Economic fishery from *Procambarus* introductions into Spain

Albert P. Gaudé

Crayfish consumption by eastern Europeans dates back to antiquity and has an illustrious role in many cultural festivities. Historically, the supply of crayfish into those markets was harvested from local streams, ponds and lakes. With the increased demand for crayfish in modern times, these supplies were increasingly harvested beyond sustainable limits. Surface waters were also impacted by anthropogenic pollution, further reducing the reproductive capacity of crayfish brood stocks.

In an effort to satisfy the increased culinary demand and reduced supply, authorized and clandestine introductions of crayfish from various regions of Europe and abroad began to occur. Along with some of these crayfish introductions came the fungal 'crayfish plague' *Aphanomyces astaci*. Believed to have entered during the late 1800s on the northern Mediterranean coast with introductions of the North American species *Orconectes*, this disease spread throughout north-central Europe and eventually into the eastern Mediterranean crayfish populations of commercially harvested *Astacus* in the 1980s.

With the sequential collapse of traditional European crayfish sources, international trade of crayfish was dynamic. Spain’s 1979 import trade of crayfish from France of 42 t and resultant monetary deficit drew the attention of fishery economists of the post-Franco Spanish government. Between 1965 and 1972, Spanish discussions continued on possible solutions to this crayfish trade deficit. After lengthy evaluations of similar situations, a decision was made in 1972 to introduce the North American crayfish, *Procambarus clarkii*, into Andalucía, southern Spain (Habsburgo-Lorena 1978).

Fishery Development

After an initial quarantine period of *P. clarkii* shipments in Spanish government ponds near Badajoz, actual commercial introductions were made in 1974 into the 30,000 ha rice-field area known as Las Marismas, immediately southwest of urban Seville. As expected, the similarity of the reclaimed tidal area of Las Marismas to the native habitat of *P. clarkii* allowed for favorable conditions and rapid population growth in rice fields, irrigation canals and streams (Gaudé 1984).

The mechanism of *P. clarkii* range expansion was a combination of natural migration in regional waterways and aggressive stock enhancement at the hands of crayfish harvesting fishermen, who were eager to stock additional water bodies that could be exploited later for profit. At the onset of the population expansion, additional and unauthorized *P. clarkii* introductions were made to accelerate this potential fishery. Aside from commercial fishermen, numerous recreational harvesters likewise sought to seed various favorite fishing sites with readily available *P. clarkii*, either as mature, captured animals, or as juveniles culled from grading at crayfish processing sites.

The rapid expansion and explosive population growth of *P. clarkii*, created by a combination of these factors, developed a harvestable range that spread to areas well outside of the initial stocking site. Populations developed throughout south-central Spain and Portugal within ten years of the Las Marismas stocking event (Gutiérrez et al. 1999).

As harvestable stocks increased, so to did the acceptance of *Procambarus* as a European culinary crayfish. Initially, *Procambarus* was accepted as a substitute for traditional crayfish, but eventually it dominated consumption as a permanent replacement. By 1981, availability of Spanish *Procambarus* effectively reversed the crayfish trade deficit between Spain and France, thus fulfilling the government’s stated mission of the crayfish introduction project (Figure 1).

Controversy

The development of an Iberian *Procambarus* sector has been embroiled in a deep and often fierce controversy con-
cerning the peripheral and unintended impacts attributed to this non-native species. Impacts are generally based on three major attributes: omnivorous diet, disease vector and behavioral damage (Geiger et al. 2005).

The omnivorous diet of the *Procambarus* has been reported to cause rice yield depression and wild habitat alteration (Gutiérrez et al. 1998), both impacts documented in their native range. The role as a possible vector of *Aphanomyces* is likewise accepted, as *Procambarus* has developed host resistance to this infection by co-evolving with the fungal agent. The behavioral impacts of *Procambarus* are centered on either their burrow damage to irrigation infrastructure or competitive aggression /exclusion with other aquatic invertebrate populations. Secondary impacts to terrestrial vertebrates are mixed between positive and negative, with many consumers of crayfish benefiting from their availability as a dietary item (Delibes and Adrian 1987).

**Commercialization of Spanish *Procambarus***

Since 1973, commercial *Procambarus* production in Spain has stabilized within the region of Las Marismas, with harvest tied to local rainfall abundance (de Andalucía 2001). Ranging yearly from 3000-5000 t (live weight) of marketable animals, annual production during the 2000 season indicates that over four percent of the global *Procambarus* harvest comes from descendants of the initial 100 kilograms of viable broodstock introduced from North America. Such harvest potential places Spain third behind USA and unrivaled global leader, China (Figure 2). Far eclipsing the combined production in the native range of USA and introduced Spain, non-native Chinese *Procambarus* are harvested predominately from large volunteer populations in waterways similar to the situation in southern Spain (Figur 3, Liu and Li 2009).

By 2000, the Spanish crayfish sector was centered near the town of Isla Major, centrally located in the rice-growing region of Andalucia. With eight crayfish processing companies employing some 700 workers, a good proportion of the product value of US$13 million is returned to the local economy, with US$7 million in salaries. Of note is the estimate that 30 percent of processed product within these plants is from traditional marine shrimp species.

While the majority of the incoming Spanish *Procambarus* product is destined to be marketed whole (live, chilled or frozen), over 32 percent of product is cooked and peeled for
Initial grading techniques for Spanish Procambarus resulted in abundant undersized crayfish that were used to stock established and new habitats.

tail meat (Figure 4) (de Andalucía 2001). The internal Spanish culinary demand overwhelmingly prefers live wholesale product, with less than 0.5 percent demand for frozen product. Similar to Chinese Procambarus product imported into the USA, Spanish crayfish enters the frozen USA markets as 66 percent tail meat.

Economic Impact of the Commercial Procambarus Sector in Spain

During the 27 years following the sanctioned introduction of Procambarus into southern Spain, over 20,000 cumulative annual incomes have come from this economic activity rooted in crustacean aquaculture. An estimated 40,000 t of marketable Procambarus, worth an estimated US$250 million retail, has provided economic opportunities in an otherwise depressed rural area.

Although the introduction project encountered some unexpected outcomes that undermined the profitability of private crayfish aquaculture ventures, the permanent colonization of the Iberian Peninsula with Procambarus can be considered an economic success. The principal outcomes include needed employment and reversal of the monetary crayfish deficit, both of which existed previous to the introduction. The positive economic input within the production area has gradually become a source of civic pride and cultural identity, with an annual crayfish festival heralding Procambarus as their regional symbol (Junta de Andalucía 2001).

As is the case in the other crayfish producing countries, the future of the Procambarus sector in southern Spain is uncertain. World demand for Procambarus has grown exponentially, thus elevating the genus Procambarus as the most economically important representative of Astacidae (FAO 2010). As a global commodity with multiple potential sources, market conditions for crayfish products are very sensitive to many factors other than the presence of harvestable crayfish populations (Figures 5 and 6). A species, such as Procambarus crayfish, that is locally well adapted and permanently naturalized can make a positive contribution to local economic development.

Notes

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References

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