Oyster capture-based aquaculture in the Republic of Korea

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SUMMARY

Oysters are considered to be the most important molluscan shellfish in the aquaculture industry of the Republic of Korea, which, in 2005, produced 251 706 tonnes of oysters. In the Republic of Korea the Pacific oyster, *Crassostrea gigas*, is widely cultured along the southern coast where a number of small, shallow bays (mostly <10 m in depth) are protected by numerous islands. Oysters are intensively cultured in these bays with a longline suspended culture system. The Korean oyster industry uses mainly wild-caught oyster spat as seed. This is collected from mid-summer to early fall. Oyster spat that settle on the strings undergoes 7–9 months of hardening in intertidal areas. After the hardening period, the oysters are relocated to a grow-out field in the middle of the bay. The market-size products are harvested during late winter and mid-spring following a grow-out period lasting 9–11 months. Approximately 3 400 families are engaged in the oyster longline culture industry on the southern coast, with 22 000 full-time employees in 2005.

INTRODUCTION

The modern oyster culture technique was introduced to the Republic of Korea at the end of Nineteenth century from neighboring Japan. According to the National Federation of Fisheries Cooperatives of Korea, the first oyster culture licence was issued in 1907 and in 1918 approximately 133 tonnes of oysters were produced from 1 425 hectares. Culture techniques in the early Twentieth century were rather primitive and limited to bottom culture in intertidal areas of inner bays using rocks or wooden poles as substrates for seed collection and subsequent grow-out. In the 1960s, modern suspended culture techniques using longlines and rafts were introduced and the culture area subsequently expanded from the intertidal area to deeper waters offshore. Owing to this technical innovation, an estimated 53 327 tonnes of oysters were landed in 1963, an approximate 7 fold increase from the previous year's landings of 7 036 tonnes. In 2005, approximately 251 700 tonnes of oysters were produced from 8 042 hectares.

Table 1 lists the oyster species occurring in Korean waters. According to Min (2004), 14 species of oyster have been identified in Korean waters, although only *Crassostrea gigas* is extensively used in the oyster industry. *Ostrea denselamellosa*, a larviparous flat oyster species, has been cultured in tidal flats on the southwest

TABLE 1
Oyster species in Korean waters

Family	Species	Common name	Distribution	Remarks
Ostreidae	*Ostrea denselamellosa* Lischke 1869	Flat oyster	West and south coasts	Used in bottom culture on the south coast
	Ostrea circumpicta Pilsbry 1904	-	Jeju Island	-
	Dendostrea folia Linnaeus 1758	-	Jeju Island	-
	Dendostrea crenulifera Sowerby 1878	-	--	-
	Crassostrea gigas Thunberg 1793	Pacific oyster, Pacific cupped oyster	West, south and east coasts	Mainly cultured in small bays off the south coast using longlines and bottom culture on the west coast
	Crassostrea pestigris Hanley 1846	-	South coast	-
	Crassostrea nipponica Seki 1934	-	East coast	-
	Crassostrea ariakensis Fujita and Wakiya 1929	-	West and south coasts	Cultured in river-mouth area
	Crassostrea nigromarginata Sowerby 1871	-	Jeju Island	-
	Saccostrea kegaki Torigoe and Inobe 1981	-	Jeju Island	-
Gryphaeidae	*Neopycnodonta cochlear* Poli 1795	-	Jeju Island	Depth 50–300 m
	Hyotissa hyotis Linnaeus 1758	-	Jeju Island	-
	Parahyotissa inermis Sowerby II 1871	Kaki-tsubata	Jeju Island	-
	Parahyotissa chemnitzii Hanley 1846	-	Jeju Island	-

Source: Min, 2004

coast using rocks and used tires as substrate. *Crassostrea ariakensis* is an estuarine species commonly occurring in low salinity environments. Due to its fast growth rate and size, e.g. achieving 100–150 mm in shell length within 2–3 years after hatching, small-scale aquaculture has been attempted using a suspended longline system off the southwest coast. Several species of oysters are also found in Jeju Island, located on the southernmost part of the Korean peninsula, although none of them are currently utilized in the oyster industry (Table 1). Although several species of oysters found in the country are potential candidates for the aquaculture industry, only the Pacific oyster (*Crassostrea gigas*) is extensively farmed. Most of the Korean oyster landings come from small bays on the south coast where *Crassostrea gigas* is cultured using the suspended longline system. In contrast, wild oysters are also harvested commercially on the west coast where they are found on rocky substrates on tidal flats (Figure 1).

ECOLOGY OF *CRASSOSTREA GIGAS*

Nomenclature

Scientific name:

Class Bivalvia
Order Ostreoida
Family Ostreidae
Crassostrea gigas Thunberg 1793 (Figure 2)

Common name:

The preferred common names are the Pacific oyster and Pacific cupped oyster. Other common names include the giant Pacific oyster and the Japanese oyster.

Distribution range in Asia

Crassostrea gigas is found in the west, south and east coast of the Korean Peninsula, Northern Bohai Bay of China to China Hong Kong Special Administrative Region (SAR), from Okinawa to Hokkaido in Japan and from Vladivostok to the Kamcharka Peninsula, Russia.

FIGURE 1
Map showing oyster farming areas in the Republic of Korea

FIGURE 2
View of a live Pacific oyster (*Crassostrea gigas*)

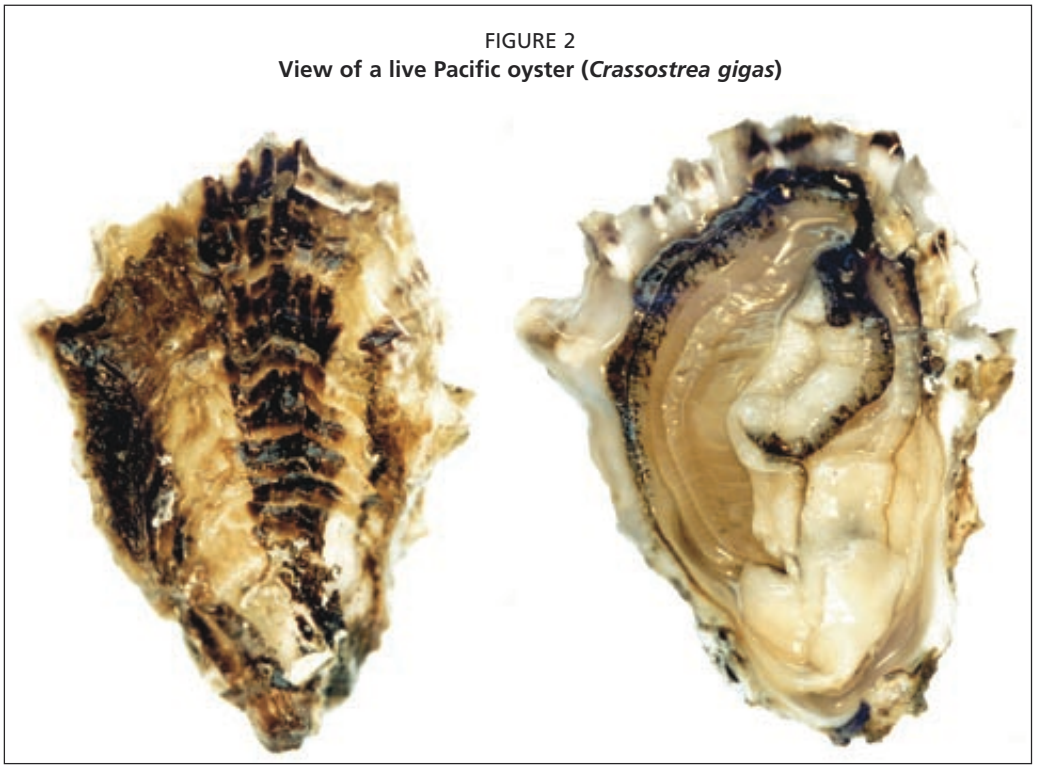
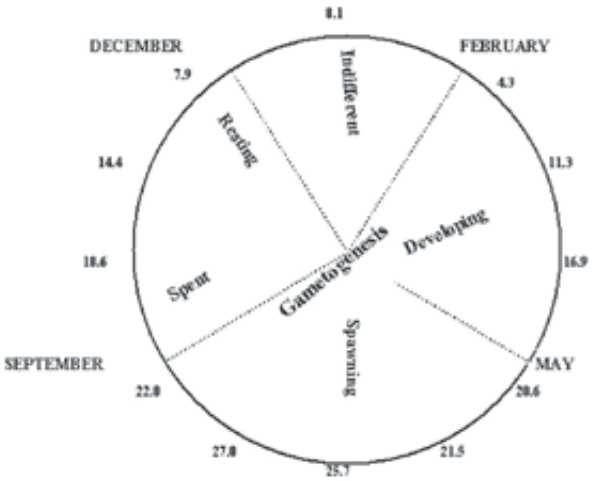


FIGURE 3
Gametogenesis cycle of oysters in Gosung Bay (numbers represent monthly mean water temperature in °C)



Source: Ngo *et al.*, 2002.

Annual gametogenesis

Ngo, Kang and Choi (2002) reported a match between seasonal changes in the surface seawater temperature and gametogenic changes in the Pacific oysters in Gosung Bay off the southeast coast of the Republic of Korea (Figure 3). *Crassostrea gigas* in the Gosung Bay commences gametogenesis in February when the water temperature reaches 4–7 °C. In late May to early June, oysters become fully mature and ready to spawn. The diameter of fully mature oocytes varies from 50–70 µm. Spawning occurs as early as mid-June and can continue until the end of September when the temperature ranges from 23–26 °C. Abrupt changes in water temperature and salinity induce spawning in oysters. Microscopy photographs of both the ovary and testis are displayed in Figure 4.

According to Kang *et al.* (2003), oysters in Gosung Bay spawn twice a year, once in late June and again in late July to mid-August. During spawning female oysters may discharge as much as 60 percent (average 40 percent) of their body weight as eggs. The spawning intensity and quantity of egg released from single oysters is greater in the first spawning peak which is late June (Figure 5). The fecundity of the oysters in Gosung Bay varies from a few million to 200 million eggs during the spawning season.

Larval development

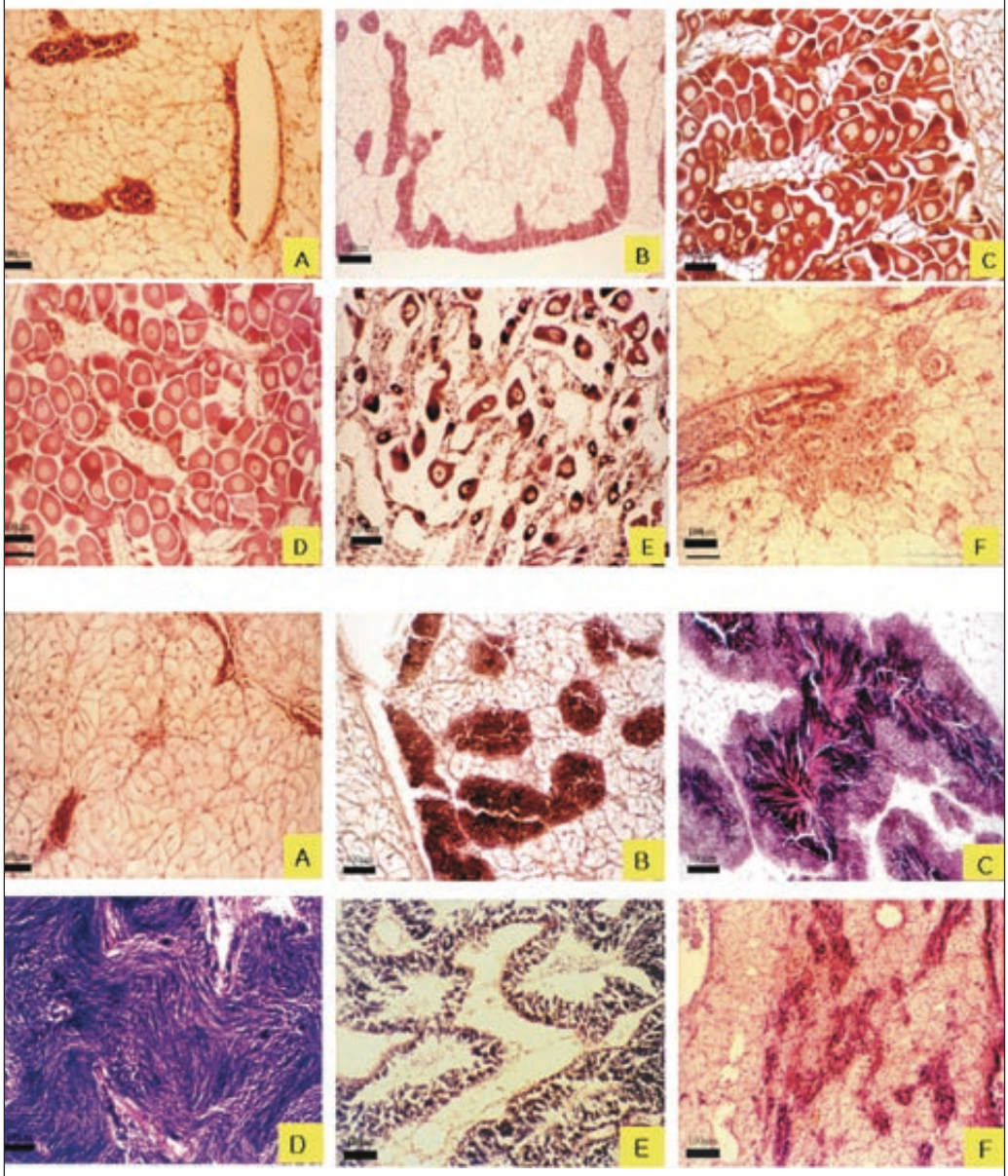
Figure 6 shows the development of the trochophore stage from the pear-shaped mature oocytes released from spawning oysters. The first polar body forms between 50 to 70 minutes after fertilization when water temperature ranges from 20–21 °C. The morula stage can be observed 3 or 3.5 hours after fertilization, while the rotating blastula larva appears between 5 and 6 hours following hatching. Fifteen to twenty-eight hours after fertilization the oyster D-shape larvae develops and, depending on the water temperature, the fully grown larvae (300–350 µm) appear in the water column 10 to 20 days after fertilization and subsequently settle on fixed substrates (Figure 7).

Temperature and salinity are the two key environmental factors that govern larval development. Numerous studies have demonstrated that low water temperatures and salinities slow down larval development, while higher temperatures shorten the duration of the larval period. According to Yoo and Yoo (1972), it takes approximately 10 days from fertilization to settlement when the water temperature remains above 27 °C. However, it takes more than 3 weeks from the fertilized egg to settlement when the water temperature ranges between 19–20 °C.

CURRENT STATUS OF OYSTER AQUACULTURE

During the 1960s and 1980s, oyster production in the Republic of Korea increased dramatically due to the introduction of suspended culture techniques, which enabled the oyster farmers to extend their farming area from intertidal areas in the bays to deeper waters in the middle of the bay. In the early 1960s, Korean oyster production remained below 20 000 tonnes, however, production increased exponentially from 1965 to 1987; in 1985 production reached its peak at 288 078 tonnes (Figure 8). During the 1990s and early 2000, the annual oyster production remained stable, between 170 000

FIGURE 4
Gonadal development in female (top set) and male (bottom set) oysters observed from Gosung Bay. (a) sexually undifferentiated stage; (b) early development stage; (c) late development stage; (d) ripe stage; (e) spawned stage; and (f) gonadal tissue atrophy



Source: Ngo *et al.*, 2002.

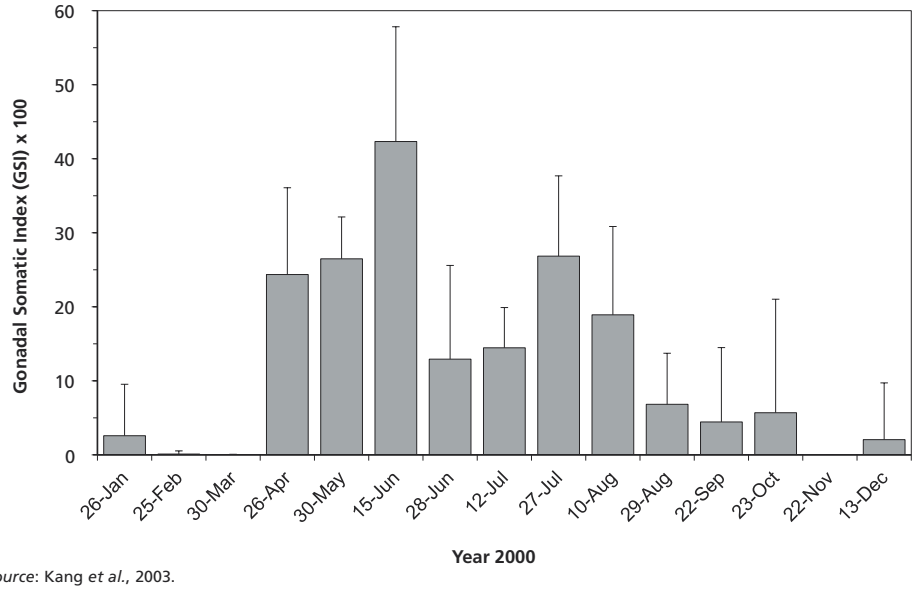
to 250 000 tonnes. Figure 9 plots the value (in US$) of the Korean oyster production from 1985 to 2005. The value decreased dramatically in 1998 due to the drop of the foreign exchange rate brought about by the economic crisis in the Republic of Korea.

In 2005, over 251 706 tonnes of shell-on oysters were produced (or 37 756 tonnes of oyster meat), valued at US$128 269 million. In this same year, an additional 27 320 tonnes of oysters were harvested from natural banks, accounting for approximately 10 percent of the total national production.

OYSTER CULTURE PROCEDURES

The process of oyster aquaculture includes: 1) seed production (collection of natural spat or artificial spat production from hatchery); 2) hardening (i.e. stunting); 3) grow-out; and 4) harvest (Figure 10).

FIGURE 5
Seasonal variation in the Gonadal Somatic Index of oysters farmed in Gosung Bay



Source: Kang *et al.*, 2003.

Seed production phase

Obtaining a sufficient quantity of healthy larvae is essential to support successful oyster production. The Korean oyster industry mainly relies on the collection of natural spat. According to the Korean Oyster Longline Culture Cooperative, natural spat supply 90 percent of the national oyster seed demand, while hatchery-produced seed provide the remaining 10 percent. As shown in Figure 3, mature oysters spawn as early as mid-May and continue to do so until the end of September. Depending on key environmental parameters, such as water temperature, salinity and food availability, the larvae settle 10–20 days after fertilization.

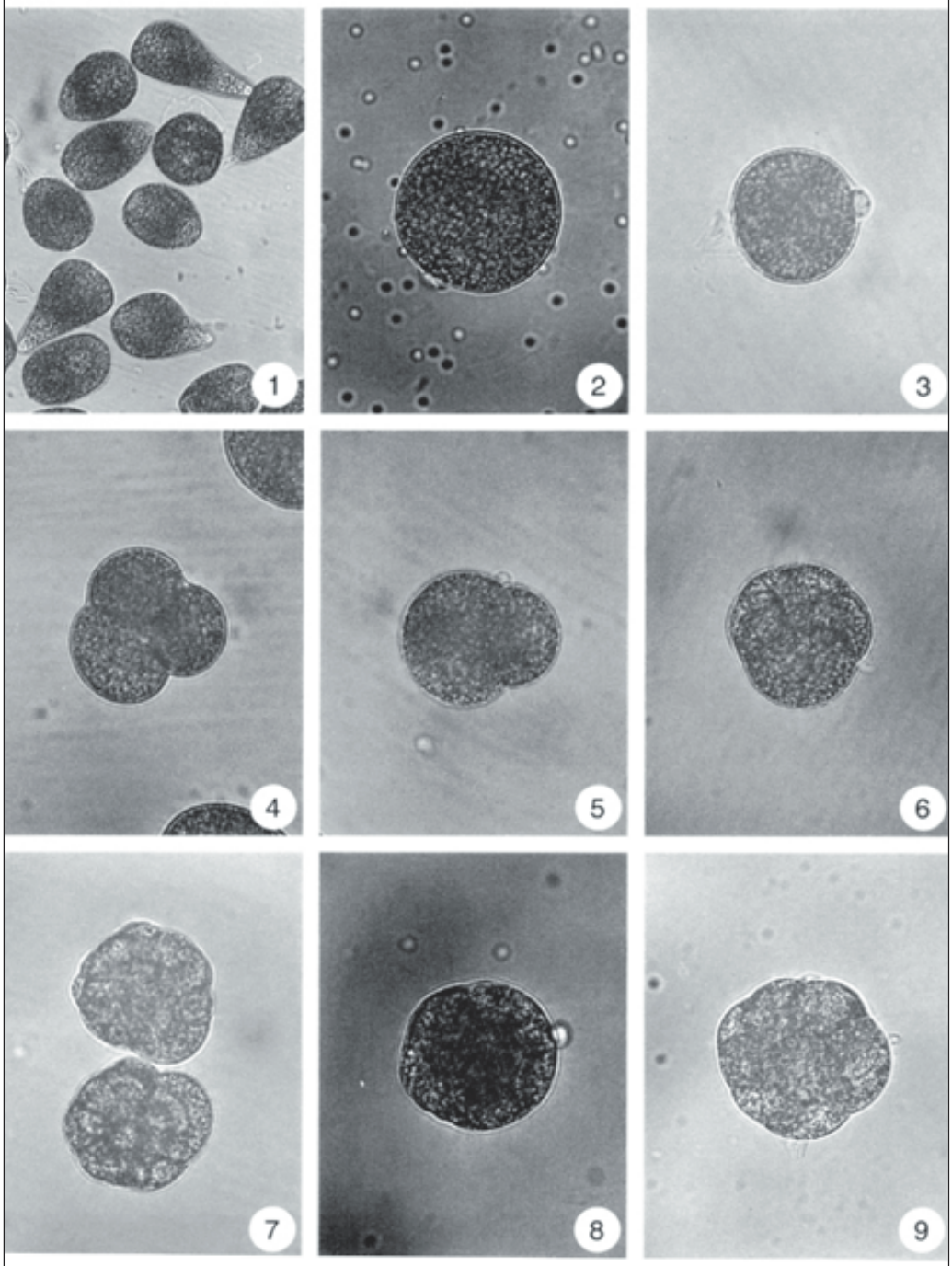
To ensure the collection of a large number of spat, the abundance and development stage of the larvae in the water column are routinely monitored by the regional marine extension services. The monitoring data, including information on the expected maximum oyster spat-fall period, are then conveyed to the oyster growers. Furthermore, an "oyster larval-forecasting" newsletter is posted on specific websites on a weekly basis from mid-May to end August. In the meantime, oyster growers prepare the spat collectors and place them at sea when the abundance of the larvae is at its highest value.

Adult oyster or scallop shells are used as substrate (i.e. cultch) for the larvae to settle on. A spat collector is prepared by first piercing a hole in the middle of the dead oyster or scallop shell and then stringing 50–60 pieces on a 1.5–2 m plastic line (Figure 11). Oyster spat are traditionally collected from the intertidal zone by suspending the collectors on wooden racks which are periodically exposed for 2–3 hours during low tide (Figure 12). Spat can also be collected from subtidal areas by submerging the collectors from the boat. The optimal spat density for each cultch (i.e. oyster or scallop shell) is considered to be 30 spat per single oyster shell or 40–50 spat for each scallop shell.

To ensure the availability of the required volume of seed, both "early spat" collection (June–July) and "late spat" collection (August–September) are targeted by the industry. In 2005, the early spat collection effort started in early June and continued till the end of June, during which time 5.5 million oyster seed collectors were utilized to collect the spat. In 2005, a total of 14.1 million oyster spat collectors were used indicating that spat settlement was more intense during late summer (late spat period).

FIGURE 6

Early developmental stages of *Crassostrea gigas* at 27 °C. (1) unfertilized egg (45 x 70 µm); (2) fertilized egg (54 x 53 µm); (3) 1st polar body formed; (4) trefoil stage; (5) 2- cell stage; (6) 16-cell stage; (7) morula stage; (8) blastula stage; and (9) trochophore stage

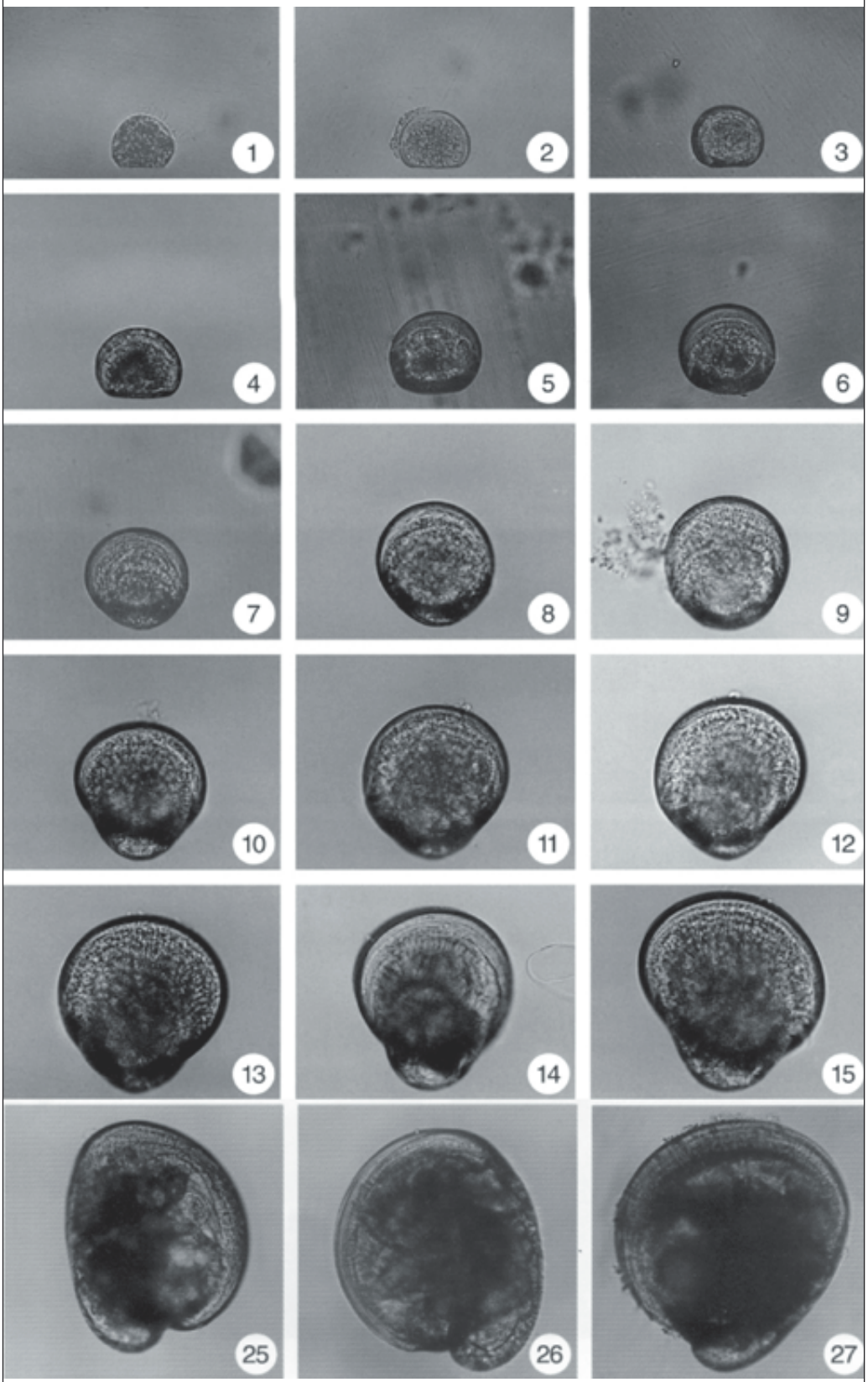


Source: NFRDI, 1997.

More recently oyster seeds have also been used from private hatcheries located on the south coast. The conditioning of broodstock allows hatchery operators to start seed production as early as February and complete the production before the natural spat collection begins. In 2005, approximately 3 percent of the oyster spat demand was supplied from private hatcheries. Spat are also imported from Japan and the United States of America. For example, in 1997 almost 16 percent of the national spat demand was supplied from hatcheries in the United States of America due to poor natural harvest that supplied only 70 percent of the industry requirement (Han, 2005).

FIGURE 7

Larval developmental stages of *Crassostrea gigas* at 27 °C. (1) early D-Shape larva (56 x 64 µm); (2–4) D-Shape larva (62 x 52 – 78 x 69 µm); (5–6) late D-Shape larvae (88 x 78 – 93 x 88 µm); (7–26) umbo stage larvae (95 x 98 – 320 x 355 µm); and (27) fully grown larvae (342 x 355 µm)



Source: NFRDI, 1997.