, sin embargo, están interesados en acelerar el desarrollo de la industria. A este respecto, los gobiernos han tomado medidas en los últimos años para elaborar una política de desarrollo regional a largo plazo y un plan para la expansión sostenible de la acuicultura, incluyendo la maricultura. También se exploran posibles socios internacionales y regionales así como las fuentes de financiación, tecnología apropiada y experticia para apoyar el desarrollo de la acuicultura en general y el criadero de mariscos en particular.

POLICY AND INSTITUTIONAL FRAMEWORK FOR AQUACULTURE

There are three regional economic cooperation organizations in the Caribbean whose mandates include facilitating regional cooperation in aquaculture and fisheries, considered in this paper. These are the Caribbean Community (CARICOM), CARIFORUM and the Caribbean Regional Fisheries Mechanism (CRFM). A brief overview of the mandates, main functions and responsibilities of these organisations is provided below. It should, however, be noted that there are several other organisations concerned with aquaculture and fisheries in the Caribbean including, *inter alia*, the University of the West Indies; the Organization of Eastern Caribbean States (OECS); the Association of Caribbean States (ACS); the Central American Integration Organisation (SICA) and its fisheries arm, OSPESCA; the United Nations Environment Programme (UNEP) Regional Coordinating Unit; the Western Central Atlantic Fisheries Commission (WECAFC); and the Intergovernmental Oceanographic Commission, Sub-Commission for the Caribbean and Adjacent Regions (IOCARIBE).

Caribbean Community

The Caribbean Community (CARICOM) is a regional economic integration organization established by the Treaty of Chaguaramas[1], 1973, comprising 15 Caribbean States. The CARICOM States are Antigua and Barbuda, Barbados, Belize, the Commonwealth of Dominica, Grenada, the Republic of Guyana, the Republic of Haiti, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, the Republic of Suriname, the Commonwealth of the Bahamas and, the Republic of Trinidad and Tobago.

The CARICOM countries decided in 1989 to further integrate their economies[2], and in this regard prepared the Revised Treaty of Chaguaramas establishing CARICOM Single Market and Economy (CSME), which was signed in 2001[3]. The objectives of the Community are: to improve standards of living and work; the full employment of labour and other factors of production; accelerated, coordinated and sustained economic development and convergence; expansion of trade and economic relations with third States; enhanced levels of international competitiveness; organization for increased production and productivity; achievement of a greater measure of economic leverage and effectiveness of Member States in dealing with third States, groups of States and entities of any description and the enhanced co-ordination of Member States' foreign and foreign economic policies and enhanced functional co-operation.

The heart of the CSME consists of a Common External Tariff regime and a liberalized single internal market and economy without barriers where nationals of the Community will have freedom of establishment, freedom to provide service, and the freedom to move capital and labour to achieve efficient, optimum production of goods and services, without discrimination based on nationality.

The Revised Treaty provides in Article 60, for the pursuit of policies and programmes to "promote the development, management and conservation of the fisheries and aquaculture resources in and among the Member States on a sustainable basis."

Forum of Caribbean States

The Forum of Caribbean States (CARIFORUM) is a sub-grouping of the African, Caribbean and Pacific States which was established in October 1992. It comprises

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1 The Treaty establishing the Caribbean Community, Chaguaramas, 4 July 1973. Caribbean Community Secretariat, Georgetown, the Republic of Guyana. 46p.

2 The Grand Anse declaration and work programme for the advancement of the integration movement. Caribbean Community Secretariat, Georgetown, the Republic of Guyana.

3 Revised Treaty of Chaguaramas Establishing the Caribbean Community Including the CARICOM Single Market and Economy (hereafter the Revised Treaty). Caribbean Community Secretariat, Georgetown, the Republic of Guyana. 288pp.

the Dominican Republic, the Republic of Cuba and 14 CARICOM States which are signatories to the ACP-EU Partnership Agreement signed in Cotonou, Benin in 2000 and revised in the Grand Duchy of Luxembourg on 25 June 2005. Montserrat is not a Member of CARIFORUM, whereas, the Republic of Cuba, although a member, is neither a signatory to the Cotonou Agreement nor a direct beneficiary of ACP-EU financing. The mandate of CARIFORUM is to coordinate policy dialogue between the Member States and the European Union and promote the widening and deepening of regional integration and co-operation.

CARIFORUM pursues the objective by promoting closer economic cooperation and eventual integration of the Dominican Republic and the Republic of Cuba into the Caribbean Community; coordinating the allocation of resources provided by the European Union; and managing the implementation of the Caribbean Regional Indicative Programme (RIP).

Caribbean Regional Fisheries Mechanism

The Caribbean Regional Fisheries Mechanism (CRFM) is a regional fisheries body established by the CARICOM States to promote sustainable use of the living marine and other aquatic resources by the development, efficient management and conservation of such resources through cooperation and consultations[4].

The CRFM is made up of three bodies as follows:

1. A Ministerial Council (Ministers Responsible for Fisheries of Member States) that has primary responsibility for *inter alia,* determining the policies of the Organisation, resource allocation, cooperative agreements, and related decision-making.
2. The Caribbean Fisheries Forum (heads of national fisheries administrations) which provide technical leadership to the Organization, including the provision of scientific advice to the Ministerial Council, and oversight to the operations of the CRFM Secretariat.
3. The technical Secretariat, which is responsible for day-to-day coordination and execution of the work programmes; collaborating with national fisheries authorities; mobilizing resources; and managing the institutional networking to ensure optimal involvement of stakeholders and efficient functioning.

There are presently 17 Member States of the CRFM. Membership is open to the CARICOM Members and Associate Members. These are: Anguilla, Antigua and Barbuda, Barbados, Belize, the Commonwealth of Dominica, Grenada, the Republic of Guyana, the Republic of Haiti, Jamaica, Montserrat, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, the Republic of Suriname, the Commonwealth of the Bahamas, the Republic of Trinidad and Tobago and, Turks and Caicos Islands. Although the Dominican Republic is not a member of the CRFM, there is a Memorandum of Understanding between the Dominican Government and the CRFM to promote and facilitate cooperation and collaboration in aquaculture and fisheries.

The CRFM contributes significantly to all aspects of aquaculture and fisheries development and management in its Member States, including data collection, analysis and data management, research, dissemination of scientific and technical information, preparation of national fisheries management plans, and strengthening national capacity for management. The Promotion "of aquaculture as a means of enhancing employment opportunities and food security, nationally and regionally" is a general guiding principle of the organization (Article 5(f) CRFM Agreement).

The work of the CRFM has planned and implemented a Long-Term Strategic Plan which is delivered through Medium-Term and Biennial Work Plans. Program-7

[4] The CRFM was established in 2002 by CARICOM States. See 2002 Agreement establishing the Caribbean Regional Fisheries Mechanism. CRFM Secretariat, Belize City.

of the CRFM Strategic Plan addresses aquaculture development. It states that "the development of this subsector will follow a two tiered strategy. The first involves the establishment of a policy framework and regulatory environment to promote commercial aquaculture ventures while the second relates to the research on aquaculture initiatives in support of strengthening the marine fisheries sector. The major elements should entail:

- A policy framework to stimulate private investment and export oriented production of aquaculture.
- Development and promotion of the required global environmental standards among operators of enterprises in aquaculture.
- Development and promotion of harmonized guidelines for regulating the subsector.
- Development and promotion of aquaculture in collaboration with the relevant agencies.
- Research and development on specific species, dictated by the needs of the marine fisheries subsector." [5]

The Second CRFM Medium Term Plan[6] provides for substantive work on promoting aquaculture development in the region. Aquaculture has been identified as a specific strategic initiative for increasing the sustainable supply of fish, shell fish and other marine products for domestic consumption, and foreign exchange earnings. The following actions are currently being pursued to realize the above objective:

- Conduct an assessment on the status of aquaculture in CRFM Member States.
- Evaluate the existing enabling environment (institutional, policy and legal frameworks) in CRFM Member States for the promotion of an aquaculture industry.
- Determine the most appropriate species for aquaculture development based on marketability, available technology, sustainability and economic viability.
- Develop and implement pilot projects to test feasibility of research findings and identify appropriate technologies for small-scale aquaculture.
- Formulate Master Plan for development aquaculture with focus on small-scale aquaculture and stock enhancement.
- Develop programmes for increasing interest and promoting investment in aquaculture.
- Develop action plans for public sector support for aquaculture enterprises.
- Identify the need for and develop framework for regionalizing research and training in aquaculture.
- Develop a Regional Protocol for sustainable aquaculture development and management and corresponding Framework for Policy and Institutional Reform.

In 2008, the CRFM and the Organization for the Network of Aquaculture Centres in Asia and the Pacific (NACA), signed a Memorandum of Understanding to promote cooperation and sharing of knowledge and expertise in small-scale aquaculture development.

CARICOM Common Fisheries Policy

In 2003, the CARICOM Heads of Government mandated the preparation of a Common Fisheries Policy and Regime as an instrument to achieve responsible and sustainable development and conservation of the fisheries and aquaculture resources of the Member States. The Revised Treaty does not provide detailed principles, rules and arrangements for sustainable use and effective management of fisheries and aquaculture resources, especially rules regarding access to and exploitation of the

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5 CRFM Strategic Plan 2003, CRFM Secretariat, Belize City, Belize.

6 The Second CRFM Medium Term Plan (2009–2012), CRFM Secretariat, Belize City, Belize.

marine resources in keep with the basic principles of the CARICOM Single Market and Economy. CARICOM States have been negotiating a framework agreement to establish the Policy. The negotiations are ongoing and are expected to conclude in 2011/2012. The Draft CFP Agreement[7] contains provisions for a common approach to aquaculture development. For example, one of the objectives of the Policy is "to promote the sustainable development of aquaculture, including mariculture in the Caribbean Region as a means of, *inter alia*, increasing trade and export earnings, food and nutrition security, and reducing fishing pressure on over-exploited fish stocks".

POTENTIAL FUNDING SOURCES FOR THE HATCHERY

While aquaculture can make significantly enhanced contribution to the long-term development of the Caribbean States, access to affordable financing for research and development and capital investment is a necessary condition for further growth and expansion of the sector. However, access to funding for aquaculture and fisheries has always been and still is a major challenge for most Caribbean states and small and medium size enterprises (SME) with an interest in the sector, especially in the Small Island Developing States. But this may be changing. Growing concern regarding the impacts of climate change, rising food prices and food insecurity are forcing governments and donors alike to pay more attention to sectors such as aquaculture and fisheries given their potential for, *inter alia*, contributing to increased food production and creation of new employment opportunities.

CARICOM/CARIFORUM States are giving increasingly greater priority to aquaculture development, evidenced by the expanding policy, legal and institutional frameworks to promote aquaculture and fisheries, and growing interest of the private sector and public sector.

Bilateral and multilateral donor organizations and financial institutions are also showing renewed interest in providing support for sustainable aquaculture and fisheries development. Among the donor organizations which are active in the Wider Caribbean and have an interest in aquaculture and fisheries or related areas are the European Commission and its affiliated institutions, the Governments of Canada (Canadian International Development Agency – CIDA and the International Development Research Centre – IDRC), Japan (Japan International Cooperation Agency - JICA), and the Kingdom of Spain, the Common Fund for Commodities, World Bank, and the Caribbean Development Bank. These are potential sources of funding for the regional hatchery project or some components of it, such as the research and development component.

European Union

The European Union is a major source of development assistance to the CARIFORUM States with funding and technical assistance provided through multiple funding mechanisms. The European Development Fund (EDF)[8] is the main instrument through which the European Union provides development assistance to the ACP States and Overseas Countries and Territories (OCTs). Each EDF is normally for a period of six years. The tenth EDF covers the period from 2008 to 2013 and provides an overall budget of EUR 22.7 billion. Of this amount, EUR 22 billion is allocated to ACP countries, EUR 286 million to OCTs and EUR 430 million to the Commission as support expenditure for programming and implementation of the EDF.

The EDF funding is allocated to ACP States under three main components: i) the national and regional indicative programme; ii) an Investment Facility managed by the

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7 The current (May 2009) draft of the Agreement Establishing the Common Fisheries Policy. Although this provision on aquaculture has survived since its introduction in 2005/2006, the negotiations regarding the scope of the Policy are ongoing and so this could change.

8 http://europa.eu/legislation_summaries/development/overseas_countries_territories/r12102_en.htm

European Investment Bank (EIB); and an "Inter-ACP" component managed jointly by the European Commission and the ACP Secretariat. The funding available under the CARIFORUM Regional Indicative Programme, the Investment Facility and the Inter-ACP Budget are especially relevant for present purposes.

Through the tenth EDF, the European Union has provided EUR 165 million to help finance a Caribbean Regional Indicative Programme over the period 2008 to 2013[9]. The Programme which is based on a CARIFORUM Regional Integration and Development strategy and an EU Response Strategy provides significant support for the following:

- Establishment of an OECS Economic Union.
- CARICOM Economic Integration, including the Single Market and Economy.
- Intra-CARIFORUM Cooperation which includes the Republic of Haiti/ Dominican Republic and Dominican Republic/CARICOM relations.
- Wider Caribbean Cooperation which covers CARIFORUM/Department Outre Mer, CARIFORUM/Overseas Countries and Territories relations and the European Union/Latin American and Caribbean process.
- Implementation of the CARIFORUM/EC Economic Partnership Agreement (EPA).
- Investing in Human Capital to provide the skills to support the priority interventions particularly in new and emerging areas, such as Competition Policy and Intellectual Property.
- Some non-focal areas including Crime and Security and Support for Civil Society/ Non-State Actors.

European Investment Bank

The European Investment Bank (EIB) was set up in 1958 by the Treaty of Rome[10] as the long-term lending Bank of the European Union. It is owned by the Member States of the European Union, and is a policy-driven bank supporting projects consistent with the European Union's objectives, especially European integration and the development of economically weak regions. A branch of the European Investment Bank was opened in Fort de France, Martinique, in 2007 to serve the CARIFORUM States and other states. The stated purpose of the Martinique office is to increase the effectiveness of EIB activities in the region, particularly with the private sector, but also with regional governments, the Caribbean Development Bank and other donor agencies, and to strengthen the Bank's identity and visibility throughout the region.

The Investment Facility managed by the EIB became effective in 2003 and supports the economic development of ACP States through private sector investments at market conditions. It also finances commercially run public sector companies, in particular those responsible for essential economic infrastructure. It provides venture capital, ordinary loans, guarantees and interest subsidies for operations considered as priorities.

The European Investment Fund (EIF), established in 1994, is an instrument for the provision of finance to small and medium-sized enterprises. The EIF provides venture capital for small firms, particularly new ones, and technology-oriented businesses. It also provides guarantees to financial institutions, such as banks, to cover their loans to SMEs. The EIF is not a lending institution: it does not grant loans or subsidies to businesses, instead, it works through existing banks and other financial intermediaries.

[9] European Community – Caribbean Region, Regional Strategy Paper and Regional Indicative Programme 2008–2013. 93pp.

[10] See information on European Union Institutions and other bodies at http://europa.eu/institutions/financial/eib/index_en.htm

The Inter-ACP budget, which is 12.3 percent of the total ACP budget (EUR 2.9 billion) under the tenth EDF, provides financing for thematic actions which are common to some or all ACP States, as well as investments in multilateral funds. In contrast to the national and regional indicative programmes, this component of the EDF promotes Intra-ACP cooperation which spans two or more geographical regions. All ACP fisheries projects have been supported under this component of the EDF over the past two decades. The recently concluded Project entitled "Strengthening Fishery Products Health Conditions in ACP/OCT countries" was financed under the eighth EDF at a cost of approximately EUR 56.7 million. Likewise, the ACP-EU Fisheries and Biodiversity Management Project which created FishBase, was an Inter-ACP Project financed under the seventh EDF; and the current EUR 30 million ACP Fish-2 Project (entitled "Strengthening Fisheries Management in ACP Countries") is funded under the ninth EDF.

Government of Canada

Canada and the CARICOM Countries have had a long-standing international relationship through which the countries of the region have benefitted from Canadian development assistance over several decades. Canada's overseas development assistance budget was approximately CAD 5.43 billion during 2008–2009[11]. The two main Canadian organizations responsible for administering Canadian overseas development assistance are the Canadian International Development Agency (CIDA) and the International Development Research Centre (IDRC).

CIDA disbursed CAD 492.1 million in development assistance in the Americas in 2007–2008. In 2007, Canada launched a CAD 600 million aid package to CARICOM to strengthen regional integration and development to be distributed over ten years. This cooperation is centered on themes of strengthening democracy, promoting freedom and human rights, facilitating economic renewal and strengthening of economic linkages and addressing security challenges[12].

The International Development Research Centre (IDRC), a Crown corporation, is one of the world's leading institutions in the generation and application of new knowledge to meet the challenges of international development. IDRC's main activity is funding applied research. At the end of 2009–2010, IDRC was supporting 1 021 research activities in 97 countries, in five themes[13]:

- Environment and natural resource management.
- Information and communication technologies for development.
- Innovation, policy, and science.
- Research for health equity.
- Social and economic policy.

The IDRC currently supports approximately 160 active projects with partners in Latin America and the Caribbean. Recent projects in the Caribbean and Latin American have included aquaculture, fisheries and coastal and marine resource conservation and management[14].

Government of Japan

The Japanese International Cooperation Agency (JICA) is a governmental agency that coordinates overseas development assistance (ODA) for the Government of Japan. It is one of the largest ODA globally with an annual budget of approximately USD 9 billion. JICA provides support for:

[11] See page 2, Statistical Report on International Development Assistance, Fiscal Year 2008–2009, CIDA, Canada.
[12] CARICOM Secretariat Press Release, at www.caricom.org.
[13] See page 2, IRDC Annual Report 2009–2010.
[14] See for example, the book entitled Coastal Resource Management in the Wider Caribbean, Ian Randle Publishers, Kingston, 2006.

- Technical assistance projects for capacity and institutional development.
- Feasibility studies and the preparation of master plans.
- Dispatch of specialists.
- Technical training programme and human resource development.
- Dispatch of Japanese volunteers.

Aquaculture and fisheries have traditionally been a priority area for Japanese ODA due presumably to their institutional capacity, expertise and interest in the sustainable use of fisheries and aquaculture. JICA has been very active in supporting national and regional aquaculture and fisheries development projects in the Latin American and Caribbean Region over the past three decades.

In November 2000, CARICOM and the Government of Japan adopted a Partnership Agreement[15] under which Japan provides ODA in several areas of economic and social development. Japan is currently providing funding and technical assistance to CARICOM under this Agreement for a development study on fisheries and aquaculture. The study[16] has as its main objective, the formulation of a master plan for sustainable fishery resource use and management, targeting local artisanal fishers and their communities, by addressing the following five main components:

- Pelagic resource development and management.
- Aquaculture development policy formulation.
- Regional fisheries database development.
- Support for community-based management.
- Education and training in the component fields in the CARICOM States.

A project inception mission[17] and a baseline survey were completed in 2009, and a preliminary master plan[18] in March 2010. Under the aquaculture component, two pilot projects, each of eighteen months duration, are being implemented, one in Belize and the other in Jamaica. In Belize, a research project is underway aimed at evaluating the cost effectiveness of using locally available low cost feed material and other low cost production techniques compared to the existing techniques which rely on the use of imported feed or commercial feed made largely from imported raw material; and determine the cost structure and profitability of small-scale tilapia farming using these low cost feed and production techniques.

In Jamaica, the feasibility of building on the existing training capabilities of the Fisheries Division to establish and operate a training centre for small-scale fish farmers and extension agents from Jamaica and other CARICOM States is being tested.

The Master Plan is expected to be completed by February 2012 after which it is hoped that Japan will continue to provide support for its implementation, or at least some components of it, under a new partnership Agreement signed on 2 September 2010 entitled “Partnership for Peace, Development and Prosperity between Japan and the Member States of the Caribbean Community (CARICOM)”.

World Bank

The World Bank (WB) has been giving increasing attention to aquaculture and fisheries in recent years in response to growing concern regarding the poor state of fisheries globally and the call for urgent reforms to achieve sustainable fisheries development through improved governance, management and conservation. The Bank stated policy

[15] The 2002 Partnership Agreement entitled “A New Framework for Japan-CARICOM Cooperation for the Twenty-first Century” was signed in Tokyo, November 2002.

[16] Scope of Work signed by JICA, CARICOM and the CRFM in December 2008.

[17] Inception Report, Study on the Formulation of Master Plan on Sustainable Use of Fisheries Resources for Coastal Community Development in the Caribbean. IC NET Ltd for JICA, July 2009. 46pp.

[18] Preliminary Master Plan, Study on the Formulation of Master Plan on Sustainable Use of Fisheries Resources for Coastal Community Development in the Caribbean. IC NET Ltd, JICA and the CRFM. 100pp.

is to help establish institutions, values, and practices that will safeguard the future of fish resources and the health and livelihood of communities who depend on these resources for their income, nutrition, and quality of life.

The Bank's current efforts in fisheries concentrate on coastal management, inland fisheries, and smallholder aquaculture operations, mostly in developing countries in Africa and East Asia. However, the Bank recently established a new Global Program on Sustainable Fisheries[19] (PROFISH) in association with other key donors and stakeholders aimed at strengthening and broadening its response to the current challenges in fisheries. The overall objective of PROFISH is to improve sustainable livelihoods in the fisheries sector and to make concrete progress towards achieving the fisheries goals identified in the WSSD Plan of Implementation. PROFISH will focus on policy reforms to achieve good governance, sustainable fisheries, and the implementation of effective fisheries strategies. Through PROFISH and other partnership initiatives, the Bank currently has a portfolio of over USD 1.2 billion in fisheries, aquaculture, coastal and aquatic environmental management and related projects serving coastal and fishing communities[20].

The Common Fund for Commodities

The Common Fund for Commodities (CFC) is an intergovernmental financial institution established by the UN Conference on Trade and Development in 1989 with a mandate to enhance social and economic development in commodity dependent developing countries, especially in the Least Developed Countries (LDC). The CFC places emphasis on poverty alleviation while supporting projects aimed at organisational strengthening, capacity building, technology transfer; market access and development; agro-processing; product competitiveness; infrastructure; marketing and access to finance, among other related activities within the commodity sector of developing states. It also promotes multi-country projects as a suitable approach to the problems and challenges in the commodity sector in its Member Countries, which is consistent with the practice in the Caribbean and Latin American Region[21].

CONCLUSION

Sustainable aquaculture in the Caribbean Region is best achieved through cooperative efforts of public and private sector actors in collaboration with donor agencies to develop the required policy, legal and institutional frameworks. Financing for research and development and for small- and medium-sized enterprises in aquaculture is a significant constraint in the region. However, several donor agencies and financial institutions are expressing renewed interest in supporting investment in aquaculture as a way of boosting food security and eradicating poverty, and are also interested in supporting regional project. The proposed regional shellfish hatchery project may benefit from such funding.

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[19] What is PROFISH? Agriculture and Rural Development, World Bank, Washington, United States of America, September 2009. 2pp.

[20] World Bank web site at http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTARD/.

[21] Annual Report for 2009, Common Fund for Commodities. See CFC's website for more information (http://common-fund.org/data/content/3.Overview.pdf).

Consumption patterns for fish and seafood in the Caribbean with special emphasis on bivalves and univalves

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PREPARATION OF THE DOCUMENT

The Food and Agriculture Organization of the United Nations (FAO) is evaluating the feasibility of a regional shellfish hatchery in the Caribbean. This project aims at encouraging sustainable aquaculture, focusing on native species of the Caribbean. Interest for a regional facility was expressed by 14 Caribbean countries through an FAO-designed questionnaire distributed to 33 countries of the Region in August 2009.

The present study is assessing the market demand of bivalves or univalves in 18 Caribbean countries, i.e. Antigua and Barbuda, Aruba, the Commonwealth of the Bahamas, Barbados, Bermuda, Cayman Islands, the Republic of Cuba, the Commonwealth of Dominica, the Dominican Republic, Grenada, the Republic of Haiti, Jamaica, Netherlands Antilles, Saint Kitts and Nevis, Saint Lucia, Saint Vincent and the Grenadines, the Republic of Trinidad and Tobago, and Turks and Caicos Islands.

THE CARIBBEAN

The Caribbean Region has a population of some 42 million people. Fish supplies (from all sources) amount to some 400 000 tonnes per annum. The average annual fish consumption is about 10.8 kg per capita, but there is a large difference between the Greater Antilles[1] (consuming less) and the Lesser Antilles (consuming more than the average). The average fish consumption is substantially below the world average.

In the collective imagination, the Caribbean stands for beaches, water and fish. However, the reality is quite different and availability of fish resources in the Caribbean Sea is surprisingly low. With the increasing tourist flow to the Caribbean Islands,

Map of the Caribbean

[1] Greater Antilles: the Republic of Cuba; Hispaniola, the Republic of Haiti, the Dominican Republic, Jamaica, the Commonwealth of Puerto Rico, and the Cayman Islands.

demand for fishery products has grown quite substantially. Most of this additional demand is satisfied by imports. In addition, some countries in the region, such as Jamaica and the Dominican Republic have a long-standing history of fish imports, mainly traditional salted cod and smoked herring, for the local population. Some of the national dishes are based on fish and seafood, such as salted cod which is the basis for many traditional recipes for breakfast dishes in many Caribbean countries.

TABLE 1

Total Caribbean catch by species (tonnes)[2]

	1950	1960	1970	1980	1990	2000	2008
Marine fishes nei	11 800	17 900	24 800	51 908	46 443	45 754	35 496
Silver carp	-	-	-	-	2 315	17 530	20 181
Caribbean spiny lobster	1 000	9 000	9 800	14 223	15 824	19 204	15 801
Stromboid conchs nei	.	750	950	5 231	15 252	9 893	13 314
Yellowfin tuna	-	-	1 120	5 730	798	5 455	7 351
Skipjack tuna	.	.	400	460	86	10 008	6 436
Nile tilapia	<0.5	<0.5	-	50	3 399	4 501	5 800
Other	11 500	29 600	100 156	161 042	187 853	107 303	64 310
TOTAL	**24 300**	**57 250**	**137 226**	**238 644**	**271 970**	**219 648**	**168 689**

Total fish production in the Caribbean was 170 000 tonnes in 2008, of which roughly one fourth coming from aquaculture. Total capture fisheries declined sharply in the last two decades, from 270 000 tonnes in 1990 to 130 000 tonnes in 2008. This decline was mainly due to the end of the Cuban long distance fleet.

The main species caught at present are tuna, coastal finfish, small pelagic, conchs and lobster. Aquaculture production, on the other hand, remained stable at about 40 000 tonnes, of which 80 percent produced in the Republic of Cuba. The most important species is silver carp with some 20 000 tonnes, while tilapia aquaculture accounts for some 5 800 tonnes.

Imports are thus, accounting for roughly half of the fish supply to the Region. These supplies are mainly salted cod, herring, canned tuna and sardines, frozen pelagic, and in recent years, tilapia and *Pangasius*.

TABLE 2

Seafood supply and consumption (including both finfish and shellfish)

Country	Total supply (tonnes)	Per capita consumption (kg)	Native population (1 000)
Antigua and Barbuda	4 484	52.1	86
Aruba	3 084	29.6	104
Bahamas	10 116	30.3	334
Barbados	11 064	43.4	255
Bermuda	2 479	38.1	65
Cayman Islands	300	5.5	55
Cuba	95 321	8.5	11 204
Dominica	2 055	30.7	67
Dominican Republic	105 715	10.8	9 814
Grenada	3 813	37.0	103
Haiti	39 045	4.0	9 720
Jamaica	82 401	30.6	2 696
Netherlands Antilles	3 998	20.8	192
Saint Kitts and Nevis	1 569	31.4	50
Saint Lucia	6 846	40.5	169
Saint Vincent and Grenadines	1 770	16.2	109
Trinidad and Tobago	19 113	14.4	1 328
Turks and Caicos Islands	992	31.0	32
Total	**394 165**	**10.8**	**36 383**

[2] In the following, the source of tables is FISHSTAT, FAO 2010, if not otherwise stated.

Protein supply in the Region is above the daily world average amount per capita, with the exception of the Republic of Haiti (0.7 g/day/capita) and the Dominican Republic (3 g/day/capita). Fish protein supply varies between 8 percent of total animal protein (the Republic of Haiti and the Commonwealth of the Bahamas) and 23 percent (Barbados). With the exception of the Republic of Haiti all countries of the region are at or above minimal standard of food requirements (in calories and proteins).

Seafood is one of the most common Caribbean recipe delicacies in the islands due in part to their geographic location. Each island will likely have its own specialty. Some prepare lobster, while others prefer certain types of fish. Barbados is known for its "flying fish", while the Republic of Trinidad and Tobago is known for its "cascadura" fish and crab. Almost in all countries, conch is available as part of the seafood consumption habits.

CONCLUSIONS: IS BIVALVE OR UNIVALVE AQUACULTURE PROFITABLE?

The study shows that there are some countries with a potential demand for bivalves and univalves. These include countries where conch are well liked such as Antigua, Bahamas, the Dominican Republic, Jamaica, Saint Kitts and Nevis, Saint Lucia, and Turks and Caicos Islands. The latter has an important conch aquaculture industry, which is albeit feeding the export rather than the domestic market. There are two countries in the Region which are importing scallops, namely, Aruba and Bermuda. For these two countries, a domestic bivalve culturing industry might be profitable.

The Turks and Caicos example demonstrated the feasibility of culturing and creating a market for a native shellfish species, as well as the potential for satisfying a demand through aquaculture. Therefore, any of the Caribbean countries could venture into a bivalve or univalve aquaculture ventures, even if the present domestic demand is not very good.

The tourist industry in all Caribbean countries is strong. In average, 14 million tourists visit the Caribbean Islands per year, with some ups-and-downs caused by the economic situation, but with an overall growing trend. This industry can utilize cultured bivalves and univalves in their menus, provided the quality of the live

TABLE 3
Per capita consumption of crustaceans, cephalopods and non-cephalopod molluscs in 18 Caribbean countries (2007) in kg

Country	Crustaceans	Cephalopods	Molluscs, excl. cephalopods
Antigua and Barbuda	7.0	0.1	8.3
Aruba	2.4	–	7.5
Bahamas	10.8	0.1	2.3
Barbados	1.3	0.2	0.8
Bermuda	4.0	0.0	6.5
Cayman Islands	0.6	–	–
Cuba	0.1	1.0	0.3
Dominica	0.2	–	0.1
Dominican Republic	0.9	0.2	0.7
Grenada	0.5	0.1	0.6
Haiti	0.2	–	0.0
Jamaica	0.6	0.0	2.0
Netherlands Antilles	1.1	0.0	0.2
Saint Kitts and Nevis	2.4	0.0	1.9
Saint Lucia	3.4	0.1	0.7
Saint Vincent and the Grenadines	0.1	0.0	0.2
Trinidad and Tobago	1.3	0.0	0.2
Turks and Caicos Islands	11.4	0.1	11.9
18 countries average	**0.6**	**0.3**	**0.5**

Source: FAO – FIPS.

specimens is good and that the safety of the product is guaranteed. The price the tourist restaurant is willing to pay depends on the situation in the country and on the category of the establishment. The relatively low priced "all inclusive" restaurants in the region might not be willing to pay a high price for quality seafood, while the upper end restaurants are good outlets for these type of products.

Very important with respect to potential demand is the strong presence of cruise ships in all Caribbean harbours. The chefs of these ships may be convinced of the quality and freshness of domestically produced bivalves or univalves, and could be encouraged to fill the cold storage holdings of the ships with this delicacy. Usually cruise ships do not buy from their destination ports, but from where they embark. Statistics show that cruise ships contribute very little to the local economy in terms of purchasing goods; there may be some exceptions in the islands.

Overall, there should be possibilities for a good domestic market of bivalves or univalves in countries with a huge population, such as the Republic of Cuba, the Dominican Republic and Jamaica. Given the present distribution structure, the products in the Republic of Cuba have to be frozen, which reduces the price of the product substantially. Those smaller countries where a conch or scallop consumption exists, such as Antigua, Aruba, the Commonwealth of the Bahamas, Bermuda, Saint Kitts and Nevis, Saint Lucia, and Turks and Caicos, should also guarantee a good demand. All the other countries, that is Barbados, the Cayman Islands, the Commonwealth of Dominica, Grenada, Saint Vincent and the Grenadines, the Republic of Trinidad and Tobago and the former Netherlands Antilles could be the base of a bivalve or univalve culture industry, intended for export. The Republic of Haiti has other problems at the moment and should not be included in this discussion.

ANTIGUA AND BARBUDA[3]

The fisheries sector in Antigua and Barbuda is generally considered to be of little significance to the country's overall economy; however, in recent years, there has been increasing recognition of its potential for the general economy and the role it plays in addressing issues related to balance of trade, food security, employment and poverty alleviation. In the past decade, fisheries has contributed, on average to half of the agricultural gross domestic product (GDP), or just under two percent of the national GDP based on current market prices.

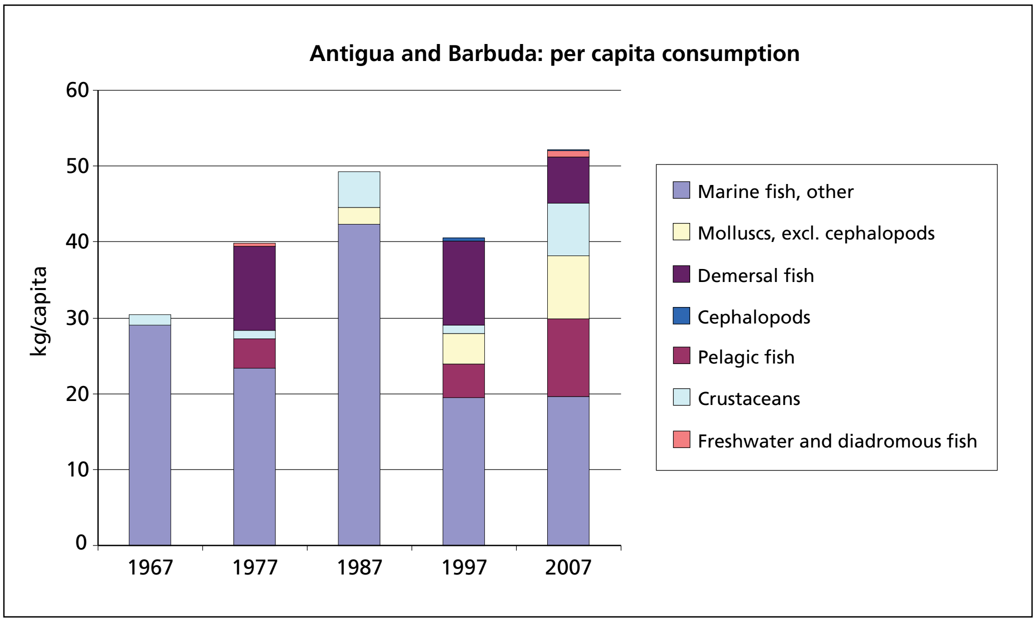
The fishery sector of Antigua and Barbuda is artisanal or small-scale commercial in nature. Capture production involves mainly small fishing units targeting demersal or reef-based resources. Demersals or reef species account for at least 85 percent of capture production.

All fishery products landed in Antigua and Barbuda are marketed fresh for direct human consumption. There are currently, only two major facilities that allow processing of fisheries products for retail (Market Wharf and Point Wharf Fisheries complexes), and both only at a very limited level. Traditional salting and drying (corning) of some species still occurs at a subsistence level.

Antigua and Barbuda supplied the French overseas territories of Guadeloupe, Martinique and Saint Barthelemy with seafood for several decades. However, with the new European Union health regulations, exports to these territories plummeted.

Hotels and restaurants buy an estimated 10 percent of landed catch, while the remainder is either sold locally or exported. Domestic markets, however, have to compete with cheaper regional imports from the Republic of Guyana and the Republic of Trinidad and Tobago. Generally speaking, there is sufficient demand and enough fish for a dynamic development of the sector; however, the development of the artisanal

[3] Tables on production, per capita consumption, imports and trade flows are given for each Caribbean country at the end of this report; for Antigua and Bermuda on pages 226–227.



fishery is hindered by the rather modest social status of the trade, tough working conditions at sea, and the availability of capital for investment.

The per capita consumption in Antigua is one of the highest in the Caribbean with 52.1 kg in 2007. While the level of consumption appears high, it has to be viewed within the context of the demands of the tourism sector, which drive imports. If the contribution of imports to food supply is ignored, per capita consumption for Antigua and Barbuda would be 13.8 kg/year, which is less than that of Europe (19.9 kg) but greater than the regional average (9.4 kg).

Antigua and Barbuda is a net importer of fish and fishery products, although domestic export of high value species (such as the spiny lobster) is slowly narrowing the trade deficit. Import levels remain high, primarily because local processors are unable to satisfy the traditional tastes for cured products (e.g. salted cod, smoked herring and pickled mackerel), as well as, the demands of the tourism sector.

Typical Antiguan recipes use cured fish products, mainly originating from Northern Europe, and combine them with tropical fruits. Salted cod is the basis for many traditional recipes. In addition, snappers are consumed fresh, in grilled or roasted form.[4] Antiguan food habits are based on British habits, which leads to an important consumption of "fish-&-chips" mainly prepared from tropical fish.

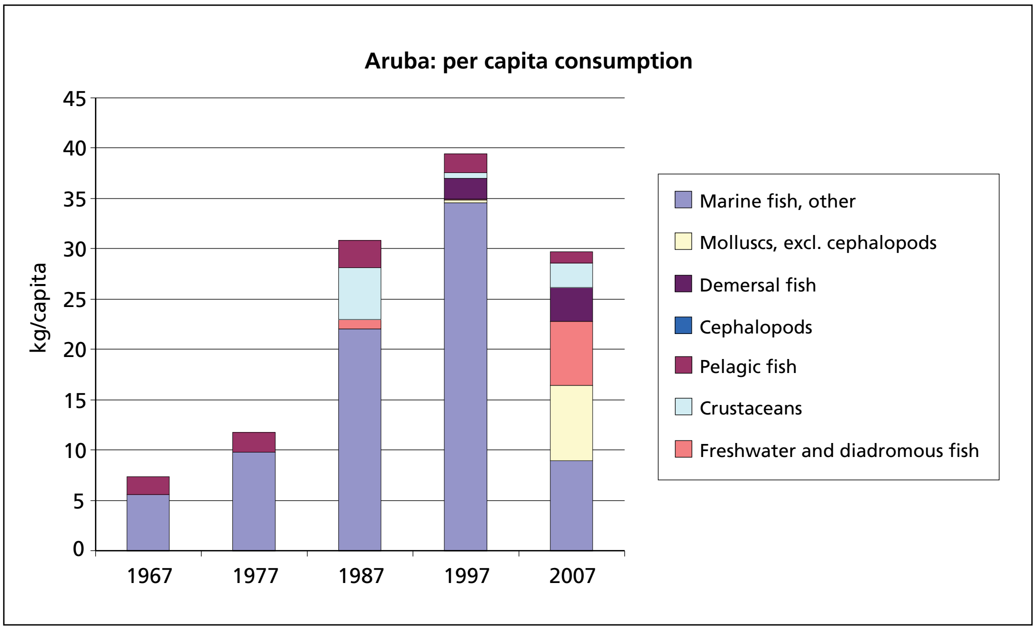
Antigua and Barbuda is a net importer of fishery products, especially traditional salted fish, but in recent years, has also imported fresh marine fish.

The trend of mollusc consumption through the years has been positive. This could indicate a potential market for native shellfish species, dependent on the most preferred product forms consumed. The tourist industry is an important driving force in the consumption of molluscs, as there is no real consumption habit among the local population for this type of seafood.

ARUBA[5]

The tourist industry is the main resource for the small island, together with some offshore banking. Aruban fish production is very small and plays a very limited role in the creation of the national GDP. Total fish production is 150 tonnes. The production includes wahoo (*Acanthocybium solandri*), snappers and groupers. Several causes for

[4] http://uktv.co.uk/food/homepage/sid/7234
[5] Statistical tables on page 228.



the low performance of the Aruba's fisheries sector include overexploitation of coastal stocks, lack of knowledge about the potential of demersal fish stocks, and inadequate fishing equipment. Imports supply exceeds domestic production by ten times, creating a strong dependence on foreign supply. Imports include live fish, frozen flatfish, prepared and preserved fish.

Aruba's per capita consumption of fish is relatively high at 30 kg per capita. However, a certain decline in per capita supply has been experienced in recent years, probably due to the increase in tourists in the country. Bivalves' consumption is important, with 7.5 kg per year. The raw material is mainly coming from imports which indicate some 100 tonnes of preserved bivalves. These are mainly scallops imported from the United States of America. Most of these imports are used in the tourist industry, in return feeding American tourists.

COMMONWEALTH OF THE BAHAMAS[6]

The Commonwealth of the Bahamas is one of the wealthiest Caribbean countries with an economy heavily dependent on tourism and offshore banking. Fisheries play a limited role in the global GDP, with an estimated 1.6 percent.

The most important fish species caught in the Bahamian waters include spiny lobster (*Panulirus argus*), snappers (various species), queen conch *(Strombus gigas*), Nassau grouper (*Epinephelus striatus*) and jacks (various species). Because of its abundance and high price the Caribbean spiny lobster is the foundation of the Commonwealth of the Bahamas fishing industry. It contributed USD 70 million out of the USD 80 million of landings recorded during 2007. Over 90 percent of spiny lobsters are exported.

The queen conch fishery represents a supplementary income-generating activity for fishers during the closed season for spiny lobster (the largest fishery in the archipelago), from 1 April to 31 July each year, particularly in the islands of Abaco, Grand Bahama and Andros. It is a largely artisanal activity, undertaken by small boats in shallow waters throughout the shallow banks

The vast majority of harvested fishery resources are for human consumption. Conch and fish are mostly consumed locally, although significant exports also take place. Tourists, many from the United States of America, are an important component of the

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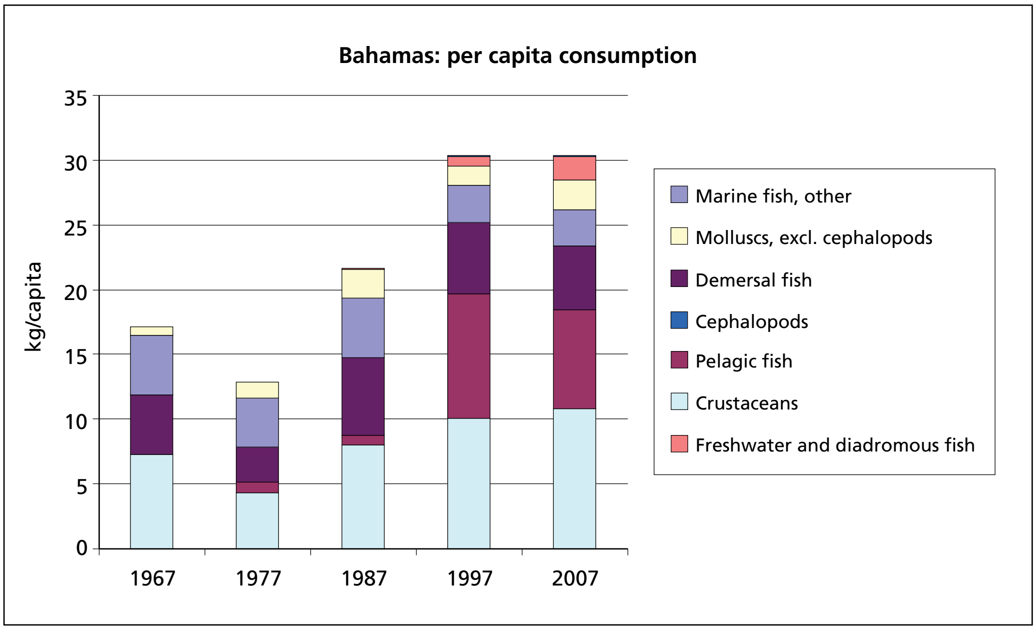
6 Statistical tables on pages 228–229.



local market. The major markets of locally consumed products are restaurants, hotels and home consumption.

There is also a local market for conch shell jewellery and artwork and a budding market for fish scale jewelry. Neither of these markets has placed additional pressure on fishery resources as no additional conch or fish are caught to supply these markets. Fishery products are also transported from other Bahamian islands to New Providence, the main market, by approximately 23 so-called "mail boats" which assure a large part of the inter-island commerce. In some instances, fishers bring their products directly to New Providence aboard their own vessel, although their home base is located on another island.

Fish consumption in the Commonwealth of the Bahamas is quite stable at 30 kg. Seafood is the staple of the Bahamian diet. Total molluscs (not cephalopod) consumption is 2.3 kg, with conch as the main item.

In the preparation of food dishes, conch meat is scored with a knife, and lime juice and spices are sprinkled over the meat. It can also be deep-fried (called "cracked conch"),[7] steamed, added to soups, salads and stews or made into conch chowder and conch fritters. These fritters are a very traditional Bahamian dish, and are excellent as an appetizer and finger food.

The Commonwealth of the Bahamas is one of the few Caribbean countries being a net exporter of fish in value terms, while in quantity terms imports exceed exports. This is mainly due to exports of the expensive lobster, while imports are more in the lower end category, such as canned tuna, mackerel and sardines.

The Bahamian "rock lobster" is a spiny variety without claws that is served broiled, minced or used in salads. Other delicacies include boiled or baked land crabs, which can be seen, before they are cooked, running across the roads after dark. Fresh fish also plays a major role in the cooking of the Commonwealth of the Bahamas – a popular brunch is boiled fish served with grits. Stew fish, made with celery, onions, tomatoes and various spices, is another local specialty.

The cuisine of the Commonwealth of the Bahamas is never ever bland. Spicy, subtly and uniquely flavoured with local meats and produce, more than any other cuisine in the West Indies, Bahamian cooking has been influenced by the American South. One very popular example of this influence is the "fish-&-grits" mentioned above.

[7] http://allrecipes.com//Recipe/conch-fritters/Detail.aspx

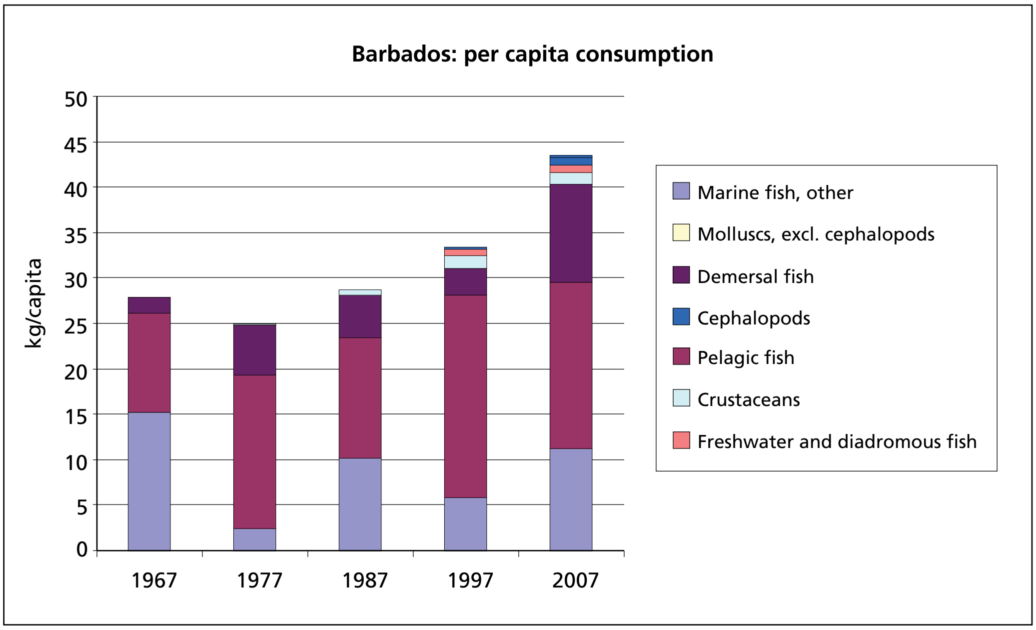
BARBADOS[8]

Total fish production in Barbados has increased in recent years, to reach 3 500 tonnes in 2008. Flying fish (*Hirundictys affinis*) is a delicacy, and accounts for 60 percent of the weight of all fish landed on the island. In 2008, capture of flying fish reached 2 300 tonnes. The second most important species is dolphin fish (*Coryphaena hippurus*), with 700 tonnes produced in 2008.

The national dish of Barbados is Cou-Cou and Flying Fish, which is steamed Flying Fish in gravy with Cou-Cou. Cou-cou is made out of corn meal and okra[9]. Flying fish travel in shoals, jumping in and out of water like dolphins. As they move through the air, their long extended fins open up as wings, hence, the flying motion which gives the fish its name.

The white sea-egg (*Tripnustes esculentus lesks*) is one of the 17 species of sea urchin (Echinoidea) which may be found in the coastal waters of Barbados. Its shell contains the golden roes which have become a local delicacy. Found in relatively shallow waters at a depth of six metres (20 feet), especially around the south coast, the sea-eggs are picked from the sea floor by divers. On the shore they break the shells, remove and wash the roes and pack them into whole shells. The sea-eggs are then steamed and marketed by hawkers. Sea-egg picking is controlled by law to avoid depletion of the species. It has therefore, become illegal to dive or market sea-eggs during any period declared closed.[10]

Imports of fish and shellfish into Barbados are quite important, with 9 000 tonnes being imported. The majority are frozen shrimp, mainly for the restaurants in the country. Bivalve and univalve consumption is very low at the moment, and these species are not really part of the traditional consumption patterns of the country. Thus, bivalve or univalve aquaculture would not have a ready market in Barbados.

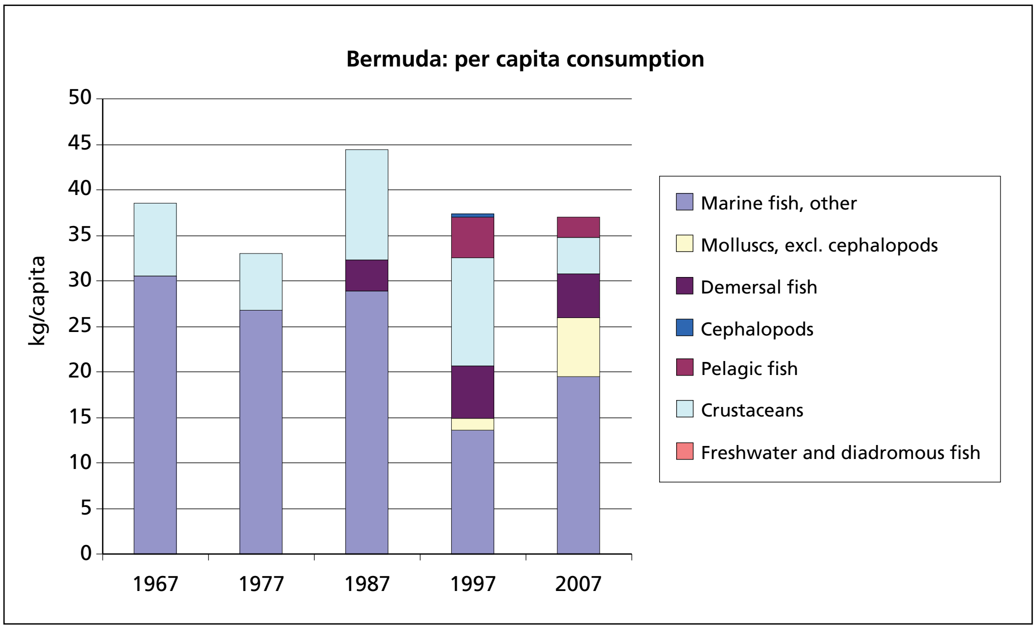


BERMUDA[11]

Fish production and consumption

The fisheries in Bermuda target mainly spiny lobster, grouper, snapper, tuna, and billfish. The fisheries are internally classified as artisanal but technologically advanced.

8 Statistical tables on page 230.
9 http://barbadostravel.squarespace.com/barbados-flying-fish
10 www.barbados.gov.bb/localrecipes.htm
11 Statistical tables on pages 231–232.



Total fish production is about 400 tonnes per year. The main species produced in 2008 was wahoo with 117 tonnes, followed by snappers and groupers. Spiny lobster plays an important role in the economy with a production of 34 tonnes in 2008.

A typical Bermudan recipe is fish chowder. It is cooked from large fish species, such as snappers and groupers.[12] In some occasions shrimp or scallops are added to the fish soup. As in other Caribbean countries, salted codfish is used for traditional breakfast meals. Fried fish fillets are also a classical Bermudan meal.

Consumption in Bermuda is quite high at about 40 kg per capita, but slightly declining in recent years. Unidentified marine fish makes up the bulk of consumption, followed by crustaceans. Scallops form an important part of the recent consumption, mainly going to the tourist market.

The strong demand and the wealth of the country, especially prior to 2008, result in high imports of all types of seafood. In recent years, scallop imports reached a significant figure of 100 tonnes imported from the United States of America. In 2008 and 2009, probably as a reaction to the economic crisis these imports declined to 6 and 4 tonnes, respectively. Here seems to be a good occasion to replace a bivalve which used to come from imports with a locally cultured species. The United States of America is the main supplier of seafood to the Bermudan market. It is interesting to see that tilapia fillet exports from this country to Bermuda reached 140 tonnes in 2009, all re-exports of Chinese tilapia.

CAYMAN ISLANDS[13]

The Cayman Islands base their existence on offshore banking. The tourist industry is aimed at the luxury market and caters mainly for visitors from North America. About 90 percent of the islands' food and consumer goods must be imported. Fish is no exception to this, about 80 percent of the consumed fish has to be imported.

In the Cayman Islands fish production is estimated at 125 tonnes. Imports vary quite a bit, but the overall trend indicates that frozen fish fillets are the main items imported and consumed in the country. Total imports were 400 tonnes in 2008. The United States of America is the main exporting country of seafood. These imports do not contain any type of bivalves or univalves.

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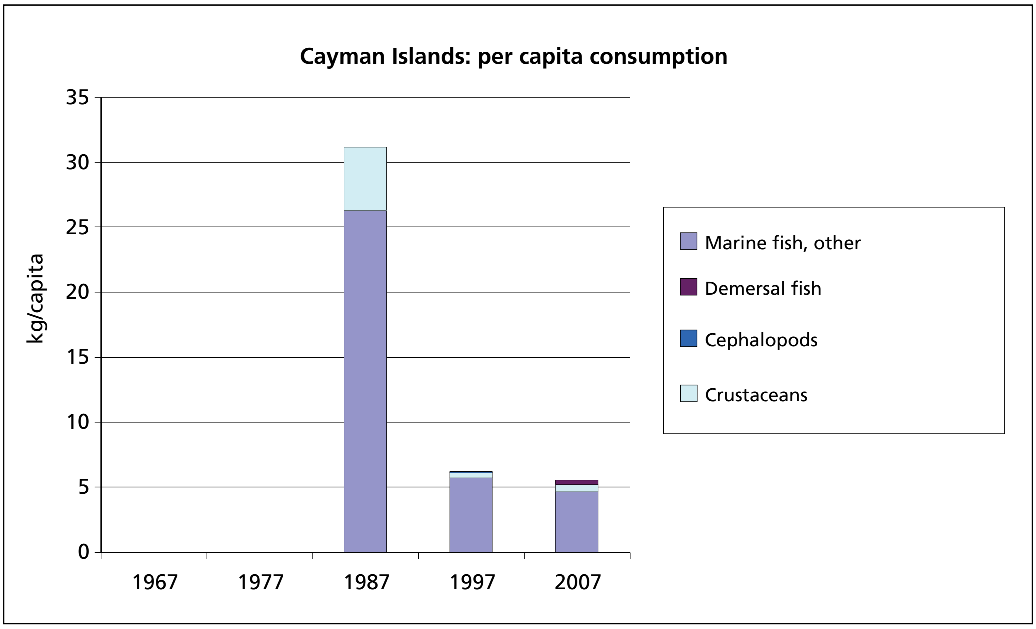
[12] http://allrecipes.com//Recipe/bermuda-fish-chowder/Detail.aspx
[13] Statistical tables on pages 232–233.



Per capita consumption is relatively low at 5.5 kg. The outlook for demand in the Cayman Islands for cultured bivalves and univalves is practically nil.

REPUBLIC OF CUBA[14]

The economy of the Republic of Cuba is a largely state-controlled, centrally planned economy overseen by the Cuban Government, though there remains significant foreign investment and private enterprise in the Republic of Cuba. Most of the means of production are owned and run by the government, and most of the labour force is employed by the State.

Tourism in the Republic of Cuba attracts over 2 million people a year, and is one of the main sources of revenue for the island. With its favourable climate, beaches, colonial architecture and distinct cultural history, the Republic of Cuba has long been an attractive destination for tourists. Foreign investment in the Cuban tourism sector has increased steadily since the tourism drive. This has been made possible due to constitutional changes to the Republic of Cuba's socialist command economy, to allow for the recognition of foreign held capital. Food supply to tourist hotels is considered as exports by the Cuban administration and is paid in hard currencies.

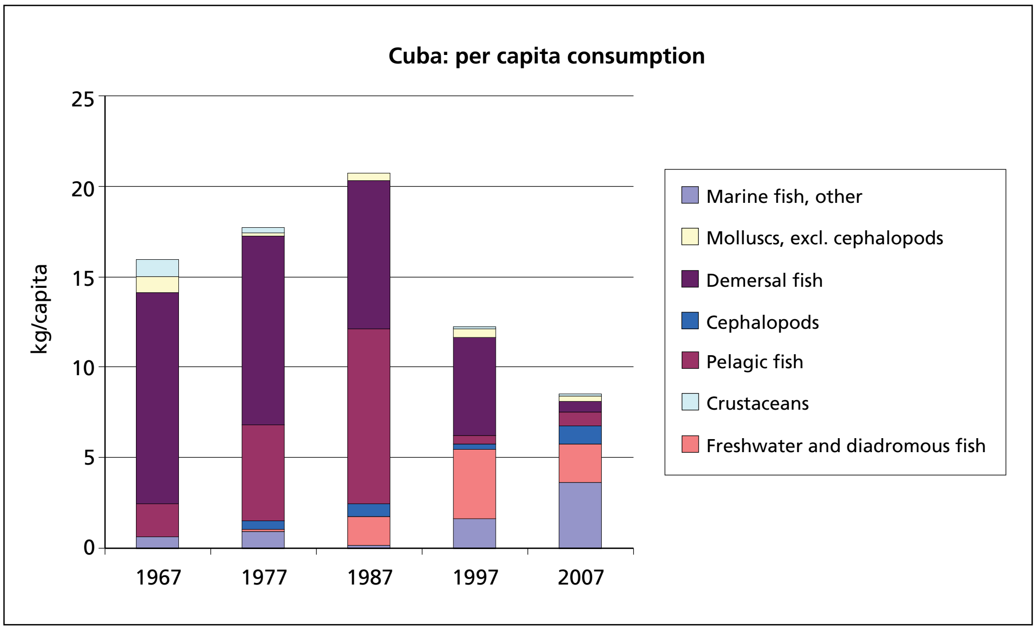
Fish production and consumption

The Cuban fish production declined sharply during the 1990s, when the long distance trawler fleet was phased out. In 2008, Cuban fisheries production was 60 000 tonnes, which compares to a peak of 240 000 tonnes in 1986. The main product produced at present is silver carp with 20 000 tonnes. This species is not very appreciated by the local population; however recently, a fish hamburger has been developed. This product was well accepted among the population.

The Cuban fisheries industry and fish consumption is characterized by export of high value species (lobster, shrimp) and the import of low value species, such as horse mackerel from the Republic of Chile and *Illex* squid from the Argentine Republic. The experience with this system is very positive, for each 1 kg of fishery products that the Republic of Cuba exports, they can import 5 kg of products for domestic consumption.

The Cuban domestic market of fishery products is divided into three major areas: 1) subsidized fish for the "libreta de in canasta basica"; 2) the specialized fish shops,

[14] Statistical table on pages 233–234.



selling in local currencies; and 3) local restaurants and shops that sell in convertible currencies (CUC), USD 4/kg. From January 2011, the "canasta basica" was reduced.

The Republic of Cuba shows one of the lowest rates of apparent seafood consumption among the Caribbean countries, which is mainly due to the complicated fish marketing structure in the country. The "canasta basica" guarantees about 1 pound of fish per month to each Cuban, while for certain groups of the population (pregnant women, children, and elderly people) this figure can reach six pounds per month. About 86 percent of the total Cuban seafood production derives from the canasta basica. As mentioned earlier, this basic supply is made up of very low value products, such as imported horse mackerel and squid, but also locally produced carp. This market segment would not be a suitable outlet for bivalves, as normally their price exceeds USD 0.10/kg, calculated for the "canasta basica". In addition to this distribution to the home market, canteens also offer fish in their menus.

The specialized fish shops, called MERCOMAR, selling in local currencies, offer quite a variety of species, which could include bivalves. Some 125 fish shops exist in the country, of which 25 in the City of Havana. The average price of fish sold in these outlets is USD 1.00/kg. The variety of species offered depends on the arrivals and the overall economic situation. Generally, the products are sold out quite quickly.

Practically all the fish consumed in the Republic of Cuba is frozen fish. This is a very distinctive feature of the Cuban fish consumption, and created by the need to store the product for longer periods. In recent years, this overall characteristic has been changing, allowing for more fresh fish sales. However, the quality control of fresh fish is more difficult, and the food quality control agencies seem to have problems in guaranteeing safe products for the market. There is no artisanal fishery in the country, only so-called subsistence fisheries which provides food for the family.

The most commonly reported marine toxin disease in the world is Ciguatera, associated with consumption of contaminated reef fish such as barracuda, grouper and snapper. Under-diagnosis and under-reporting (especially in endemic areas such as the Caribbean) makes it difficult to know the true worldwide incidence of marine toxins.

The main outlets for seafood are, however, shops selling in convertible currencies and the strong tourist industry. In the case of the Republic of Cuba, the tourist industry is considered an export market, so per capita supply does not take this part of consumption into account.

At the beginning of the 20th century, the heavy Spanish immigration made the Cuban gastronomy and cuisine even more markedly Spanish. In gastronomy, the Spaniards took up posts as cooks in restaurants and family homes. The Galician immigrants brought with them the fish recipes as well. The most characteristic feature of Cuban cuisine is this mixture where the tomato sauce with few sautéed spices or Cuban sauce takes over the rest of the ingredients. The Cuban way of cooking is natural, with very specific ingredients, scarce spices (oregano and cumin), that limits or banishes the use of pepper and other hot spices. The Cuban cooking way, that identifies its cuisine, is frying. Thus, the traditional Cuban fish recipes are fried fish fillets. It is apparent, however, that fish recipes do not figure among the typical Cuban recipes.

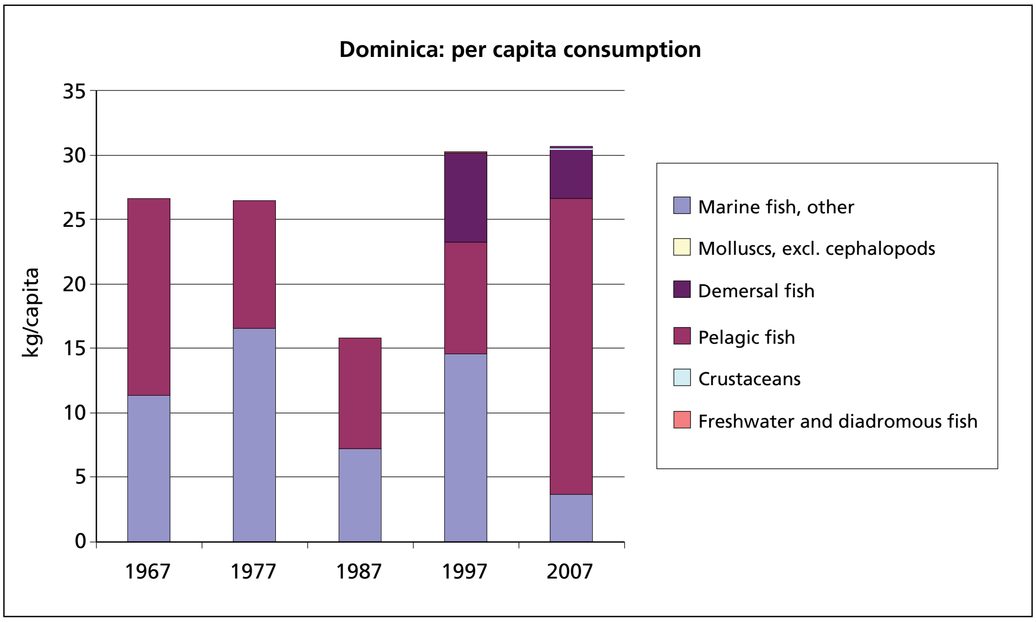
Cuban fish consumption went down in recent years, mainly due to decline in catches, attributed to the problems of the aging of the industrial fisheries. The long distance trawler fishery was dismantled in the nineties of the last century. At present, per capita supply is estimated at 8.5 kg, which compares to 20 kg back in the eighties. Cephalopods are an important part of the diet, especially in years when squid production in Argentina is plentiful. The freshwater fish supply is 2 kg, mainly carp.

The consumption of bivalves is very low. The Cuban domestic fish consumption will not be able to afford the purchase of bivalves from aquaculture production. However, the tourist industry looks like an excellent outlet for live bivalves from a potential domestic aquaculture industry. The tourist hotels nowadays offer clams, scallops and mussels in their buffets.

COMMONWEALTH OF DOMINICA[15]

The fisheries subsector employs approximately 3 100 fishers and fish vendors and contributes about 2.0 percent to GDP. The Commonwealth of Dominica fishing industry is small-scale and of an artisanal nature. The value of fish landings is about USD 2.2 million annually and most of the fish landed is consumed locally making a significant contribution to national food security. In 2007, the industry was damaged by hurricane Dean severely affecting landing and marketing sites at Scott's Head, San Sauveur and Fond Saint Jean.

All the fish caught is for local consumption. Catches declined quite sharply in recent years and were recorded at 700 tonnes, which compares to a peak of 1 200 tonnes at the turn of the century. Main species caught are wahoo and dolphin fish.



[15] Statistical tables on pages 234–235.

Most fish landed in the Commonwealth of Dominica is sold directly to the public at the landing sites. Since 1997, following the completion of the Roseau Fisheries Complex (built with the assistance of the Japanese Government), fishermen have been selling their catch directly to the Complex, particularly in times of heavy glut on the market. Overall, the complex is underutilized and has partly been destroyed by hurricanes.

With the rapid decline in the major cash crop (bananas), many farmers began moving into the fishing sector. If properly managed, the returns from fishing can be considerable. The price of fish ranges from USD 1.85–2.60/lb, depending on the village where it is landed. Prices are lower for demersal fish than for pelagics. Prices are of course lower in the more rural districts.

Fish is not usually gutted when sold to the public. Very often small pelagic fish species such as flying fish, skipjack, and robin, are sold from landing sites, but blackfin tuna, yellowfin tuna, marlin, swordfish and dolphin fish are only sold in rural communities when a glut exist. The Commonwealth of Dominica imports some quantities of canned seafood, salted cod and very small amounts of frozen fish.

Because the Commonwealth of Dominica is mostly volcanic and has few beaches, development of tourism has been slow compared with that of neighbouring islands. Nevertheless, the Commonwealth of Dominica's high, rugged mountains, rainforests, freshwater lakes, hot springs, waterfalls, and diving spots make it an attractive destination. Cruise ship stopovers have increased following the development of modern docking and waterfront facilities in the capital. Eco-tourism is also a growing industry on the island.

Due to the fact that it was under English occupation for almost two centuries and that it borders French colonies, Dominican cuisine integrates various English and French influences. The main source of protein for most inhabitants is fish such as dorado, kingfish and snapper. They also consume a large quantity of spiny lobster and octopuses. In the mountainous areas, there are crayfishes and land crabs. Main dishes include Creole fish prepared from blue marlin, dolphin, grouper, kingfish snapper and lobster in abundance.

Imports account for about one third of fish consumed in the Commonwealth of Dominica. The imports include canned mackerel, tuna and sardines, and some salted cod. The Kingdom of Thailand is an important supplier of canned tuna to the Commonwealth of Dominica market.

Consumption in the Commonwealth of Dominica concentrates on wahoo and dolphin fish, and some imported mackerel and tuna. Therefore, consumption of pelagic fish is very high at an estimated 23 kg per year.

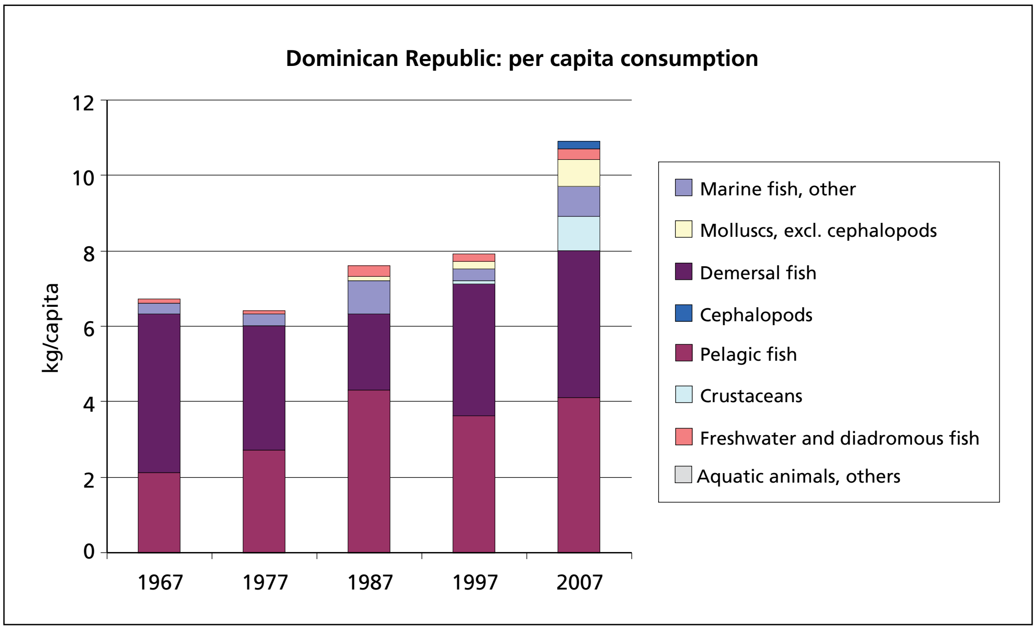
There is at present no market for bivalves or univalves, and the outlook for these products are practically nil. In addition to the local consumers, there are only very few foreigners visiting the country, so there is no outlet for bivalves or univalves in this sector either.

DOMINICAN REPUBLIC[16]

Surprisingly for a country with a long coastline, the resource base for the Dominican Republic fisheries is not very ample, and production is very low. In 2008, production was 16 000 tonnes, of which the majority are unidentified marine species. The country also has a significant conch production of around 1 000 tonnes per year.

The tourist industry is ever expanding, and is also a driving force behind higher fish consumption in the country. Tourists are visiting the Dominican Republic and expect plenty of seafood, which is not the reality. So hotels and tourist restaurant have to import fish, in order to satisfy the demand. Imports account for 80 percent of the seafood consumed in the country.

[16] Statistical tables on pages 235–236.



The Dominican Republic food mixes Spanish influences and the cultural and cooking practices of the native Taino Indians. Paella, the most famous Spanish dish, is now common in just about every Dominican kitchen. However, the paella is different from the traditional Spanish dish, as the Dominicans now seem to see it as a rice dish that involves whatever ingredients are available.

Compared to other Caribbean countries, food in the Dominican Republic is less spicy. Beef is not so common because it is very expensive. Dominicans consume goat and chicken as it is less expensive than fish and seafood. Tourists can enjoy fresh seafood, especially shrimp, marlin, mahi-mahi, rock lobster and Dorado.

Street food is important in the Dominican Republic, and one of the classic recipes is shrimp fritter, a mixture of shrimp, Munster cheese, and potato.[17]

The Dominican Republic has an important seafood market, including some traditional products such as klipfish from the Kingdom of Norway and the Republic of Iceland, and smoked herring from Canada. In 2009, the country imported some 10 280 tonnes of klipfish from the Kingdom of Norway, an impressive quantity. In the past, some of these products had been supplied through food aid, creating a good market for these products. This type of imports dates back to the 1980s, when the government at that time wanted to supply good quality protein throughout the population. The acquired taste also continues at present, and the imported klipfish and herring reach all parts of the population. There is also some unrecorded export of fish to the Republic of Haiti.

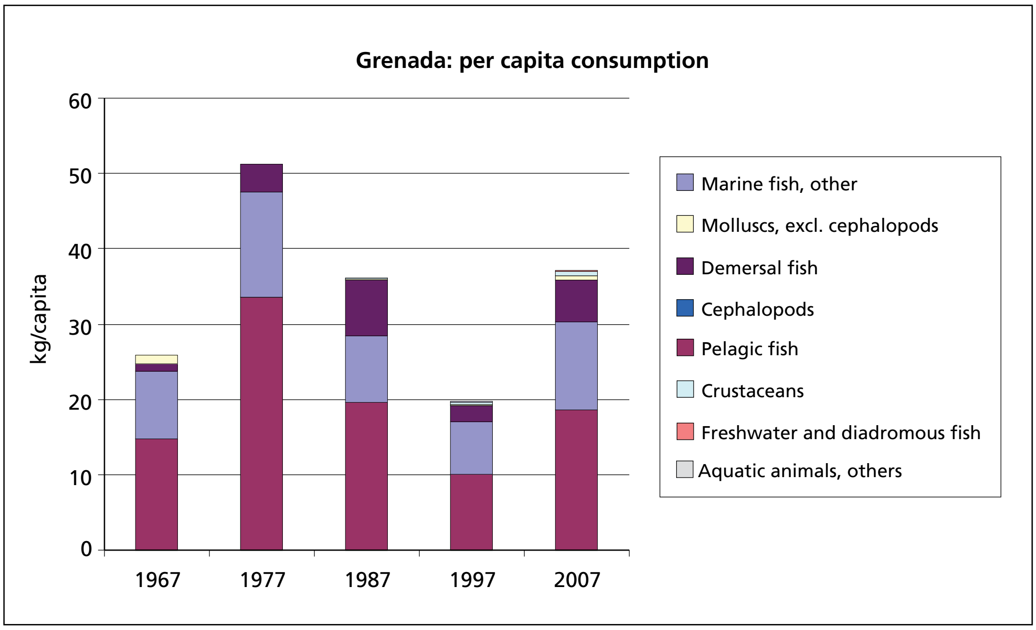
For the tourist industry, the country is importing huge quantities of cuttlefish, squid, and shrimp, all in frozen form; some limited quantities of mollusks are imported.

Overall, domestic bivalves or univalve culture should find a ready market in the Dominican Republic. The tourist industry would be interested in buying live or fresh bivalves for their buffets, and some of the present crustaceans imports could be replaced by good quality domestically produced bivalves.

GRENADA[18]

The tourist industry is growing in Grenada and contributes significantly to the local GDP. The contribution of fisheries to the national economy, too, has been increasing with an average annual contribution of USD 25.1 or about 2.5 percent of the GDP.

[17] http://latinfood.about.com/od/appetizersandsnacks/r/shrimpbomba.htm
[18] Statistical tables on page 237.



The fishery sector in Grenada is artisanal and small-scale in nature, and in recent years the sector has been developing from subsistence to commercial operations in order to increase earnings and employment, which contribute to food security and assist in reducing poverty. A major area of growth has been in the oceanic pelagic fishery that involves targeting of yellowfin tuna mainly for exports.

Total fish production increased during the last decade to reach 2 400 tonnes. Yellowfin tuna for export is the main species caught, with 755 tonnes. Other large pelagic fish also plays an important role in the production. Tropical demersal species have a relatively lower importance, with some 120 tonnes. Wahoo and dolphin fish contribute with 200 tonnes to total fish production. Tuna is mainly exported, while on the import side, salted codfish plays an important role.

Eight fish market centres are strategically located around the islands to deliver various services, but fish is also landed at thirty-seven other landing sites. These are categorized as primary (with market and port facilities), secondary (beaches/bays without infrastructure), and tertiary (processing plants).

Marketing of fish is solely a private undertaking, and self-employed fish vendors operate within the onshore facilities provided by the government. Additionally, there are fish processing establishments operated by private partnerships, companies and fisherman's co-operatives, primarily engaged in marketing of fresh fish for export. Local markets for fish consumption consist of households, hotels, supermarkets and restaurants, while exports are supplied through foreign wholesale agents.

Oildown, is Grenada's national dish and consists of a stew made with salted meat, (mainly pig), breadfruit, onion, carrot, celery, dasheen (a root vegetable grown locally) and dumplings, all boiled in coconut milk until the liquid is absorbed and the mixture becomes "oily". Conch (called "lambie") stew is another traditional dish. Conch comes from domestic landings.

Traditional fish dishes included klipfish. The dish called saltfish-souse includes salted cod, tomatoes and eggs for breakfast dishes. The saltfish is mainly imported from Norway. In 2009, imports reached 134 tonnes, which is only half of the imports one year earlier. The Grenadian Government is considering training local fishermen to produce saltfish from the local fish, rather than receiving it from imports.

Per capita supply of fish in Grenada is high at about 40 kg per annum. Apart from conch, there is no tradition in consumption of molluscs, therefore, there seems to be little opportunity for a market for cultured bivalves or univalves. As in many other

Caribbean countries, though, the tourist industry might represent an interesting market, provided the quality and the safety of the product are guaranteed.

REPUBLIC OF HAITI[19]

The Republic of Haiti is the poorest country in the Americas as per the Human Development Index. It has experienced political violence throughout its history. On 12 January 2010, a 7.0 Richter scale magnitude earthquake struck the Republic of Haiti and devastated the capital city. In recent months, a strong cholera epidemic hit the country, adding more sorrow.

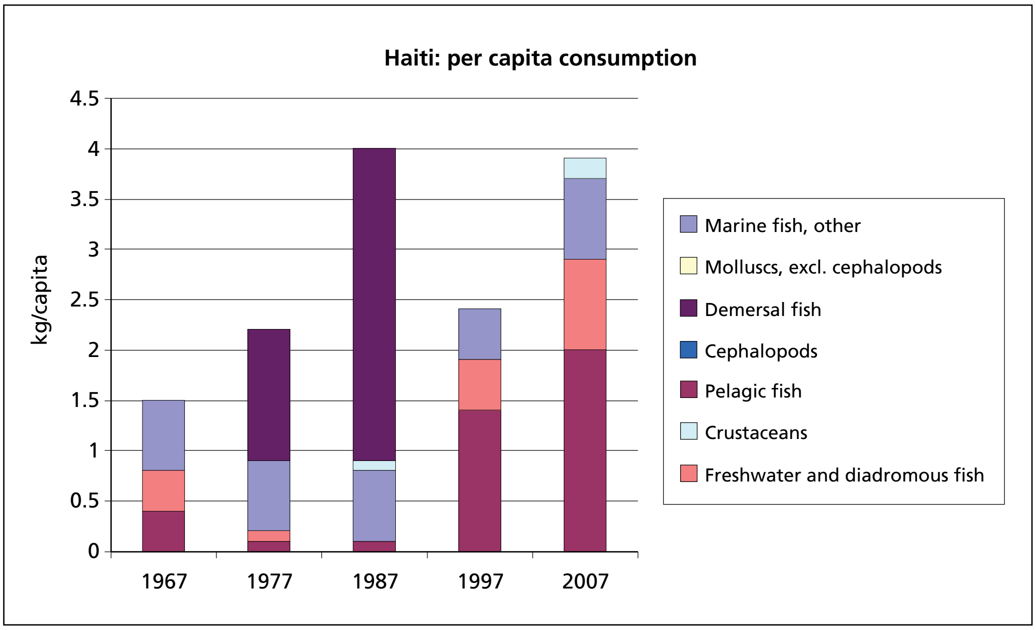
The fish market in the Republic of Haiti was severely impacted by the cholera epidemic in late 2010. Because of a call to avoid raw or undercooked shellfish and fish, people in the Republic of Haiti avoided fish altogether for fear of falling ill. This has been highly detrimental for the seafood trade. Fishermen and major distributors in this sector say they have to close down, if the situation continues.

In normal years, fish production is distributed in the following way:

- High value products (lobster, shrimp) for export markets.
- Demersal fish and large-sized pelagics for the urban market.
- Second choice fish for the rural and landing areas.
- Freshwater fish for subsistence consumption.

Haitian cuisine is kréyol cuisine, a mixture of French, African, Spanish and indigenous cooking methods, ingredients and dishes. Rice and beans are a staple. Vegetable and meat stews are popular too. Goat, beef, chicken and fish are complemented with plantains, cabbage, tomatoes and peppers. Calalou, consisting of crabmeat, salted pork, spinach, onion, okra, and peppers, and pain patate, a sweetened potato, fig, and banana pudding, is a native dish to the Republic of Haiti. Overall, however, fish plays a very marginal part of the traditional Haitian cuisine. Haiti has in fact one of the lowest fish consumption in the world estimated at 4 kg per head, pelagic fish accounts for about half of this.

Imports of fishery products are not insignificant with an average of 15 000 tonnes a year, of the lowest price range, such as horse mackerel and smoked herring. In 2010, the whole supply changed as a consequence of the earthquake. Some food aid reaching the country also included fish, however, the impact of these on the supply patterns still have to be seen.



19 Statistical tables on pages 238–239.

There are, however, some positive results as a consequence of the earthquake and the global assistance resulting from this. There is some tilapia farming starting in Lake Azuei, assisted by an American non-governmental organization, which if successful, will supply tilapia to the local population.

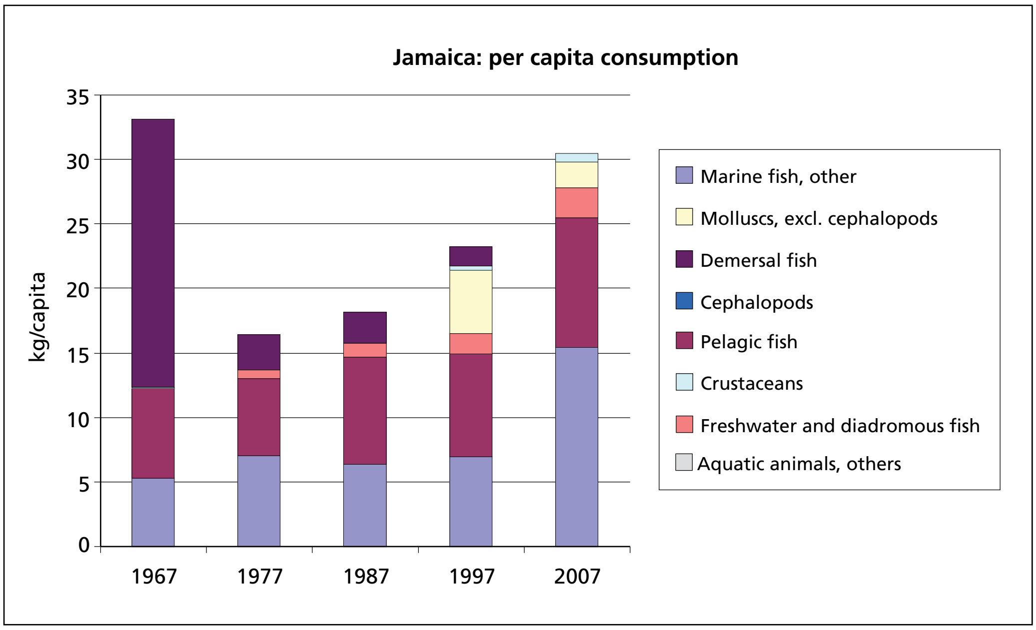
There is definitively no local market for bivalves or univalves which will unlikely develop in the near future.

JAMAICA[20]

The country continues to derive most of its foreign exchange from tourism, remittances, and bauxite/alumina. The contribution to GDP by aquaculture amounts to approximately 0.25 percent, while that of capture fisheries may be a bit higher. Apart from some small registration and licence fees, access to fishing grounds is practically free for all categories. Recent economic data on the conch and lobster fisheries are not available.

The industrial fisheries in Jamaica are mainly involved in the export of conch and lobster, but also some first quality fish is exported. Artisanal fisheries, which generally serve the domestic market, fish on the island shelf and reefs, as well as on the offshore banks, and dispose of the catch on beaches on a daily basis, or via carriers in Kingston Harbour. Industrial fishers tend to be oriented towards the export market, while the catch of artisanal fisheries is generally sold locally, either to the population or hotel chains. Shrimp is also exported, but it is not clear how much of the locally produced shrimp is sold on the domestic market, which imports a significant amount of frozen shrimp from the CARICOM area.

Artisanal fishers generally sell their catch to a vendor or sell the catch themselves on the beach. Other modes of distribution that are also used are "for own use", and supply to a wholesaler, hotel or restaurant. Very few artisanal fishers reported supplying catch to a processor. Supermarkets tend to concentrate on the sale of imported fish, including a large amount of frozen demersal fish, typically the bycatch of shrimp trawl fisheries in CARICOM countries, in addition to salted fish, a traditional component of Jamaica's breakfast. There are only a couple of dedicated fish markets in the country. Hygienic conditions are below standard at landing places where so-called fish cleaners operate. Large pelagics are not easily absorbed by the



[20] Statistical tables on pages 239–240.

local market. Hotel chains that used to buy this product are now concentrating on cheaper imported fish.

Jamaica has one of the highest fish consumption in the region with 30 kg per capita. Fish is popular in Jamaica and one can find fresh days catch on the road side or in the market at any time. A sizable demand exists for fresh fish in Jamaica. This result is manifested through:

(a) high prices of other fish in existing markets;
(b) high prices of competitive protein food products.

The head of the fish is eaten in most cases and is said to be "de bes part a de fish". The main ways of preparation are stewing, grilling, frying and steaming, always with plenty of pepper, garlic and onions. Since ancient times, Jamaica imported dried, salted codfish from the Kingdom of Norway, and also cod heads from the Republic of Iceland. The annual import of dried salted codfish from the Kingdom of Norway is around 5 000 tonnes per year, thus, representing an important part of the fish consumption in Jamaica. In 2009, Norwegian exports of salted cod to the Jamaican market reached a record of 5 129 tonnes. Saltfish together with ackee[21] a local fruit, forms a very traditional breakfast dish, widely defined as the Jamaican national dish.

Most of the marine fish not identified is probably saltfish. Bivalves and univalves (conches mainly) represent an important part of the seafood supply to the Jamaican market.

Jamaican waters contain considerable resources of fresh and saltwater fish. The chief varieties of saltwater fish are kingfish, jack mackerel, whiting, bonito, and tuna. Freshwater varieties include snook, jewfish, gray and black snapper, and mullet. There is some concern of overfishing, driven by strong demand, both from the export and from domestic markets. It is a well-established fact that near shore resources are unable to sustain fisheries at current rates of exploitation.

In April 2010, Jamaica exercised its rights under World Trade Organization (WTO) rules to suspend fish imports from South East Asia. The ban was implemented after the veterinary division of the agriculture ministry said the imports had not met sanitary and phytosanitary standards. However, on 2 November 2010, the ban was lifted, but imports of tilapia were restricted to quantities brought in before the ban. In 2009, some 250 tonnes of tilapia fillets were imported for hotels and fast food chains, while local consumers can only purchase local fish. The price of domestic produced fish is USD 5.30/lb, while the imported tilapia fillets sells at half this price.

Conch consumption is quite important in the Jamaican diet, which would indicate that there is a potential market for cultured bivalves or univalves.

FORMER NETHERLANDS ANTILLES[22]

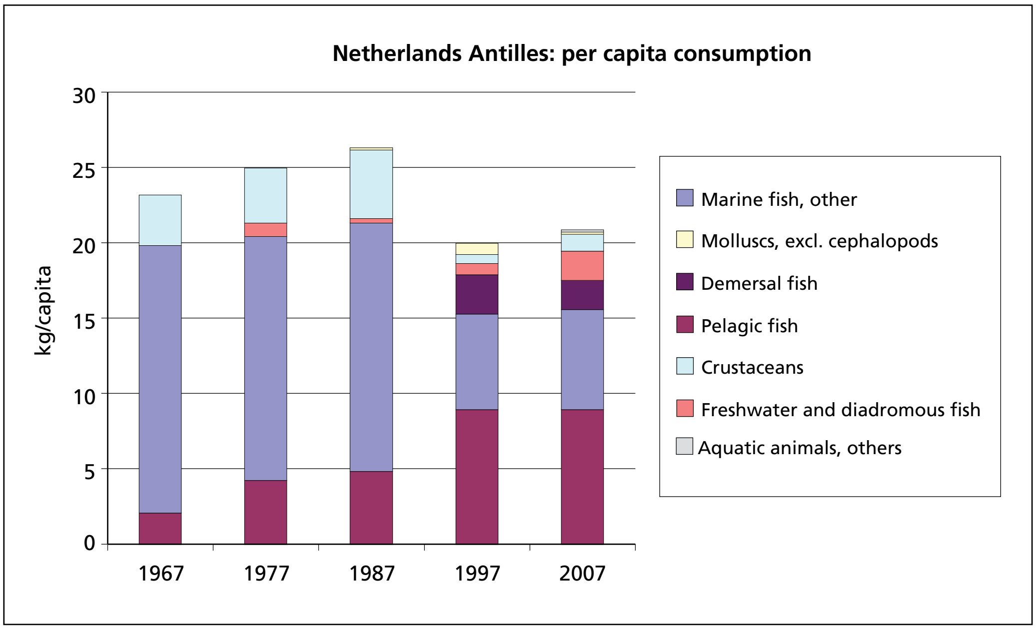
The Netherlands Antilles, an autonomous Caribbean country within the Kingdom of the Netherlands, was dissolved on 10 October 2010. After the dissolution, the islands of Bonaire, Saba, and Saint Eustatius became special municipalities of the Netherlands proper, while Curacao and St Maarten became constituent countries within the Kingdom of the Netherlands, along the lines of Aruba, which had separated from the Netherlands Antilles in 1986.

The cuisine is one of the most clearly ethnically diverse parts of Curacao. Seafood is everywhere; mahi-mahi, lobster, crab, salt cod, tuna, conch, and snapper are cooked in a variety of ways for many meals.

It is also interesting and amazing to see, how the Dutch culture has influenced the cuisine in Curacao. Indonesian cuisine plays an important role in Curacao's culinary scene. Brought to the island by the Dutch after establishing colonies in Southeast Asia,

[21] http://en.wikipedia.org/wiki/Ackee_and_saltfish

[22] Curaçao, St Maarten, Bonaire, Saint Eustatius and Saba; Statistical tables on pages 240–241.



Indonesian ingredients and cooking techniques (the so-called Padang dishes) have found their way into many favourite local recipes. One such dish is "rijisttafel" (Dutch for "rice table"), a combination of rice, vegetables, meat or seafood and the hearty kick of chili peppers.

Also the Dutch home cuisine introduced cheese into the diet; stuffed cheese is in fact the national dish of Curacao.

The tourist industry is the main source of income for the St Maarten economy. Fresh seafood appears on virtually all menus in St Maarten. Stuffed crab is a very traditional dish in Saint Maarten. Conch and dumplings is the traditional dish in Saint Maarten.

Dutch food culture in the former Netherlands Antilles does not seem to include the preference for bivalves. Thus, it is most unlikely that there would be a good market for cultured bivalves in these countries.

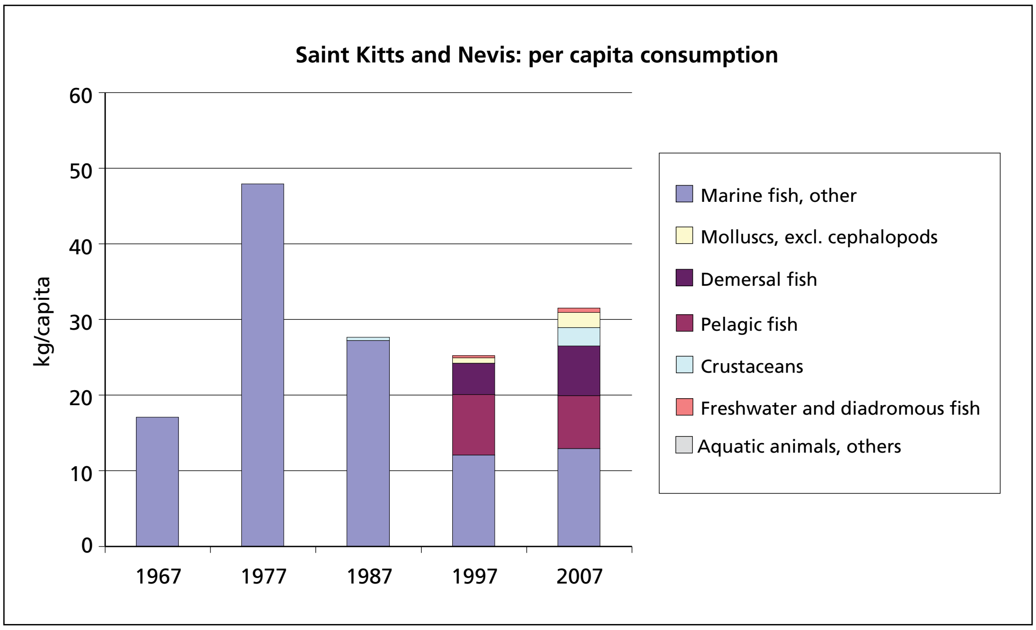
SAINT KITTS AND NEVIS[23]

The marine capture fisheries in the two islands are mainly artisanal. Capture fisheries are all marine – there are no inland fisheries. There are four major fisheries being monitored regularly, namely: demersal or reef/bank; coastal pelagic; ocean pelagic; and conch. The latter is the main species produced with 90 tonnes per year, or 20 percent of the total fisheries production of the country. In addition, the islands produced demersals, mainly goatfish, snappers and parrotfish.

Fish is usually sold at landing sites, direct from boats, except for the main fisheries centres in Basseterre and in Charlestown. Conch is the only fishery product that has significant exports. All other species caught are consumed locally. The national dish is stewed salt fish with dumplings, spicy plantains and breadfruit[24]. The salted fish is mainly imported from Canada.

In addition to the domestic production, some 1 000 tonnes are imported, which include all types of fresh and frozen fish species. Conch fritters seem to be the favourite food item in Nevis. The interesting feature for this study is that the recipes claim "You might get away with this recipe by using minced clams"[25]. This would indicate that a good market for cultured bivalves exists in those countries producing and consuming conches.

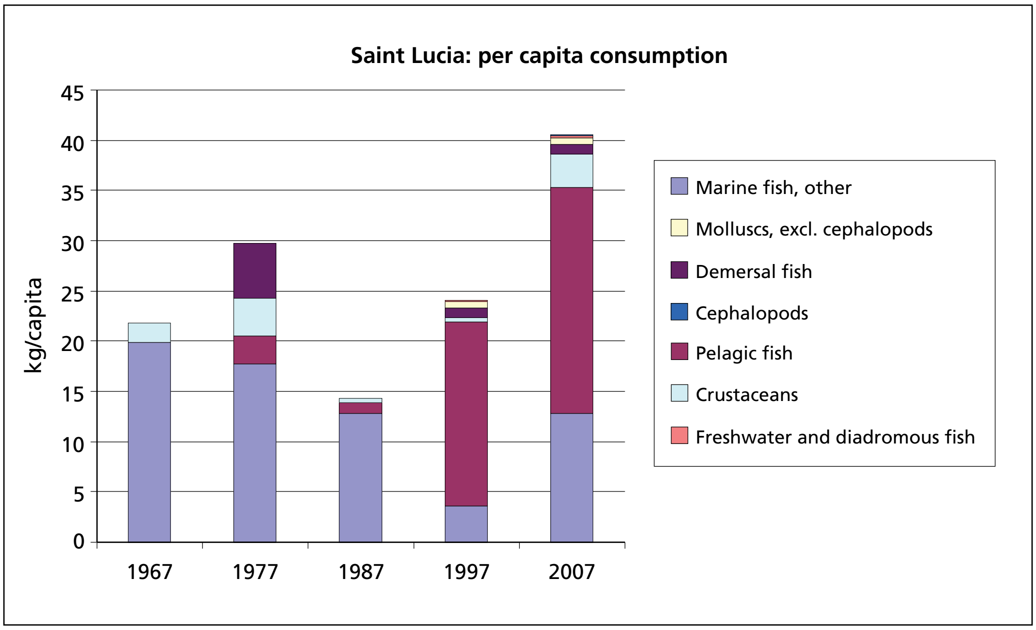
[23] Statistical tables on pages 241–242.
[24] www.caribbeanamericanfoods.com/?page=recipes&recipe_ID=16
[25] www.nevis1.com/conch-fritters-recipe.html



SAINT LUCIA[26]

Total fish landings in Saint Lucia reached 1 700 tonnes in 2008, showing an overall growing trend during the years. Over 65 percent of annual fish landings comprise offshore migratory pelagics such as dolphin fish (340 tonnes), wahoo (180 tonnes) and tuna and tuna-like species (450 tonnes) captured mainly between December and June each year. Flying fish (250 tonnes) form an important but variable component of the catch, and a multitude of shallow reef and bank fish species and several coastal pelagic species are also key components of the catch.

Virtually all the catch is consumed locally. Fish landings occur at 17 coastal communities, with the largest proportion of the catch being landed at the town of Vieux Fort, the village of Dennery and the town of Gros Islet. There are now facilities at most of the landing sites offering changing rooms, a fish market, gear mending facilities and a cooperative facility for the fishermen. At five landing sites, cold storage and/



[26] Statistical tables on pages 242–243.

or ice making facilities are also found. The main cold storage and processing facilities have been established in Vieux Fort and Castries. The Governments of Japan and of Canada have provided substantial financial and technical assistance for infrastructure development. Some vessels now use ice at sea, and fish is often transported on ice. The use of ice continues to be promoted among fishermen.

The industry provides a major portion of the fresh and frozen fish currently consumed in Saint Lucia for the local and tourism markets. The government continues to strive for self-sufficiency in fish and at present the bulk of imports are of exotic seafood (e.g. smoked salmon, shrimp, and scallops) and smoked/salted cod and herring. Imports reached 1 800 tonnes in 2008. Main imports were canned tuna and salted cod.

Throughout the history, St Lucia's cuisine has been influenced by French, West Indian and Creole food, and its most popular dishes are pepper pot stew, callaloo and fried jackfish. Shellfish and fish are a daily dish, as well as vegetables like cassava, dasheen or taro, and sweet potatoes. The national dish of St Lucia is saltfish and green fig pie[27]. This dish is made with green figs, (which are not figs but bananas), salted codfish, seasonings and cheese are the pie's filling.

Fish consumption has increased considerably, due to both expansion of the tourism sector and increased local demand for fish, partly due to the adoption of healthier lifestyles by the local population. Tourism continues to be a major focus for development, particularly with constraints facing banana on the international market.

Currently, St Lucia has the highest per capita consumption of fishery products in the region with 40 kg. It is envisaged that, given the rate of the population increase (1.6 percent) and continued growth in the tourism sector, annual demand for fish products may exceed the 4 000 tonnes mark within the next five to ten years. The government is committed to fill the gap with local produces. With the great variety of fish products already consumed in the country, and with its growing tourist industry, there seems to be a good market for cultured bivalves and univalves.

SAINT VINCENT AND THE GRENADINES[28]

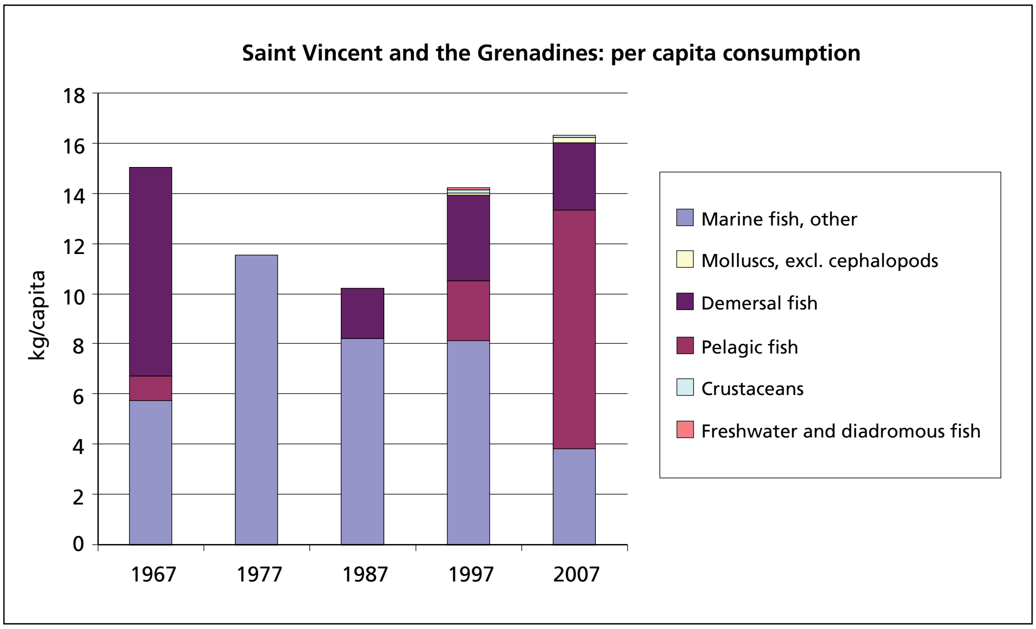
The fishing industry in Saint Vincent and the Grenadines used to be predominantly small-scale and artisanal, employing traditional gear, methods and vessels. In recent years, however, a flag of convenience fishery for yellowfin tuna has started in the country. Some 3 000 tonnes of yellowfin tuna are produced every year, landed directly in foreign ports. For the daily consumption of fish in the country, this fishery does not play any role. In the following, the text concentrates on the local fisheries. Most fishers are daily operators, going out to sea in the morning and returning to land in the late afternoon or evening.

Most of the catch is sold fresh or chilled on ice. The large pelagic species are usually gutted before they are taken to the market. The larger fishing vessels, with insulated fish holds, process their catch at sea and may keep their catch on board until it is sold. Demersals are generally not processed and are sold whole to consumers. A small quantity of lobster and conch is sold live to hotels and restaurants for storage in corrals until required for use.

A small proportion of the catch is salted and dried, mainly from unsold catch and in the Grenadines. Blackfish meat is cut into strips and dried on bamboo, while the blubber is boiled to a crisp in vats to extract the oil. The crisps remaining from the blubber is sold as "blackfish crisps". Fish is often filleted or sliced, tray packed, and sold in supermarkets. Small quantities of fish are filleted, dipped in brine, lightly smoked and vacuum packed for sale to restaurants and for export. Roasted breadfruit

[27] http://uptodatestlucia.com/listing.php?id=55

[28] Statistical tables on pages 243–244.

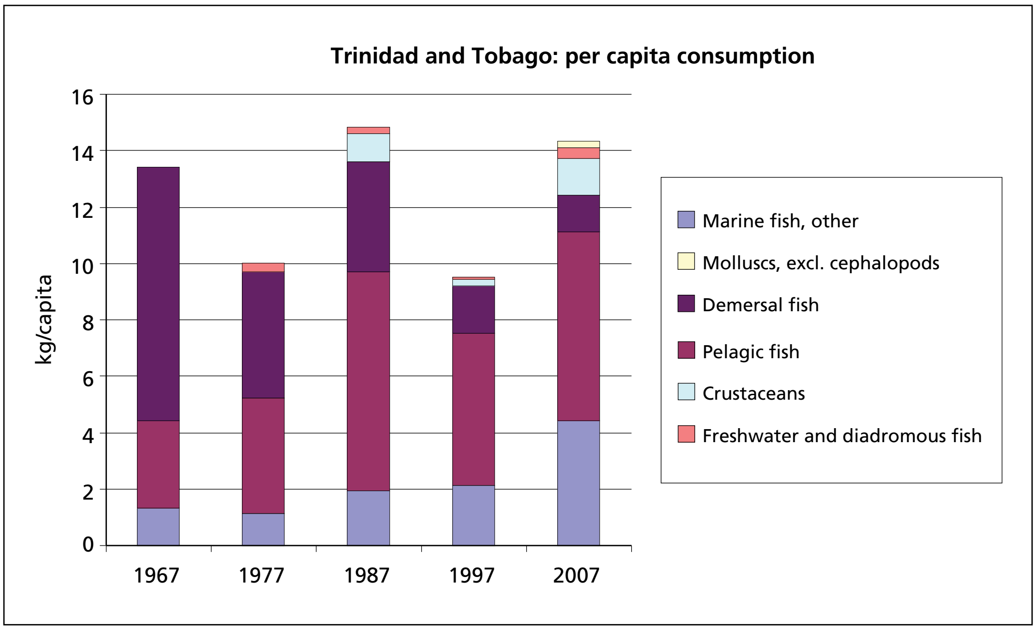


and fried jackfish[29] is the national dish of Saint Vincent and the Grenadines. This dish is often served with Golden Apple Drink, which is the national drink.

In addition to the catch destined to local consumption which is about 700 tonnes, some 600 tonnes are imported (products weight), again mainly salted cod for the traditional breakfast meals. There is no market for cultured bivalves or univalves, as the present preference for this type of food is practically nil. Conch catches account for a mere 4 tonnes per year.

REPUBLIC OF TRINIDAD AND TOBAGO[30]

The inshore artisanal contributed to an estimated 75–80 percent of the landing, estimated at 13 800 tonnes in 2008. In the local domestic market, fish landed at landing sites around the country are generally purchased by processing plants or wholesalers who may resell to supermarkets, hotels, and restaurants of retail vendors.



[29] www.tastethecaribbean.eu/reciperoastedbreadfruit.html

[30] Statistical tables on pages 244–245.

In general, the infrastructure for the handling and marketing of fish at landing sites cannot be classified as well developed, since many of the sanitary requirements fall short of the established standards. There are three major wholesale markets in the Republic of Trinidad while in Tobago there are four principal purchasing areas, although they cannot be classified as markets in the true sense as those in Trinidad.

International trade in fish and fish products out of Trinidad and Tobago comprise mainly the export of shrimp, flying fish, dolphin fish, swordfish, snappers and tunas either frozen or chilled with minimal processing and little value added. All the flying fish is exported out of Tobago in the frozen form.

Imports are mainly saltfish, from Northern European and Canada. In addition, some canned tuna and sardines are imported, together with frozen marine fish.

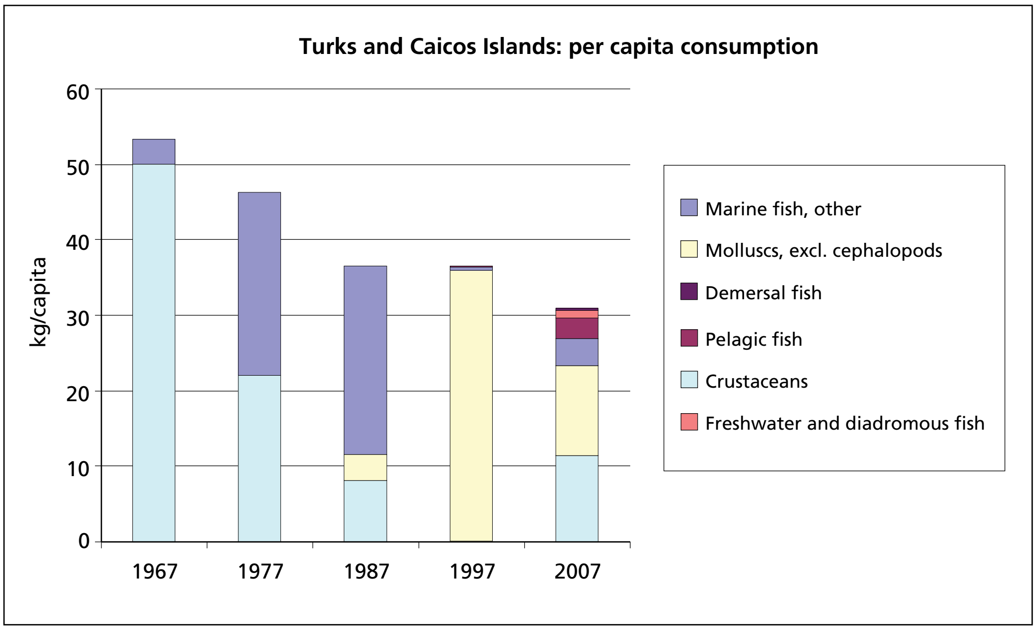
Crab and Calalloo[31] is a favourite dish of Trinidad and Tobago, and generally considered as a national dish. Crab and Calalloo is prepared and served on Sundays during lunchtime. This dish is traditionally made with ocean fresh land crabs[32].

The overall consumption patterns indicate very limited potential for cultured bivalves or univalves in the country. Compared to other Caribbean countries, the tourist industry is still very limited, which also does not help any potential demand for these species.

TURKS AND CAICOS ISLANDS[33]

The Islands are home to a vast array of seafood, such as lobsters, conch and various types of seafood.

As in other Caribbean countries, Conch Chowder is an important dish.[34] Conch is a major staple in the Turks and Caicos diet, with conch aplenty in the islands' shallow waters and the world's only conch farm. As the fishery sector on the islands is mostly artisanal and landings are mainly composed of conchs and other coastal species, queen conch fishing represents a source of food and income for practically all the fishers recorded in Turks and Caicos. The conch fishery in the Turks and Caicos Islands appears to be in a good state and the resource well-managed.



[31] Callaloo: made of tender Dasheen leaves.
[32] http://caribbeanpot.com/tag/trinidad-callaloo
[33] Statistical tables on pages 245–246.
[34] www.islands.com/article/Conch-Recipes

Local restaurants use conch provided by area divers, but the conch farm exports at least 13 000 pieces of conch meat a week to high-end restaurants in New York and Miami (United States of America). In fact, total production of conch is 5 600 tonnes per year, an outstanding figure.

Conch is quickly becoming a rising star food with top chefs from the United States of America and round the World choosing to use Turks and Caicos Conch Farmed products in their new dishes. The Conch Farm specializes in exporting the conch including Pacific Rim, Ocean Escargot and Island Princess Conch. The farm even offers tourist tours to its premises. This conch farm is a very successful example demonstrating the potential for native shellfish species and culture systems can easily be adapted by other Caribbean countries.

Statistical tables[34]

TABLE 4
Yearly imports of fish and fishery products (USD 1 000)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008
Antigua and Barbuda	3 954	1 618 F	2 623 F	5 391 F	4 187 F	4 877	6 423	7 882	6 545 F
Aruba	9 926	9 640	10 262	11 546	12 828	12 190	13 074	14 164	14 888
Bahamas	14 765	13 725	14 387	13 200	14 638	16 688	17 990	17 806	21 780
Barbados	10 886	12 360	13 346	13 516	11 673	17 269	18 750	18 847	20 291
Bermuda	7 030 F	8 387 F	8 204 F	8 274 F	8 431 F	8 203 F	8 639 F	7 286 F	6 116 F
Cayman Islands	954 F	1 492 F	1905 F	1 880 F	1 623 F	855 F	2 997 F	4 005 F	2 796 F
Cuba	43 005	37 387	29 088	36 165	51 556	51 413	39 443	49 188	66 390
Dominica	1 581	1 254	1 408	1 312	1 551	1 645	1 666	1 815	1 964
Dominican Republic	52 992 F	57 099 F	71 875 F	57 377 F	67 572 F	94 992 F	108 223 F	102 195 F	140 418 F
Grenada	2 181	2 556	2 557	2 550	2 676	2 965	3 919	4 701	4 619
Haiti	5 949 F	7 085 F	4 694 F	7 912 F	8 628 F	9 827 F	16 511 F	17 014 F	21 882 F
Jamaica	51 608	59 693	58 193	59 323	59 737	76 796	81 110	94 406	102 792
Netherlands Antilles	8 184 F	7 015 F	4 507 F	6 143 F	6771 F	7734 F	10 256 F	11 126 F	14 001
St Kitts and Nevis	2 807	2 063	1 946	1 862	2 654	982	4 114	3 927	3 538 F
St Lucia	4 795	4 147	4 237	5 065	5 618	5 988	6 319	6 810	8 338
St Vincent and the Grenadines	1 146	1 290	1 358	1 395	1 609	1 889	2 033	2 226 F	2 523
Trinidad and Tobago	7 066	8 726	11 758	12 063	13 729	21 990	19 443	25 655	26 615
Turks and Caicos Islands	2 001	2 154	2 120	2 316	2 258	2 242 F	2 372 F	1 896 F	1 505 F
TOTAL	**230 830**	**237 691**	**244 468**	**247 290**	**277 739**	**338 545**	**363 282**	**390 949**	**467 001**

TABLE 5
Yearly imports of fish and fishery products (tonnes, product weight)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008
Antigua and Barbuda	1 643	439 F	739 F	1 679 F	1 442 F	1 553	1 806	2 180	1 455 F
Aruba	1 705	1 575	1 630	1 959	2 013	1 782	2 188	2 021	2 145
Bahamas	4 966	4 080	3 595	3 694	3 340	3 496	3 907	8 788	9 860
Barbados	3 798	4 343	4 769	4 853	4 411	8 168	9 258	14 676	9 026
Bermuda	995 F	1 300 F	1 161 F	1 088 F	1 120 F	1 109 F	1 083 F	960 F	948 F
Cayman Islands	139 F	223 F	260 F	250 F	261 F	171 F	500 F	855 F	417 F
Cuba	35 035	33 979	22 514	37 736	54 667	43 727	22 797	35 759	41 708
Dominica	676	571	574	510	583	517	431	556	523
Dominican Republic	28 630 F	28 311 F	37 698 F	32 817 F	37 594 F	38 642 F	45 009 F	40 477 F	47 133 F
Grenada	673	974	923	1 228	1 191	1 310	1 555	1 406	1 121
Haiti	9 054 F	11 005 F	6 660 F	8 834 F	10 426 F	9 432 F	13 535 F	14 484 F	15 079 F
Jamaica	23 363	27 672	28 398	28 886	28 472	30 633	32 342	35 605	30 895
Netherlands Antilles	2553 F	2302 F	1451 F	1722 F	1889 F	1415 F	1945 F	2085 F	3 728
St Kitts and Nevis	1 157	802	857	616	663	565	805	729	1 212 F
St Lucia	1 243	1 134	1 321	1 515	1 943	2 649	1 830	1 844	1 867
St Vincent and the Grenadines	420	427	427	472	470	489	476	503	589
Trinidad and Tobago	4 028	5 845	8 619	7 044	8 323	12 844	8 806	9 090	8 570
Turks and Caicos Islands	323 F	367 F	338 F	339 F	358 F	308 F	342 F	307 F	257 F
TOTAL	**120 401**	**125 349**	**121 934**	**135 242**	**159 166**	**158 810**	**148 615**	**172 325**	**176 533**

[34] In the following pages, for each country the landings of the seven main species, the per capita supply and the imports are listed. For the per capita supply tables the source is FAO-FIPS, for all other tables the source is FISHSTAT FAO 2010. F= FAO estimate; nei= not elsewhere identified.

TABLE 6
Yearly exports of fish and fishery products (USD 1 000)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008
Antigua and Barbuda	190	706 F	971 F	1 395 F	679 F	328	734 F	259	1 089 F
Aruba	246	358	777	435	1 017	251	70	82	23
Bahamas	109 952	73 770	91 574	108 339	87 158	78 036	95 041	84 100	82 509
Barbados	1 252	1 347	928	887	878	1 440	780	993	771
Bermuda	272 F	46 F	46 F	78 F	4 F	94 F	44 F	15 F	283 F
Cayman Islands	180 F	94 F	108 F	50 F	213 F	196 F	397 F	77 F	–
Cuba	88 116	80 110	93 121	65 443	89 221	73 561	69 419	81 563	79 740
Dominica	1	<0.5	11	21	8	37	1	6	6
Dominican Republic	2 965	2 905	3 738 F	4 286 F	3 093 F	5 308 F	6 410 F	4 882 F	4 227 F
Grenada	3 408	4 052	3 863	3 258	3 086	3 517	3 734	4 115	2 957
Haiti	3 969 F	3 868 F	4 449 F	4 130 F	3 586 F	4 269 F	3 818 F	5 029 F	4 875 F
Jamaica	10 001	11 817	5 531	8 177	7 411	9 545	10 820	8 447	8 241
Netherlands Antilles	5 696 F	5 952 F	5 285 F	9 168 F	9 987 F	5 261 F	6 304 F	6 172 F	21 670 F
St Kitts and Nevis	245	131	149	267	196	45	242	422	297 F
St Lucia	28	47	106	40	10	1	1	<0.5	107
St Vincent and the Grenadines	961	630	712	510	410	434	217	269	510
Trinidad and Tobago	10 630	10 503	11 438	9 977	6 894	8 646	10 002	8 732	10 470
Turks and Caicos Islands	3 837	3 981	3 793	3 517	5 345	8 831 F	8 094 F	8 900 F	7 366 F
TOTAL	**241 949**	**200 317**	**226 600**	**219 978**	**219 196**	**199 800**	**216 128**	**214 063**	**225 141**

TABLE 7
Yearly exports of fish and fishery products (tonnes, product weight)

Country	2000	2001	2002	2003	2004	2005	2006	2007	2008
Antigua and Barbuda	27	369 F	129 F	577	113	50 F	225 F	36	288 F
Aruba	81	110	335	242	190	106	13	10	4
Bahamas	3 930	2 734	2 810	3 604	2 785	2 310	2 649	5 136	5 445
Barbados	280	329	208	241	249	391	237	236	169
Bermuda	15 F	<0.5 F	3 F	94 F	20 F	9 F	21 F	2 F	20 F
Cayman Islands	100 F	62 F	60 F	8 F	36 F	102 F	75 F	34 F	–
Cuba	7 699	6 877	8 784	6 283	10 292	6 750	7 244	7 113	6 108
Dominica	<0.5	<0.5	4	3	2	4	<0.5	1	1
Dominican Republic	1 907	2 178	1 884 F	2 043 F	1 493 F	1 615 F	1 454 F	1 195 F	1 206 F
Grenada	1 143	709	624	630	455	497	519	530	436
Haiti	639 F	634 F	743 F	616 F	654 F	477 F	444 F	553 F	577 F
Jamaica	811	1 352	500	904	1 241	1 467	1 601	1 124	1 249
Netherlands Antilles	7 326 F	7 925 F	6 608 F	8 320 F	9 305 F	5 488 F	6 069 F	4 555 F	11 880 F
St Kitts and Nevis	73	43	35	135	156	25	62	95	70 F
St Lucia	2	1	15	2	1	<0.5	<0.5	<0.5	25
St Vincent and the Grenadines	251	140	140	95	74	53	34	46	51
Trinidad and Tobago	4 366	5 098	5 076	4 008	3 091	3 217	6 483	3 929	3 771
Turks and Caicos Islands	569	537	499	492	729	922 F	845 F	878 F	858 F
TOTAL	**29 219**	**29 098**	**28 457**	**28 297**	**30 886**	**23 483**	**27 975**	**25 473**	**32 158**

TABLE 8
Antigua and Barbuda – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Caribbean spiny lobster	–	<0.5	100	64	97	275	165
Groupers seabasses nei	–	–	–	–	–	–	258
Grunts sweetlips nei	–	–	–	–	–	–	216
Parrotfishes nei	–	–	–	–	–	–	259
Snappers jobfishes nei	–	–	–	–	–	–	525
Stromboid conchs nei	–	–	–	–	104	315	1 357
Surgeonfishes nei	–	–	–	–	–	–	236
Other	100	600	800	1 107	684	1 164	505
Totals	**100**	**600**	**900**	**1 171**	**885**	**1 754**	**3 521**

TABLE 9

Antigua and Barbuda – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Marine fish, other	28.9	23.3	42.2	19.4	19.6
Pelagic fish	–	3.8	–	4.5	10.2
Molluscs, excl. cephalopods	–	–	2.3	3.9	8.3
Crustaceans	1.5	1.2	4.7	1.2	7.0
Demersal fish	–	11.1	–	11.0	6.0
Freshwater and diadromous fish	–	0.3	–	–	0.9
Cephalopods	–	–	–	0.4	0.1
Totals	**30.4**	**39.7**	**49.2**	**40.3**	**52.1**

TABLE 10

Antigua and Barbuda – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	190	706 F	971 F	1 395 F	679 F	328	696 F	259	1 089 F
Re-export Value	26	–	–	–	–	4	–	68	–
Import Value	3 954	1 618 F	2 623 F	5 391 F	4 187 F	4 877	6 423 F	7 882	6 545 F

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	27	369 F	129 F	577 F	113 F	50	171 F	36	288 F
Re-export Value	4	–	–	–	–	–	–	5	–
Import Value	1 643	439 F	739 F	1 679 F	1 442 F	1 553	1 806	2 180	1 455 F

TABLE 11

Antigua and Barbuda – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000 F	2001 F	2002 F	2003 F	2004 F	2005	2006	2007	2008 F
Marine fish, fresh or chilled, nei	6	0	79	109	2	–	–	–	282
Miscellaneous dried fish, whether or not salted, nei	82	47	29	32	49	402	344	348	164
Tusk, dried, salted or in brine	143	121	143	153	164	–	–	–	132
Fish fillets, frozen, nei	173	5	16	23	180	112	161	139	123
Sardines, sardinellas, brisling or sprats, prep. or pres	–	7	0	3	6	51	103	101	101
Tunas prepared or preserved, not minced, nei	166	59	28	38	47	190	169	251	85
Shrimps and prawns, frozen, nei	84	0	62	811	113	126	175	125	68
Fish meat, whether or not minced, frozen, nei	45	–	26	76	70	57	105	90	64
Saithe, dried, salted or in brine	36	33	40	36	60	–	–	–	60
Herrings nei, smoked	8	19	31	34	44	22	35	35	52
Mackerels nei, salted or in brine	24	27	32	32	43	–	–	–	41
Jack and horse mackerel prep. or pres. not minced	–	–	–	17	33	–	–	–	35
Mackerel prepared or preserved, not minced, nei	31	14	20	14	34	–	–	–	31
Squid rings, frozen	–	–	–	3	–	–	–	–	19
Tilapia fillets, frozen	–	–	–	–	1	–	–	–	15
Squids, frozen	–	–	1	–	0	–	–	–	15
Marine fish nei, minced, prepared or preserved	10	–	12	9	5	5	8	7	14
Shrimps and prawns, not cooked, frozen	–	–	5	4	6	–	–	–	12
Pilchards (*Sardinops* spp.), prep. or pres.	74	–	–	0	0	–	–	–	12
Salmonoids, frozen	2	–	29	23	15	4	11	1	11
Swordfish meat, frozen	–	–	–	–	–	–	–	–	10

TABLE 12
Aruba – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Atlantic sailfish	–	–	<0–5	30	13	–	–
Freshwater fishes nei	<0–5	<0–5	<0–5	<0–5	<0–5	–	–
Groupers nei	–	–	–	–	–	18	16
Marine fishes nei	<0–5	200	300	625	337	40	45
Snappers, jobfishes nei	–	–	–	–	–	45	40
Wahoo	–	–	100	115	70	60	50
Other	0	0	0	0	0	0	0
Totals	**0**	**200**	**400**	**770**	**420**	**163**	**151**

TABLE 13
Aruba – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	246	358	777	435	1 017	251	70	82	23
Import Value	9 926	9 640	10 262	11 546	12 828	12 190	13 074	14 164	14 888

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	81	110	335	242	190	106	13	10	4
Import Value	1 705	1 575	1 630	1 959	2 013	1 782	2 188	2 021	2 145

TABLE 14
Aruba – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Fish live, nei	639	609	601	713	748	653	589	711	765
Flatfishes nei, frozen	445	312	352	408	392	334	430	507	591
Marine fish nei, prep. or pres. not minced	447	416	435	563	500	449	759	479	471
Molluscs and other aq. invertebrates, prep. or pres.	–	57	65	73	130	117	121	104	98
Marine fish, fresh or chilled, nei	58	86	62	81	98	90	151	91	74
Yellowfin tuna, fresh or chilled	–	31	36	54	64	62	55	48	74
Crab meat nei, prepared or preserved	–	26	35	21	40	60	55	41	43
Shrimps, prawns, prepared or preserved, nei	–	13	14	11	19	2	13	13	19
Pacific salmon, frozen, nei	–	7	5	6	4	3	4	3	6
Skipjack tuna, fresh or chilled	–	18	25	29	18	12	11	24	4
Crustaceans and molluscs, prep. or pres., nei	116	–	–	–	–	–	–	–	–

TABLE 15
Aruba – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Marine fish, other	5.5	9.7	22.0	34.5	8.9
Molluscs, excl. cephalopods	–	–	0.0	0.3	7.5
Freshwater and diadromous fish	–	–	0.9	0.1	6.3
Demersal fish	–	–	–	2.1	3.4
Crustaceans	–	–	5.2	0.5	2.4
Pelagic fish	1.8	2.0	2.7	1.9	1.2
Cephalopods	–	–	–	0.0	–
Totals	**7.3**	**11.7**	**31.0**	**39.5**	**29.6**

TABLE 16
Bahamas – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Caribbean spiny lobster	–	700	1 100	2 894	5 808	9 023	6 896
Groupers nei	–	–	400	808	490	132	102
Grunts sweetlips nei	–	–	100	170	28	62	50
Marine shells nei	–	–	–	–	6	40	71
Nassau grouper	–	–	–	–	–	226	171
Snappers nei	–	–	200	376	254	721	936
Stromboid conchs nei	–	–	100	322	335	667	858
Other	600	900	200	427	620	239	103
Totals	**600**	**1 600**	**2 100**	**4 997**	**7 541**	**11 110**	**9 187**

TABLE 17

Bahamas – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Crustaceans	7.2	4.3	8.0	10.0	10.8
Pelagic fish		0.8	0.7	9.6	7.6
Demersal fish	4.6	2.7	6.0	5.5	4.9
Marine fish, other	4.6	3.8	4.6	2.9	2.8
Molluscs, excl. cephalopods	0.7	1.2	2.2	1.5	2.3
Freshwater and diadromous fish	–	–	0.1	0.7	1.8
Cephalopods	–	–	–	0.1	0.1
Aquatic animals, others	–	0.2	0.1	0.0	0.0
Totals	**17.0**	**12.9**	**21.6**	**30.3**	**30.3**

TABLE 18

Bahamas – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	109 952	73 770	91 574	108 339	87 158	78 036	95 041	84 100	82 509
Re-export Value	40	4	–	177	3	22	81	132	1 069
Import Value	14 765	13 725	14 387	13 200	14 638	16 688	17 990	17 806	21 780

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	3 930	2 734	2 810	3 604	2 785	2 310	2 649	5 136	5 445
Re-export Value	0	0	0	8	1	2	7	22	158
Import Value	4 966	4 080	3 595	3 694	3 3340	3 496	3 907	8 788	9 860

TABLE 19

Bahamas – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Tunas prepared or preserved, not minced	1 365	1 065	1 350	1 070	1 216.	1 199	1 131	2 440	2 926
Mackerel prepared or preserved, not minced, nei	156	78	85	183	233	315	542	1 130	1 260
Pilchards (*Sardinops* spp.), prep. or pres., not minced	912	330	309	233	315	266	270	538	698
Shrimps and prawns, frozen, nei	107	80	81	84	79	140	220	492	670
Fish meat, whether or not minced, frozen, nei	93	165	169	231	210	298	327	836	531
Fish, fresh or chilled, nei	146	31	21	40	61	10	81	362	522
Marine fish nei, minced, prepared or preserved	45	63	106	195	87	36	90	175	411
Flatfishes nei, frozen	1	17	2	12	3	23	119	281	292
Fish roes, prepared, nei	152	132	–	–	–	83	98	239	236
Salmon nei, not minced, prep. or pres.	42	31	31	33	42	43	46	112	163
Salmons, smoked	55	107	102	510	107	143	90	179	161
Grouper, frozen	37	37	–	–	–	37	107	123	144
Cuttlefishes, frozen	6	35	22	5	6	20	31	79	126
Miscellaneous coastal fishes fillets, nei, frozen	211	92	–	–	–	85	45	137	121
Crabs nei, frozen	41	16	25	30	22	16	23	64	108
Shrimps and prawns, not frozen, nei	180	210	160	113	53	13	7	110	89
Fish fillets, frozen, nei	82	75	124	92	157	57	55	104	82
Freshwater fish nei, live	5	0	–	–	–	14	37	105	75
Miscellaneous crustaceans, not frozen, nei	6	30	3	8	23	70	64	89	67
Spiny lobsters (*Panulirus* spp.), nei, frozen	0	1	–	–	–	1	9	38	65
Scallops, other than live, fresh or chilled	11	3	5	6	19	12	25	57	65
Shrimps, prawns, prepared or preserved, nei	48	50	49	52	26	25	32	53	55
Marine fish nei, smoked	105	55	22	31	20	27	30	65	53
Cods nei, dried, salted or in brine	12	7	6	10	5	8	16	41	49
Fish live, nei	16	17	40	58	87	54	44	85	47
Pacific salmon, frozen, nei	8	3	2	2	4	2	2	24	47
Fish, frozen, nei	173	281	260	175	85	38	8	19	40

TABLE 20
Barbados – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Common dolphin fish	700	1 100	500	619	906	728	693
Flyingfishes nei	1 400	2 500	1 100	933	1 670	1 916	2 354
Marine fishes nei	100	200	100	1 584	54	60	109
Marlins, sailfishes, etc.	–	–	–	–	–	4	100
Swordfish	–	–	–	–	–	13	39
Wahoo	–	–	–	–	51	39	34
Yellowfin tuna	–	–	<0.5	40	89	210	156
Other	800	1 400	600	559	248	205	66
Totals	**3 000**	**5 200**	**2 300**	**3 735**	**3 018**	**3 175**	**3 551**

TABLE 21
Barbados – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	11.0	16.9	13.3	22.2	18.3
Marine fish, other	15.1	2.4	10.1	5.8	11.2
Demersal fish	1.7	5.5	4.6	3.0	10.7
Crustaceans	–	0.1	0.6	1.4	1.3
Freshwater and diadromous fish	–	0.0	–	0.7	0.9
Molluscs, excl. cephalopods	–	–	–	0.2	0.8
Cephalopods	–	–	–	–	0.2
Totals	**27.8**	**24.9**	**28.5**	**33.2**	**43.4**

TABLE 22
Barbados – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	1 247	1 324	896	869	817	1 348	689	899	734
Re-export Value	62	41	31	–	–	15	12	–	–
Import Value	10 886	12 360	13 346	13 516	11 673	17 269	18 750	18 847	20 291

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	278	327	207	241	239	391	237	236	169
Re-export Quantity	19	19	12	–	–	4	3	0	7
Import Quantity	3 798	4 343	4 769	4 853	4 411	8 168	9 258	14 676	9 026

TABLE 23
Barbados – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Shrimps and prawns, frozen, nei	140	149	124	136	58	170	2 802	8 479	3 109
Marine fish, frozen, nei	582	851	1 109	1 308	1 147	2 991	1 867	1 773	1 662
Tunas prepared or preserved, not minced, nei	593	750	848	667	755	1372	971	994	1117
Cods nei, dried whether or not salted	461	531	517	450	424	528	905	867	576
Fish fillets, frozen, nei	193	123	207	267	157	371	266	388	417
Pilchards (*Sardinops* spp.), prep. or pres., not minced	515	337	452	417	384	554	394	419	402
Miscellaneous dried fish, whether or not salted, nei	50	58	50	213	217	321	325	358	368
Mackerel prepared or preserved, not minced, nei	377	452	358	459	361	540	404	409	302
Yellowfin tuna, frozen, nei	5	111	133	79	75	303	246	210	194
Salmon nei, not minced, prepared or preserved	63	92	97	115	96	164	121	97	108
Miscellaneous pelagic fishes fillets nei, frozen	–	76	119	142	270	48	54	88	59
Shrimps, prawns, prepared or preserved, nei	5	16	29	13	12	30	31	24	59
Fish meals, nei	19	48	68	6	27	65	46	67	56
Cuttlefish and squid, other than live, fresh or chilled	39	29	11	11	17	29	18	7	44
Sharks nei, frozen	4	14	25	18	21	47	25	37	42
Fish meat, whether or not minced, frozen, nei	229	181	178	65	5	112	267 [F]	43	38

TABLE 24

Bermuda – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Carangids nei	–	–	–	–	45	30	49
Caribbean spiny lobster	150	150	200	23	10	29	34
Groupers nei	–	–	–	–	49	27	54
Marine fishes nei	350	350	700	372	173	55	67
Snappers, jobfishes nei	–	–	–	–	45	23	37
Wahoo	–	–	–	46	74	61	117
Yellowfin tuna	–	–	–	35	15	31	15
Other	0	0	0	3,629	52	34	27
TOTAL	**500**	**500**	**900**	**4,105**	**463**	**290**	**400**

TABLE 25

Bermuda – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Marine fish, other	30.5	26.7	28.8	13.5	19.4
Molluscs, excl. cephalopods	–	–	–	1.3	6.5
Demersal fish	–	–	3.4	5.8	4.8
Crustaceans	8.0	6.3	12.1	11.9	4.0
Pelagic fish	–	–	–	4.5	2.2
Cephalopods	–	–	–	0.3	0.0
Totals	**38.5**	**33.0**	**44.3**	**37.8**	**38.1**

TABLE 26

Bermuda – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	272 F	46 F	46 F	78 F	4 F	94 F	44 F	15 F	280 F
Import Value	7 030 F	8 387 F	8 204 F	8 274 F	8 431 F	8 203 F	8 639 F	7 286 F	6 116 F

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	15 F	0 F	3 F	94 F	20 F	9 F	21 F	2 F	20 F
Import Quantity	995 F	1 300 F	1 161 F	1 088 F	1 120 F	1 109 F	1 083 F	960 F	948 F

TABLE 27

Bermuda – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000 F	2001 F	2002 F	2003 F	2004 F	2005 F	2006 F	2007 F	2008 F
Fish fillets, frozen, nei	424	437	399	393	444	367	390	311	306
Tunas prep. or pres., in airtight containers	–	–	–	–	–	–	–	64	97
Fish, frozen, nei	–	–	–	–	–	–	–	–	91
Shrimps and prawns, not cooked, frozen	61	68	82	79	66	75	66	74	54
Tunas prepared or preserved, not minced, nei	62	137	119	95	65	68	66	8	50
Toothfish (*Dissostichus* spp.), fillets, frozen	–	–	–	–	–	–	–	1	45
Freshwater fishes nei, frozen	–	–	–	–	–	–	13	78	44
Marine fish nei, smoked	34	30	35	26	34	42	40	41	31
Marine fish nei, minced, prepared or preserved	8	4	0	6	7	2	2	27	24
Fish nei, salted or in brine	–	–	2	–	1	–	–	–	23
Saithe (=Pollock), frozen	–	–	–	–	–	–	–	23	19
Cuttlefish and squid, other than live, fresh or chilled	2	6	5	–	–	–	5	0	17
American/European lobsters (*Homarus* spp.), nei, frozen	27	41	49	43	97	48	45	14	16
Fish meal fit for human consumption, nei	–	–	–	–	–	0	–	1	15
Squid rings, frozen	2	5	4	1	4	–	3	–	14
Squids (*Ommastrephes sagittatus, Loligo* spp.), frozen	–	–	–	–	–	–	–	–	12
Scallops, other than live, fresh or chilled	78	87	107	124	154	122	79	169	6

TABLE 27

Bermuda – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000 [F]	2001 [F]	2002 [F]	2003 [F]	2004 [F]	2005 [F]	2006 [F]	2007 [F]	2008 [F]
Fish fillets, frozen, nei	424	437	399	393	444	367	390	311	306
Tunas prep. or pres., in airtight containers	–	–	–	–	–	–	–	64	97
Fish, frozen, nei	–	–	–	–	–	–	–	–	91
Shrimps and prawns, not cooked, frozen	61	68	82	79	66	75	66	74	54
Tunas prepared or preserved, not minced, nei	62	137	119	95	65	68	66	8	50
Toothfish (*Dissostichus* spp.), fillets, frozen	–	–	–	–	–	–	–	1	45
Freshwater fishes nei, frozen	–	–	–	–	–	–	13	78	44
Marine fish nei, smoked	34	30	35	26	34	42	40	41	31
Marine fish nei, minced, prepared or preserved	8	4	0	6	7	2	2	27	24
Fish nei, salted or in brine	–	–	2	–	1	–	–	–	23
Saithe (=Pollock), frozen	–	–	–	–	–	–	–	23	19
Cuttlefish and squid, other than live, fresh or chilled	2	6	5	–	–	–	5	0	17
American/European lobsters (*Homarus* spp.), nei, frozen	27	41	49	43	97	48	45	14	16
Fish meal fit for human consumption, nei	–	–	–	–	–	0	–	1	15
Squid rings, frozen	2	5	4	1	4	–	3	–	14
Squids (*Ommastrephes sagittatus, Loligo* spp.), frozen	–	–	–	–	–	–	–	–	12
Scallops, other than live, fresh or chilled	78	87	107	124	154	122	79	169	6

TABLE 28

Cayman Islands – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Freshwater fishes nei	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	–
Marine fishes nei	<0.5	<0.5	<0.5	<0.5	110	125	125
Natantian decapods nei	–	–	–	500	727	–	–
Skipjack tuna	–	–	–	289	–	–	–
Yellowfin tuna	–	–	–	602	–	–	–
Other	0	0	0	0	0	0	0
Totals	**0**	**0**	**0**	**1 391**	**837**	**125**	**125**

TABLE 29

Cayman Islands – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	180 [F]	94 [F]	108 [F]	50 [F]	202 [F]	196 [F]	1 288 [F]	76 [F]	–
Import Value	954 [F]	1 492 [F]	1 905 [F]	1 880 [F]	1 623 [F]	855 [F]	2 997 [F]	4 006 [F]	2 796 [F]

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	100 [F]	62 [F]	60 [F]	8 [F]	34 [F]	102 [F]	107 [F]	34 [F]	–
Import Quantity	139 [F]	223 [F]	260 [F]	250 [F]	261 [F]	171 [F]	500 [F]	855 [F]	417 [F]

TABLE 30

Cayman Islands – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Marine fish, other	–	–	26.3	5.7	4.6
Crustaceans	–	–	4.8	0.4	0.6
Demersal fish	–	–	–	–	0.3
Cephalopods	–	–	–	0.1	–
Totals	–	–	**31.1**	**6.1**	**5.5**

TABLE 31
Cayman Islands – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000 F	2001 F	2002 F	2003 F	2004 F	2005 F	2006 F	2007 F	2008 F
Fish fillets, frozen, nei	4	89	132	113	99	45	208	99	91
Shrimps, prawns, prepared or preserved, nei	–	2	–	0	4	0	3	33	45
Fish fillets, fresh or chilled, nei	–	1	0	0	0	0	6	191	36
Trouts and chars, fresh or chilled	–	1	–	1	–	–	–	1	35
Tunas, fresh or chilled, nei	–	–	1	–	–	–	–	15	24
Shrimps and prawns, not cooked, frozen	49	18	–	2	1	3	8	1	18
Sardines, sardinellas, brisling or sprats, frozen	–	–	–	–	–	–	–	–	16
Tunas prepared or preserved, not minced, nei	–	–	10	33	16	12	26	16	14
Salmons, fresh or chilled, nei	–	–	–	–	1	0	–	–	12
Salmonoids, fresh or chilled, nei	–	0	–	–	–	–	–	–	11
Fish nei, salted or in brine	–	–	–	–	–	–	–	1	10
Octopus, frozen	–	–	–	–	–	–	–	133	–

TABLE 32
Cuba – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Blue tilapia	–	–	–	5 059	18 663	3 670	3 464
Caribbean spiny lobster	1 000	8 000	8 000	10 567	7 957	7 478	5 725
Channel catfish	–	–	–	–	228	105	2 276
Freshwater fishes nei	<0.5	<0.5	200	573	156	10 216	4 501
Marine fishes nei	1 000	–	5 000	28 329	25 862	22 676	6 109
Silver carp	–	–	–	–	2 315	17 530	20 181
Whiteleg shrimp	–	–	–	–	–	–	3 697
Other	7 800	22 400	90 100	140 666	131 936	39 454	14 942
Totals	**9 800**	**30 400**	**103 300**	**185 194**	**187 117**	**101 129**	**60 895**

TABLE 33
Cuba – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Fish, frozen, nei	5 090	2 733	10 066	21 790	49 666	35 516	13 010	18 119	20 618
Cuttlefish and squid, other than live, fresh or chilled	466	288	6 106	9 089	228	329	698	10 809	10 750
Mackerels nei, frozen	0	2	1	1145	301	287	–	–	3 956
Sardines, sardinellas, brisling or sprats, prep. or pres.	1 490	2 422	366	456	409	2 496	891	1 530	2 230
Tunas prepared or preserved, not minced, nei	1 210	7 211	475	770	655	538	818	1 448	2 123
Fish meals, nei	3 718	3 064	499	535	445	612	318	520	571
Livers, roes, milt, smoked, dried, salted or in brine	0	–	1	–	–	0	–	0	386
Marine fish nei, minced, prepared or preserved	20 253	12 561	2 513	1 109	1 093	441	125	91	299
Hake nei, frozen	20	21	546	1 007	45	40	42	24	103
Mussels nei, other than live, fresh or chilled	475	2 294	47	72	93	90	91	107	99
Molluscs and other aq. invertebrates, prep. or pres.	192	54	55	88	108	127	128	96	95
Octopus, other than live, fresh or chilled	18	47	13	28	40	68	74	34	74
Salmons, smoked	26	18	18	15	41	39	38	20	73
Salmonoids, frozen	–	0	0	2	–	1	5	0	54
Pacific salmon, frozen, nei	61	37	66	56	61	70	180	79	53
Fish waste, nei	45	14	5	–	–	14	26	25	37
Miscellaneous molluscs, other than live, fresh or chilled	6	4	8	9	16	27	27	18	33
Sardines, sardinellas, brisling or sprats, frozen	14	9	12	12	17	34	35	40	32
Tunas nei, frozen	2	11	2	57	2	6	1	1	27
Anchovies, prepared or preserved, not minced	14	19	33	46	32	39	39	23	21
Shrimps and prawns, frozen, nei	0	60	31	10f	18	0	0	23	20
Crab meat nei, prepared or preserved	2	0	0	1	4	8	0	5	18
Oysters, live fresh or chilled, nei	0	0	0	1	9	8	16	9	11

TABLE 34
Cuba – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Marine fish, other	0.6	0.9	0.1	1.6	3.6
Freshwater and diadromous fish		0.1	1.6	3.8	2.1
Cephalopods	0.0	0.5	0.7	0.3	1.0
Pelagic fish	1.8	5.3	9.7	0.5	0.8
Demersal fish	11.7	10.4	8.2	5.4	0.6
Molluscs, excl. cephalopods	0.9	0.2	0.4	0.5	0.3
Crustaceans	0.9	0.3	0.0	0.1	0.1
Totals	**16.0**	**17.7**	**20.8**	**12.1**	**8.5**

TABLE 35
Cuba – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Export Value	87 226	79 431	92 273	64 578	88 517	73 097	68 648	81 000	79 731
Re–export Value			532						
Import Value	43 005	37 387	29 088	36 165	51 556	51 413	39 443	49 188	66 390

Trade Flow (tonnes)	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**
Export Quantity	7 639	6 837	8 732	6 234	10 251	6 721	7 207	7 084	6 108
Re–export Quantity		106							
Import Quantity	35 035	33 979	22 514	37 736	54 667	43 727	22 797	35 759	41 708

TABLE 36
Dominica – Landings (tonnes)

Species	**1950**	**1960**	**1970**	**1980**	**1990**	**2000**	**2008**
Blackfin tuna	–	–	–	–	19	83	37
Blue marlin	–	–	–	–	–	–	107
Common dolphin fish	–	–	–	–	–	–	125
Marine fishes nei	600	500	500	1 445	323	872	227
Skipjack tuna	–	–	–	–	60	86	45
Wahoo	–	–	–	–	38	46	16
Yellowfin tuna	–	–	–	–	18	78	124
Other	0	0	0	0	0	42	13
Totals	**600**	**500**	**500**	**1 445**	**458**	**1 207**	**694**

TABLE 37
Dominica – Per capita consumption by species groups (kg/capita)

	1967	**1977**	**1987**	**1997**	**2007**
Pelagic fish	15.3	9.9	8.6	8.7	23.0
Demersal fish	–	–	–	6.9	3.8
Marine fish, other	11.3	16.5	7.2	14.5	3.6
Crustaceans	–	–	–	0.0	0.1
Molluscs, excl. cephalopods	–	–	–	–	0.1
Freshwater and diadromous fish	–	–	–	0.1	0.0
Totals	**26.6**	**26.4**	**15.7**	**30.3**	**30.7**

TABLE 38

Dominica – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	–	0	2	4	1	32	1	6	6
Re-export Value	10	1	–	168	–	–	–	0	0
Import Value	1 581	1 254	1 408	1 312	1 551	1 645	1 666	1 815	1 964

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	–	0	0	1	0	3	0	1	1
Re-export Quantity	6	1	–	1	–	–	–	0	0
Import Quantity	676	571	574	510	583	517	431	556	523

TABLE 39

Dominica – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Mackerel prepared or preserved, not minced, nei	63	51	42	33	45	40	38	111	112
Miscellaneous dried fish, whether or not salted, nei	97	69	55	89	127	120	92	116	103
Tunas prepared or preserved, not minced, nei	69	67	105	54	102	101	63	98	100
Cods nei, dried, salted or in brine	196	185	166	174	142	131	98	83	64
Pilchards (Sardinops spp.), prep. or pres., not minced	76	69	86	65	102	55	76	74	57
Herrings nei, smoked	67	89	69	78	50	36	44	53	53

TABLE 40

Dominican Republic – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Caribbean spiny lobster	–	–	100	166	750	1 286	1 272
Groupers nei	–	–	300	826	1 180	873	653
Marine fishes nei	600	1 100	1 400	–	2 760	2 382	4 166
Penaeus shrimps nei	–	–	100	821	120	429	569
Snappers, jobfishes nei	–	–	100	259	70	753	1 213
Stromboid conchs nei	–	–	100	706	5 120	1 778	1 634
Tilapias nei	–	100	100	1 490	600	994	769
Other	0	100	3 000	6 223	9 169	4 645	6 128
Totals	**600**	**1 300**	**5 200**	**10 491**	**19 769**	**13 140**	**16 404**

TABLE 41

Dominican Republic – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	2.1	2.7	4.3	3.6	4.1
Demersal fish	4.2	3.3	2.0	3.5	3.9
Crustaceans	–	0.0	0.0	0.1	0.9
Marine fish, other	0.3	0.3	0.9	0.3	0.8
Molluscs, excl. cephalopods	–	0.0	0.1	0.2	0.7
Freshwater and diadromous fish	0.1	0.1	0.3	0.2	0.3
Cephalopods	–	0.0	0.0	0.0	0.2
Aquatic animals, others	0.0	0.0	0.0	0.0	0.0
Totals	**6.7**	**6.4**	**7.6**	**7.9**	**10.8**

TABLE 42
Dominican Republic – Yearly seafood imports by main commodities (tonnes)

Commodity	2000 F	2001 F	2002 F	2003 F	2004 F	2005 F	2006 F	2007 F	2008 F
Saithe, dried, salted or in brine	9 776	9 322	10 255	6 733	5 893	7 675	7 834	8 563	9 660
Herrings nei, smoked	7 002	7 310	9 932	7 240	5 818	6 979	5 530	5 578	5 675
Marine fish, frozen, nei	885	1 067	2 695	2 369	2 857	4 127	4 554	2 806	4 632
Fish fillets, frozen, nei	762	627	763	522	542	783	1 120	1 043	3 408
Sardines, sardinellas, brisling or sprats, prep. or pres.	4 626	1 816	1 054	960	322	4 998	5 608	4 160	3 321
Marine fish nei, prepared or preserved, not minced	177	204	1 311	1 507	795	473	3 283	3 807	3 137
Tunas prepared or preserved, in airtight container	–	–	–	–	–	–	–	1 468	2 084
Fish meals, nei	228	299	121	81	50	718	1 261	1 719	1 459
Pilchards (*Sardinops* spp.), prep. or pres., not minced	–	2 172	4 088	4 864	19	54	670	689	1 442
Shrimps, prawns, prepared or preserved, nei	36	30	155	334	229	823	1 166	1 590	1 432
Cuttlefishes, frozen	20	19	342	500	663	884	1 076	1 035	1 389
Cuttlefish and squid, other than live, fresh or chilled	–	25	25	66	246	277	392	320	1 043
Anchovies, prepared or preserved, not minced	1	–	–	–	52	–	38	72	818
Pacific salmon, frozen, nei	29	32	56	369	484	811	825	487	793
Fish fillets, fresh or chilled, nei	100	138	492	799	1 107	2 395	2 474	1 278	730
Tunas prepared or preserved, not minced, nei	2 090	1 727	2 727	1 468	1 835	1 759	3 013	1 100	589
Fish, frozen, nei	–	–	–	–	–	–	–	200	526
Shrimps and prawns, frozen, nei	31	49	6	73	215	207	539	28	499
Freshwater fishes nei, frozen	–	0	–	–	–	–	–	111	310
Fish meat, whether or not minced, frozen, nei	–	–	–	81	25	60	32	70	297
Molluscs nei, prepared or preserved	65	16	8	186	207	301	448	658	225
Mackerel prepared or preserved, not minced, nei	–	–	17	1	76	7	32	–	194
Fish fillets, dried, salted or in brine	34	70	138	36	37	138	58	121	193
Marine fish nei, minced, prepared or preserved	465	519	236	145	123	121	165	165	182

TABLE 43
Dominican Republic – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	2 965	2 905	3 738 F	4 286 F	3 093 F	5 308 F	6 410 F	4 882 F	4 227 F
Import Value	52 992 F	57 099 F	71 875 F	57 377 F	67 572 F	94 992 F	108 223 F	102 195 F	140 418 F

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	1 907	2 178	1 884 F	2 043 F	1 493 F	1 615 F	1 454 F	1 195 F	1 206 F
Import Quantity	28 630 F	28 311 F	37 698 F	32 817 F	37 594 F	38 624 F	45 009 F	40 447 F	47 133 F

TABLE 44
Grenada – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Atlantic sailfish	–	–	–	31	124	164	215
Blackfin tuna	–	–	100	68	293	164	290
Common dolphin fish	–	–	<0.5	31	137	167	146
Parrotfishes nei	–	–	–	–	<0.5	18	114
Red hind	100	100	100	17	81	67	165
Snappers, jobfishes nei	<0.5	100	<0.5	17	36	48	122
Yellowfin tuna	–	–	100	487	302	403	755
Other	200	100	1 000	764	934	669	576
Totals	**300**	**300**	**1 300**	**1 415**	**1 907**	**1 700**	**2 383**

TABLE 45
Grenada – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	14.7	33.5	19.5	10.0	18.5
Marine fish, other	8.9	14.0	8.9	7.0	11.7
Demersal fish	1.1	3.6	7.4	2.1	5.6
Molluscs, excl. cephalopods	1.1	–	0.1	0.2	0.6
Crustaceans	–	–	0.1	0.2	0.5
Freshwater and diadromous fish	–	–	0.0	0.0	0.1
Cephalopods	–	–	–	–	0.1
Aquatic animals, others	–	–	0.1	0.1	0.0
Totals	**25.8**	**51.2**	**36.0**	**19.7**	**37.0**

TABLE 46
Grenada – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	3 408	4 052	3 863	3 258	3 086	3 517	3 734	4 115	2 957
Re-export Value	–	14	13	23	16	0	–	–	–
Import Value	2 181	2 556	2 557	2 550	2 676	2 965	3 919	4 701	4 619

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	1 143	709	624	630	455	497	519	530	436
Re-export Quantity	–	3	1	21	1	0	–	–	–
Import Quantity	673	974	923	1 228	1 191	1 310	1 555	1 406	1 121

TABLE 47
Grenada – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Miscellaneous dried fish, whether or not salted, nei	293	384	392	320 F	408	402	199	436	389
Tunas prepared or preserved, not minced, nei	34	58	51	53 F	62	82	93	80	139
Mackerel prepared or preserved, not minced, nei	36	108	134	126	171	157	204	192	133
Pilchards (*Sardinops* spp.), prep. or pres., not minced	77	116	131	245	173	121	133	186	114
Herrings nei, smoked	54	72	57	59	79	61	73	89	110
Shrimps and prawns, frozen, nei	10	6	8	37	8	12	17	39	38

TABLE 48
Haiti – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Spiny lobster	<0.5	100	100	200	800	360	1 000
Freshwater fishes nei	<0.5	100	300	300	350	400	300
Marine crabs nei	–	–	–	–	–	110	350
Marine fishes nei	2 000	2 800	3 600	4 500	3 500	4 750	7 200
Natantian decapods	–	–	–	–	100	280	850
Stromboid conchs	–	–	–	–	400	300	300
Other	0	0	0	0	0	0	0
Totals	**2 000**	**3 000**	**4 000**	**5 000**	**5 150**	**6 200**	**10 000**

TABLE 49
Haiti – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	0.4	0.1	0.1	1.4	2.0
Freshwater and diadromous fish	0.4	0.1	0.0	0.5	0.9
Marine fish. other	0.7	0.7	0.7	0.5	0.8
Crustaceans	0.0	0.0	0.1	0.0	0.2
Demersal fish	–	1.3	3.1	0.0	0.0
Molluscs. excl. cephalopods	–	–	0.0	0.0	0.0
Cephalopods	–	–	–	0.0	–
Totals	**1.5**	**2.1**	**4.0**	**2.4**	**4.0**

TABLE 50
Haiti – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	3 969 F	3 868 F	4 449 F	4 130 F	3 586 F	4 269 F	3 818 F	5 029 F	4 875 F
Import Value	5 949 F	7 085 F	4 694 F	7 912 F	8 628 F	9 827 F	16 511 F	17 014 F	21 882 F

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	639 F	634 F	743 F	616 F	654 F	477 F	444 F	553 F	577 F
Import Quantity	9 054 F	11 005 F	6 660 F	8 856 F	10 426 F	9 432 F	13 535 F	14 484 F	15 079 F

TABLE 51

Haiti – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000 F	2001 F	2002 F	2003 F	2004 F	2005 F	2006 F	2007 F	2008 F
Herrings nei, smoked	260	424	384	432	701	1140	2887	3656	3859
Jack and horse mackerel, frozen	6134	6872	3559	3327	4349	2492	2428	3258	2580
Alewife, dried, salted or in brine	549	800	1641	2247	1773	1751	2104	2937	2304
Marine fish nei, prepared or preserved, not minced	121	139	10	156	303	67	3214	1902	1412
Fish, frozen, nei	–	–	–	–	–	–	–	10	1213
Mackerel prepared or preserved, not minced, nei	373	0	284	753	127	236	17	165	716
Jack and horse mackerel prepared or preserved	1155	1600	0	1144	2392	2233	1780	911	664
Marine fish, frozen, nei	195	353	154	141	85	108	362	732	452
Mackerels nei, frozen	0	25	55	0	3	7	–	–	448
Sardines, sardinellas, brisling or sprats, prep. or pres.	74	12	114	5	259	768	66	429	344
Jack and horse mackerels, fresh or chilled	–	–	–	–	–	–	–	–	223
Anchovies, prepared or preserved, not minced	–	–	1	–	–	–	–	19	189
Fish roes, frozen, nei	–	–	0	–	–	–	–	55	110
Atlantic redfishes, frozen	–	–	0	–	–	–	–	24	98
Red mullet, frozen	–	–	60	73	111	0	–	109	86
Miscellaneous dried fish, whether or not salted, nei	–	10	0	2	178	8	103	27	76
Saithe, dried, salted or in brine	–	–	–	–	–	–	–	50	50
Fish fillets, fresh or chilled, nei	–	–	–	–	–	–	–	–	40
Tunas prepared or preserved, in airtight container	–	–	–	–	–	–	–	16	36

TABLE 52

Jamaica – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Caribbean spiny lobster	–	–	<0.5	<0.5	200	517	300
Freshwater fishes nei	–	–	–	200	450	400	400
Giant river prawn	–	–	–	–	30	10	12
Marine fishes nei	5 000	8 500	8 500	9 000	7 000	4 508	9 475
Nile tilapia	<0.5	<0.5	–	50	3 364	4 500	5 800
Stromboid conchs nei	–	–	–	–	6 000	<0.5	3 000
Whiteleg shrimp	–	–	–	–	–	–	136
Other	0	0	0	0	10	117	0
Totals	**5 000**	**8 500**	**8 500**	**9 250**	**17 054**	**10 052**	**19 123**

TABLE 53

Jamaica – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Marine fish. other	5.2	7.0	6.3	6.9	15.4
Pelagic fish	7.0	6.0	8.3	8.0	10.0
Freshwater and diadromous fish	–	0.6	1.1	1.6	2.4
Molluscs. excl. cephalopods	–	–	0.0	4.9	2.0
Crustaceans	0.1	0.0	0.0	0.3	0.6
Cephalopods	–	–	–	–	0.0
Demersal fish	20.8	2.8	2.4	1.5	0.0
Aquatic animals. others	–	–	–	0.0	–
Totals	**33.1**	**16.5**	**18.1**	**23.2**	**30.6**

TABLE 54

Jamaica – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	10 001	11 817	5 531	8 177	7 411	9 545	10 820	8 442	8 241
Re-export Value	–	30	62	122	94	88	–	789	1 193
Import Value	51 608	59 693	58 193	59 323	59 737	76 796	81 110	94 406	102 792

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	811	1 352	500	904	1 241	1 467	1 601	1 116	1 249
Re-export Quantity	–	29	24	40	42	27	–	219	297
Import Quantity	23 363	27 672	28 398	28 886	28 472	30 633	32 342	35 605	30 895

TABLE 55

Jamaica – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Mackerel prepared or preserved, not minced	4 344	5 941	4 969	7 040	5 981	8 222	6 022	8 883	7 800
Marine fish, frozen, nei	–	5 273	–	–	5 437	6 064	–	5 634	6 702
Miscellaneous dried fish, whether or not salted,	5 443	5 692	5 541	5 771	5 752	5 990	5 814	5 713	6 343
Sardines, sardinellas, brisling or sprats, prep. or pres.,	–	2 696	–	–	2 628	2 392	–	2 756	2 619
Mackerels nei, frozen	2 925	3 063	3 733	2 548	2 189	1 511	1 666	1 487	1 415
Fish fillets, frozen, nei	444	588	1 116	1 359	1 210	1 590	1 708	1 491	1 382
Fish, frozen, nei	4 864	827	6 517	6 461	1 547	1 399	10 980	5 347	1 335
Shrimps and prawns, frozen, nei	255	334	284	277	362	483	496	813	638
Atlantic mackerel, fresh or chilled	–	46	–	–	24	–	–	303	368
Tunas prepared or preserved, not minced, nei	184	288	259	293	233	407	420	471	346
Fish meals, nei	278	416	636	621	815	633	1 006	421	259
Fish minced nei, prepared or preserved	–	–	–	–	–	–	–	84	218
Herrings nei, smoked	211	236	188	186	213	188	177	239	215
Shrimps, prawns, prepared or preserved, nei	1	27	37	40	50	110	106	195	196
Miscellaneous marine fishes, salted or in brine	254	330	827	780	793	684	449	604	150

TABLE 56

Netherlands Antilles – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Bigeye tuna	–	–	–	–	–	2 359	1 721
Freshwater fishes nei	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	–
Frigate tuna	–	–	–	–	–	1 122	485
Marine fishes nei	400	500	300	536	580	455	700
Skipjack tuna	–	–	–	–	–	10 008	6 436
Stromboid conchs nei	–	–	–	–	20	10	5
Yellowfin tuna	–	–	–	–	–	5 441	7 351
Other	0	100	357	554	620	492	0
Totals	**400**	**600**	**657**	**1 090**	**1 220**	**19 887**	**16 698**

TABLE 57

Netherlands Antilles – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	2.0	4.2	4.8	8.9	8.9
Marine fish, other	17.8	16.2	16.5	6.3	6.6
Demersal fish	–	–	–	2.6	2.0
Freshwater and diadromous fish	–	0.9	0.3	0.8	1.9
Crustaceans	3.3	3.6	4.5	0.6	1.1
Molluscs, excl. cephalopods	–	–	0.2	0.7	0.2
Aquatic animals, others	–	–	–	0.0	0.1
Cephalopods	–	–	–	0.0	0.0
Totals	**23.0**	**25.0**	**26.2**	**19.9**	**20.8**

TABLE 58

Netherlands Antilles – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	5 693 F	5 948 F	5 278 F	9 162 F	9 987 F	5 261 F	6 260 F	6 172 F	21 670 F
Import Value	8 184 F	7 015 F	4 507 F	6 143 F	6 771 F	7 734 F	10 256 F	11 126 F	14 001

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	7 326 F	7 924 F	6 603 F	8 319 F	9 305 F	5 488 F	5 973 F	4 555 F	11 880 F
Import Quantity	2 553 F	2 302 F	1 451 F	1 722 F	1 889 F	1 415 F	1 945 F	2 085 F	3 728

TABLE 59

Netherlands Antilles – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Miscellaneous crustaceans, not frozen, nei	–	–	–	–	–	–	–	–	529
Fish meat, whether or not minced, frozen, nei	11	1	18	10	21	29	26	8	392
Tunas prepared or preserved, not minced, nei	34	79	69	69	192	102	130	111	368
Fish fillets, frozen, nei	106	50	74	44	132	133	133	71	305
Salmonoids, fresh or chilled, nei	–	2	–	24	8	1	1	–	303
Pacific salmon, frozen, nei	–	22	–	–	–	–	–	2	289
Shrimps and prawns, frozen, nei	64	61	38	18	35	37	26	95	208
Cods nei, dried whether or not salted	–	10	–	–	4	4	16	2	193
Fish, frozen, nei	–	–	–	–	–	–	–	113	165
Sardines, sardinellas, brisling or sprats, prep. or pres.	32	–	11	13	11	19	22	7	101
Fish fillets, fresh or chilled, nei	1	1	20	7	6	7	15	11	93
Fish nei, smoked	–	–	–	–	–	–	–	–	64
Crustaceans nei, prepared or preserved	–	–	–	–	–	–	–	–	57
Shrimps, prawns, prepared or preserved, nei	12	5	15	25	37	28	17	36	54

TABLE 60

Saint Kitts and Nevis – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Caribbean spiny lobster	–	–	–	–	–	26	40
Goatfishes, red mullets nei	–	–	–	–	–	<0.5	80
Groupers nei	–	–	–	–	–	6	25
Parrotfishes nei	–	–	–	–	–	2	45
Snappers nei	–	–	–	–	–	19	70
Stromboid conchs nei	–	–	–	–	–	73	90
Surgeonfishes nei	–	–	–	–	–	1	40
Other	300	600	1 000	1 935	623	342	60
Totals	**300**	**600**	**1 000**	**1 935**	**623**	**469**	**450**

TABLE 61
Saint Kitts and Nevis – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Marine fish, other	17.0	47.8	27.2	12.0	12.9
Pelagic fish	–	–	–	8.0	6.9
Demersal fish	–	–	–	4.1	6.7
Crustaceans	–	–	0.4	0.1	2.4
Molluscs, excl. cephalopods	–	–	–	0.6	1.9
Freshwater and diadromous fish	–	–	–	0.3	0.6
Cephalopods	–	–	–	–	0.0
Totals	**17.0**	**47.8**	**27.6**	**25.1**	**31.4**

TABLE 62
Saint Kitts and Nevis – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	245	131	149	267	196	45	242	422	296 F
Re-export Value	–	–	0	0	2	0	–	12	–
Import Value	2 807	2 063	1 946	1 862	2 654	982	4 114	3 927	3 538 F

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	73	43	35	135	156	25	62	95	70 F
Re-export Quantity	–	–	0	0	1	0	–	1	–
Import Quantity	1 157	802	857	616	663	565	805	729	1 212 F

TABLE 63
Saint Kitts and Nevis – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Fish, frozen, nei	109 F	91	72	197	118	101.	220	153	370
Fish fillets, fresh or chilled, nei	1	1	5	3	2	1	2	9	141
Miscellaneous dried fish, whether or not salted	360	130	384	148	191	164	148	134	141
Shrimps and prawns, frozen, nei	13	11	13	9	22	19	22	23	75
Herrings nei, frozen	–	0	1	1	0	0	1	1	74
Fish fillets, frozen, nei	25	23	31	32	40	43	65	57	72
Fish meat, whether or not minced, frozen	5	1	0	1	7	1	14	11	60
Toothfish (Dissostichus spp.), fillets, frozen	–	–	–	–	–	–	–	–	36
Gadiformes, salted or in brine, nei	–	–	–	–	–	–	–	–	34
Tunas prepared or preserved, not minced,	73	34	73	53	67	40	66	74	34
Marine fish nei, minced, prepared or preserved	10	1	1	1	1	1	2	1	33

TABLE 64
Saint Lucia – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Blackfin tuna	–	–	–	–	17	45	179
Common dolphin fish	–	–	–	–	–	552	341
Flyingfishes nei	–	–	–	–	–	99	249
Marine fishes nei	300	500	1 000	781	628	352	330
Skipjack tuna	–	–	71	40	37	216	168
Wahoo	–	–	–	–	77	243	180
Yellowfin tuna	–	–	48	27	58	134	106
Other	0	100	300	121	114	215	160
Totals	**300**	**600**	**1 419**	**969**	**931**	**1 856**	**1 713**

TABLE 65
Saint Lucia – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	–	2.8	1.1	18.4	22.5
Marine fish, other	19.8	17.7	12.7	3.5	12.7
Crustaceans	2.0	3.7	0.5	0.4	3.4
Demersal fish	–	5.5	–	0.9	0.9
Molluscs, excl. cephalopods	–	–	–	0.7	0.7
Freshwater and diadromous fish	–	–	–	0.1	0.2
Cephalopods	–	–	–	–	0.1
Totals	**21.8**	**29.7**	**14.3**	**24.0**	**40.5**

TABLE 66
Saint Lucia – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	0	37	93	30	0	0	1	0	107
Re-export Value	10	9	15	69	–	–	–	11	–
Import Value	4 795	4 147	4 237	5 065	5 618	5 988	6 319	6 810	8 338

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	0	0	14	1	0	0	0	0	25
Re-export Quantity	7	1	3	7	–	–	–	3	–
Import Quantity	1 243	1 134	1 321	1 515	1 943	2 649	1 830	1 844	1 867

TABLE 67
Saint Lucia – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Tunas prepared or preserved, not minced, nei	430	448	556	585	580	1121	566	594	654
Miscellaneous dried fish, whether or not salted, nei	256	240	253	287	321	462	339	314	315
Marine fish, frozen, nei	44	31	18	43	53	174	74	98	185
Fish fillets, frozen, nei	30	20	52	90 F	102	172	174	225	183
Shrimps and prawns, frozen, nei	40	46	37	81	181	254	89	100	86
Herrings nei, smoked	37	33	55	58	105	63	58	66	71
Miscellaneous marine fishes, salted or in brine, nei	16	0	1	4	–	–	26	15	56
Mackerel prepared or preserved, not minced, nei	114	71	108	59	171	147	114	118	49
Pilchard, canned	55	56	58	47	54	53	–	56	42
Fish meat, whether or not minced, frozen, nei	2	1	1	1	0	10	11	9	32
Shrimps, prawns, prepared or preserved, nei	1	1	2	3	10	28	22	50	22
Salmons, smoked	7	7	5	10	12	6	11	21	16
Scallops, other than live, fresh or chilled	7	11	5	7	9	6	9	16	16
Mussels nei, other than live, fresh or chilled	7	9	3	8	7	8	13	9	14
Crabs nei, frozen	6	11	2	7	9	6	17	22	12

TABLE 68
Saint Vincent and the Grenadines – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Albacore	–	–	–	–	–	704	201
Atlantic bonito	–	–	–	–	–	–	27
Bigeye tuna	–	–	–	–	<0.5	1 216	171
Marine fishes nei	300	400	600	500	1 158	675	600
Skipjack tuna	–	–	–	–	29	68	83
Tuna-like fishes nei	–	–	–	–	–	–	124
Yellowfin tuna	–	–	–	–	40	1 989	2 547
Other	0	0	0	0	7 739	23 042	75
Totals	**300**	**400**	**600**	**500**	**8 966**	**27 694**	**3 828**

TABLE 69
Saint Vincent and the Grenadines – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	1.0	–	–	2.4	9.5
Marine fish, other	5.7	11.5	8.2	8.1	3.8
Demersal fish	8.3	–	2.0	3.4	2.7
Molluscs, excl. cephalopods	–	–	–	0.1	0.2
Crustaceans	–	0.0	0.0	0.1	0.1
Freshwater and diadromous fish	–	–	–	0.1	0.0
Cephalopods	–	–	–	–	0.0
Totals	**14.9**	**11.5**	**10.2**	**14.2**	**16.2**

TABLE 70
Saint Vincent and the Grenadines – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	961	630	712	510	409	434	216 F	269	510
Re-export Value	–	–	–	41	–	–	–	7	–
Import Value	1 146	1 290	1 358	1 395	1 609	1 889	2 033	2 226	2 523

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	251	140	140	95	74	53	34 F	46	51
Re-export Quantity	–	–	–	26	–	–	–	1	–
Import Quantity	420	427	427	472	470	489	476	503	589

TABLE 71
Saint Vincent and the Grenadines – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Miscellaneous dried fish, whether or not salted, nei	156	161	200	245	195	150	175	176	249
Sardines, sardinellas, brisling or sprats, prep. or pres.	105	90	82	101	103	113	108	94	115
Tunas prepared or preserved, not minced, nei	34	48	33	41	52	49	54	49	63
Shrimps and prawns, frozen, nei	8	33	20	18	10	13	12	44	36
Cods nei, dried, salted or in brine	35	22	18	13	34	96	61	47	26
Atlantic herring, smoked	22	19	19	13	19	19	26	20	18
Marine fish nei, minced, prepared or preserved	2	1	2	2	3	3	5	6	12

TABLE 72
Trinidad and Tobago – Landings (in tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Demersal percomorphs	–	100	200	683	990	2 010	1 951
Jacks, crevalles nei	–	100	200	277	370	206	427
King mackerel	–	–	–	–	432	432	1 043
Marine fishes nei	500	1 000	1 200	1 016	1 990	7 405	6 282
Penaeus shrimps nei	100	300	700	452	815	755	782
Serra Spanish mackerel	300	600	800	1 337	2 471	1 722	1 472
Yellowfin tuna	–	–	–	–	304	112	520
Other	100	300	500	696	4 992	1 617	1 356
Totals	**1 000**	**2 400**	**3 600**	**4 461**	**12 364**	**14 259**	**13 833**

TABLE 73

Trinidad and Tobago – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Pelagic fish	3.1	4.1	7.8	5.4	6.7
Marine fish, other	1.3	1.1	1.9	2.1	4.4
Demersal fish	9.0	4.5	3.9	1.7	1.3
Crustaceans	–	0.0	1.0	0.2	1.3
Freshwater and diadromous fish	–	0.3	0.2	0.1	0.4
Molluscs, excl. cephalopods	–	0.0	–	0.0	0.2
Totals	**13.5**	**10.0**	**14.9**	**9.6**	**14.4**

TABLE 74

Trinidad and Tobago – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	10 612	10 475	11 436	9 976	6 894	8 646	9 983	8 718	10 364
Re-export Value	–	–	–	–	–	–	–	5	6
Import Value	7 066	8 726	11 758	12 063	13 729	21 990	19 443	25 655	26 615

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	4 361	5 092	5 076	4 007	3 091	3 217	6 472	3 920	3 741
Re-export Quantity	–	–	–	–	–	–	–	0	0
Import Quantity	4 028	5 845	8 619	7 044	8 323	12 844	8 806	9 090	8 570

TABLE 75

Trinidad and Tobago – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Miscellaneous dried fish, whether or not salted, nei	835	998	2 054	1 636	1 314	1 386	1 566	1 539	1 606
Marine fish, frozen, nei	128	660	1 056	408	1 115	1 306	2 210	434	1 304
Tunas prepared or preserved, not minced, nei	485	1 167	630	662	991	1 616	1 137	1 091	968
Sardines, sardinellas, brisling or sprats, prep. or pres.	–	–	–	–	–	–	737	1 134	673
Fish fillets, frozen, nei	1	10	22	77	105	191	314	310	608
Albacore (=Longfin tuna), frozen, nei	5	7	–	1 066	1 139	4 046	641	1 564	507
Herrings nei, smoked	513	435	499	546	676	513	489	613	460
Shrimps and prawns, frozen, nei	9	6	27	13	71	238	115	183	369
Mackerel prepared or preserved, not minced, nei	179	216	200	186	226	385	259	371	362
Shrimps, prawns, prepared or preserved, nei	16	28	33	42	59	109	179	194	277
Salmon nei, not minced, prepared or preserved	138	97	139	163	207	236	317	217	275
Sharks nei, frozen	6	147	148	80	268	330	160	184	220
Mackerels nei, frozen	–	2	2	19	3	49	36	60	120
Marine fish nei, minced, prepared or preserved	18	26	23	27	35	146	82	119	94
Atlantic salmon and Danube salmon, frozen	0	–	4	5	396	428	51	135	85
Fish meat, whether or not minced, frozen, nei	1	20	30	36	29	48	103	235	72
Fish fillets, dried, salted or in brine	0	84	120	0	144	65	96	163	53
Molluscs and other aq. invertebrates, prep. or pres.	–	–	–	–	–	–	34	54	49

TABLE 76

Turks and Caicos Islands – Landings (tonnes)

Species	1950	1960	1970	1980	1990	2000	2008
Blue marlin	–	–	–	–	–	–	<0.5
Caribbean spiny lobster	<0.5	200	400	330	210	187	380
Freshwater fishes nei	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	–
Marine crabs nei	–	–	–	–	–	<0.5	–
Marine fishes nei	<0.5	100	300	300	300	1	60
Stromboid conchs nei	–	750	750	4 200	3 200	5 540	5 693
Yellowfin tuna	–	–	–	–	–	–	<0.5
Other	0	0	0	0	0	0	0
Totals	**0**	**1 050**	**1 450**	**4 830**	**3 710**	**5 728**	**6 133**

TABLE 77

Turks and Caicos Islands – Per capita consumption by species groups (kg/capita)

	1967	1977	1987	1997	2007
Molluscs, excl. cephalopods	–	–	3.5	35.9	11.9
Crustaceans	50.0	21.9	8.0	–	11.4
Marine fish, other	3.3	24.3	25.0	0.4	3.5
Pelagic fish	–	–	–	0.1	2.8
Freshwater and diadromous fish	–	–	–	–	1.0
Demersal fish	–	–	–	–	0.3
Cephalopods	–	–	–	–	0.1
Totals	**53.3**	**46.1**	**36.5**	**36.4**	**31.0**

TABLE 78

Turks and Caicos Islands – Trade flow, in terms of value (USD 1 000) and volume (tonnes, product weight)

Trade Flow (USD 1 000)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Value	3 825	3 978	3 789	3 499	5 265	8 808 F	8 054 F	8 869 F	7 366 F
Import Value	2 001	2 154	2 120	2 316	2 258	2 242 F	2 372 F	1 896 F	1 505 F

Trade Flow (tonnes)	2000	2001	2002	2003	2004	2005	2006	2007	2008
Export Quantity	561 F	533 F	493 F	474 F	639 F	913 F	838 F	874 F	858 F
Import Quantity	323 F	367 F	338 F	339 F	358 F	308 F	342 F	307 F	1 867 F

TABLE 79

Turks and Caicos Islands – Yearly seafood imports by main commodities (tonnes, product weight)

Commodity	2000	2001	2002	2003	2004	2005	2006	2007	2008
Fish meat, whether or not minced, frozen, nei	108	102	101	99	119	70	75	70	70
Shrimps, prawns, prepared or preserved, nei	2	5	5	4	2	10	40	36	37
Shrimps and prawns, frozen, nei	34	36	31	37	36	32	30	30	25
Fish fillets, prep. or pres, incl. raw, coated in batter	–	–	–	–	–	10	12	24	21
Tunas prepared or preserved, not minced, nei	15	21	18	23	24	26	27	21	20
Fish fillets, frozen, nei	–	–	–	–	–	15	16	23	16
Crabs, not frozen	13	12	5	19	15	12	13	10	10
Scallops, other than live, fresh or chilled	9	10	11	10	12	11	12	10	10
Toothfish (*Dissostichus* spp.), fillets, frozen	–	–	–	–	–	–	–	–	9
Squids nei, frozen	–	–	–	–	–	–	–	–	6
Saithe (=Pollock), frozen	–	–	–	–	–	–	–	–	5
Shrimps and prawns, peeled, frozen	–	–	–	–	–	1	2	2	4
Squids (*Ommastrephes sagittatus*, *Loligo* spp.), frozen	–	–	–	–	–	–	–	–	4
Fish fillets, fresh or chilled, nei	–	–	–	–	–	–	–	2	3
Salmons, fresh or chilled, nei	–	–	–	–	–	–	–	1	2