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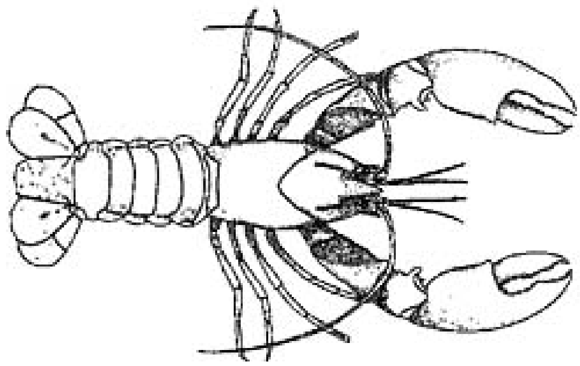

RED SWAMP CRAYFISH (*PROCAMBARUS CLARKII*) IN RIVER NILE, EGYPT

CASE STUDY

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EXECUTIVE SUMMARY

The red swamp crayfish, *Procambarus clarkii* (Girard, 1852), is an autochthonous species from the Northeast of Mexico and South Central USA, which was introduced worldwide and has become the dominant freshwater crayfish in almost all areas it occupies. It is a hardy warm water freshwater crayfish that is typically found in marshes, rivers, slow flowing water, reservoirs, irrigation systems, and rice fields. It may become a keystone species, affecting many components of the ecosystem inhabits and altering the nature of native plant and animal communitiesand its burrowing behavior may cause significant problems.

P. clarkii have been introduced latterly in Egypt. The only available explanation is that the initial access and colonization of *P. clarkii* started a commercial aquaculture in Giza (Manial- Sheiha), in the early 1980's, when the first immigrants of this species were introduced from USA. This project was shortly terminated due to administrative failure.

The study included the morphological aspects of this crayfish (description, colour) and its biology (spawning habits, embryonic development, lifecycle stages and implications of the geographic variation of the reproduction period). Also the study described ecology of species (food and feeding habits, habitat description).

Invasion pathways of *P. clarkii* to new locations included:

i. Agriculture

ii. Biological control

iii. Live food trade

iv. Pet/aquarium trade

v. Self-propelled

vi. Smuggling

The study presented case studies in some countries such as Portugal and Spain, USA and Kenya.

The impacts on Egyptian waters include negative impacts which are:

1. A destructive impact upon the local biota and might lead to considerable stress on the freshwater ecosystems.
2. They attack fish inside nets, on the other hand, trammel nets used by fishermen in the Nile River were frequently torn by wrongly entrapped crayfish and cause loses for fishermen.

3. *P. clarkii* was found to be a host for some protozoa and may act as an intermediate host for some parasitic helminthes.

The Positive impacts include:

1. The biological control of snails transmitting blood and liver flukes.
2. The flesh of *P. clarkii* is recommended to stand as a source of animal protein for Egyptian citizens and its carapace can be used as forage for animals
3. Crayfish can be used as bio-indicator of trace metals pollution in aquatic environment.

The study survey most previous studies carried on this species in Egypt and analysis results. The results showed clearly that there is a little information about its population dynamics and ecology in Nile and its canals. Most of results carried on this species are mostly academic and focused on its histology, histopathology and effect of some chemicals on its organs and muscles. Also, no studies were carried on methods for controlling this crayfish or benefit from it. The distribution and quantity of this species in River Nile and its irrigation canals and drains is still unknown.

The study recommended establishes a program to determine the population dynamics, distribution and geographical extent of this species in River Nile and irrigation canals. According to the results of such program the research activities put the best possible strategy for solving the problems through 2 scenarios:

Scenario 1: Elimination of crayfish from River Nile and irrigation canals

Scenario 2: Use of crayfish as a resource of animal protein for Egyptian people, where the crayfish muscles contain higher values of protein and the dried carapace can also act as a rich constituent of poultry food.

The two scenarios will used the following steps:

1. Developing methods for eradicating them using a natural biocide, harvest it and export frozen it to Scandinavia as the Iranians do with their natural stocks of narrow-clawed crayfish
2. To develop an integrated model for the management and production of crayfish (*Procambarus clarkii*) in River Nile, assuming that crayfish population's size will be controlled by their use as a resource, and potential damages mitigated through the application of a non harmful chemical procedure.

3. To define based on the model results, a "best possible strategy" for crayfish populations management in River Nile, using a combination of crayfish harvest and the non harmful chemical procedure.

INTRODUCTION

In the most parts of the world, nonindigenous species (NIS) are the first or second (after land use change) most important threat to freshwater biodiversity and ecosystem function (Sala *et al*. 2000). The economic costs alone of a small subset of freshwater NIS in the United States have recently been estimated at 4.1 billion dollars annually (Pimentel *et al*. 1999).

The red swamp crayfish, *Procambarus clarkii* (Girard, 1852), is an autochthonous species from the Northeast of Mexico and South Central US (*Hobbs et al.*, 1989), which was introduced worldwide and has become the dominant freshwater crayfish in almost all areas it occupies (Henttonen and Huner, 1999). It is a hardy warm water freshwater crayfish that is typically found in marshes, rivers, slow flowing water, reservoirs, irrigation systems, and rice fields. It may become a keystone species, affecting many components of the ecosystem inhabits and altering the nature of native plant and animal communities. It is an aggressive competitor with native crayfish, and its burrowing behavior may cause significant agricultural problems. *Procambarus clarkii* is heavily exploited as a fishery product and used widely in aquaculture. It is representets an important food source. The yield of its abdominal muscles ranges from 10- 40% of the total body weight, depending on size, and maturity. It is further used as bait for sport fishing. Its economic importance led to widespread introductions on four continents. The species has been used extensively in laboratory studies, but studies of its population biology in the wild have been rare (Huner, 1988). From the medical point of view, *P. clarkii* may serve in controlling certain human diseases caused by helminthes parasites since it has shown to subsist on the vectors for such pathogens (Hunner & Barr, 1991). On the other hand, *P.clarkii* acts as intermediate host for numerous parasitic of vertebrates. It is further assumed that this crawfish may create new public or veterinary health problems when successfully established (Hobbs *et al*, 1989).

There are 3 taxonomic families of crawfish including Astacidae and Cambaridae and Parastacidae. There are over 400 species, but widespread commercial aquaculture is limited to no more than 10 species including 3 astacids, *Astacus astacus* Linnaeus, 1758, *Astacus leptodacylus* Eschscholtz, 1823 and *Pacifastacus leniusculus* (Dana 1852); 4 cambarids, *Orconectes immunis* (Hagen 1870), *Procambarus acutus acutus (*Girard 1852); *Procambarus Clarkii* (Girard 1852), and *Procambarus zonangulus* Hobbs and Hobbs, 1990; and 3 parastacids, *Cherax destructor* Clark, 1936, *Cherax quadricarinatus* (Clark 1936) and *Cherax tenuimanus* (Clark 1936). The most important species is *P. clarkii* which accounts for 90% of the 60 – 70.000 tonnes of crawfish cultured annually (Huner, 1995).

TAXONOMY

Kingdom	Animalia
Phylum	Arthropoda
Subphylum	Crustacea
Class	Malacostraca
Subclass	Eumalacostraca
Superorder	Eucarida
Order	Decapoda
Suborder	Pleocyemata
Infraorder	Astacidea
Superfamily	Astacoidea
Family	Cambaridae
Subfamily	Cambarinae
Genus	*Procambarus*
Species	*Procambarus clarkii* (Girard, 1852)

MORPHOLOGICAL ASPECTS

i - Description:

The size rang of *P. clarkii* are about 8 to 13 cm in length. Crayfish are small lobster-like freshwater crustaceans that have a hard outer skeleton or carapace, which protects the body and makes it rigid. The carapace is dark red bordering on black, and there is with a wedge-shaped stripe on the abdomen. Juveniles are gray, sometimes overlain by dark wavy lines, but without spots. Pincers are narrow and long. The rostrum (spike like protrusion over the head) has lateral spines or notches near its tip.

The palm of cheliped comes with a row of tubercles along the mesial margin of palm. The chela is elongate. There are hooks on the ischia of male at the 3rd and 4th pereiopods. A male's first pleopod terminates in four elements, and the cephalic process is strongly lobate with a sharp angle on the caudodistal margin that is lacking subapical setae. The setae have a strong angular shoulder on cephalic margin that is quite proximal to terminal elements. The right pleopod is wrapped around the margin to appear reduced or absent (Hamdi, 1994).

ii. Colour:

The colour of young *P. clarkii* is greenish-brown with some faint pink pigmentation. A wide middorsal faint brown stripe extends on the abdomen bordered on either side by a dark line. In the adult, the colour ranges from deep red or reddish-brown to almost black with deep red sides and claws. The eyes are coloured black (Fig., 1).

Figure (1). Different pictures of *Procambarus clarkii*

BIOLOGY

i. Spawning Habits:

Sexually mature crayfish shown to mat in open water in late spring and early summer. The females dig burrows in dry banks to lay eggs. Each female produces 200 to 400 young crayfish.

ii. Embryonic development:

Embryonic development is temperature-dependent, with an inverse relationship. Thus, the period from egg-laying till hatching which took 20 days during March (20-21 ºC) and 17 days during April and May (23-26 ºC) and only 11-14 days during late September and mid October (26-29 ºC).

iii. Lifecycle stages

The development of the hatched young of *P.clarkii* was carried out through 7 successive stages. After the young hatch, metamorphosis takes place, followed by two to three weeks of voracious eating. After this they moult and again assume their immature appearance (Hunner and Barr, 1991). Egg production can be completed within six weeks, incubation and maternal attachment within three weeks and maturation within eight weeks. Since their carapaces do not grow, they are molted periodically. Young crayfish may grow fast enough to require shedding every 10 days, whereas adults shed 2-3 times per year.

P. clarkii shows two patterns of activity, a wandering phase, without any daily periodicity, characterized by short peaks of high speed of locomotion, and a longer stationary phase, during which crayfish hide in the burrows by day, emerging only at dusk to forage. Other behaviours, such as fighting or mating, take place at nighttime. During the wandering phase, breeding males move up to 17 km in four days and cover a wide area. This intensive activity helps dispersion in this species (Gherardi and Barbaresi, 2000).

iv. Implications of the geographic variation of the reproduction period

In the original distribution area, *P. clarkii* recruitment usually takes place by the end of summer and during fall (Huner, 1988). Nevertheless, this period is quite variable depending on environmental factors (e.g. climate), and on endogenous physiologic factors (Sommer, 1984).

Due to the conjugated effects of these factors, the reproduction period may change after the species introduction in different regions. In Louisiana, for instance, where crayfish is produced in the rice fields, females lay eggs by the end of summer, and normally the reproduction peaks with the decrease of the water level in the fields (De la Bretonne & Avault, 1977). Nevertheless, when growth takes place under controlled conditions, it has been observed that gonad maturation occurs in different periods and females lay eggs several times. In such situation, the peak of recruitment occurs by the middle of September, followed by a second period in November and December, in which take part individuals (adults or juveniles) that were not sexually active during summer. Still, a third recruitment period takes place in March, resulting from the maturation of juveniles born in September (Romaire & Lutz, 1989). In California, the reproduction shows maxima of recruitment in January and February, followed by smaller peaks in March, August and September (Sommer, 1984).

Other changes can occur in different geographic regions, like in Japan, where two peaks have been observed, respectively in spring and fall, and reproduction is continuous from April to December (Suko, 1958). In the south of Spain recruitment takes place in early summer and by the end of October. Finally, in Portugal, the main recruitment period extends from October to February, but reproduction also takes place in April, May, and August.

Therefore, the reproduction period changes according to the place, apparently related to the hydrological cycle and temperature. For instance, a short dry interchanging with a prolonged rainy season will increase the species sexually active period, causing the development of dense populations with high growth rates. The opposite situation will decrease the sexually active period. Nevertheless, alternating rainy and dry seasons do not fit precisely with reproduction and sexual rest periods (Sommer, 1984). On the other hand, the influence of water temperature is obvious and, from north to south, *P. clarkii* populations tend to change from univoltin to multivoltin life cycles (Huner, 1977).

Changes in the life cycle are apparently the main cause for the fluctuation of typical population’s size after the species introduction in new areas. Unsuccessful control is thus frequent, and possible solutions cannot be standardized. Consequently, the planning of practical measures for population size control demands substantial knowledge of the population biology and ecology, namely of adaptation to the new habitats, in order to evaluate the environmental impacts.

ECOLOGY

i. Food and feeding habits:

The bulk of the diet consists mainly of plant detritus as well as living planet material. This consists of a mixture of aquatic plants such as Elodea and smart weeds, exemplified by *Ceratphyllum demersum, Potamogeton nodosus and Echhornia crassipes,* which are edible and \or shelter plants. Living animals such as live earthworms and small fishes are also eaten by *P.clarkii.* Ibrahim *et al* (1995) stated that this species can devour any kind of fish depending on the facility of catching the prey. They observed also that the snails *Bimphlaria alexandrina, Bulinus truncates, Limnaea cailliaudi* and *Physa acuta* are easier preys to be attacked by the crayfish.

ii. Habitat description

P. clarkii is a native species of northeastern Mexico and the south central USA (Henttonen and Huner, 1999). Unlike the native crayfish species of Europe (which belong to the small family Astacidae) *P. clarkii* is able to tolerate dry periods of up to four months (Henttonen and Huner, 1999). Because of this, it is able to occupy a wide variety of habitats, including subterranean situations, wet meadows, seasonally flooded swamps and marshes, and permanent lakes and streams. It thrives in warm, shallow wetland ecosystems, such as are found in natural and agricultural areas throughout south central Europe, where it has been introduced (Henttonen and Huner, 1999). In the cooler regions of Europe, it prefers small permanent ponds, unable to tolerate the predatory fishes found in large water bodies (Henttonen and Huner, 1999). In countries where it occurs it is commonly found in irrigation reservoirs and channels, and rice fields. It can even be found in sluggish streams and lentic situations, being tolerant of low oxygen levels and high temperatures (Oliveira and Fabião, 1998).

INVASION PATHWAYS TO NEW LOCATIONS

The invasion pathways of this species can be summarized as follows:

i. Agriculture:

P. clarkii is a popular dining delicacy, accounting for the vast majority of crayfish commercially produced in the United States (Washington Department of Fish and Wildlife, 2003). It was the most dominant freshwater crayfish in the world during the 20th century and its commercial success led to intentional introductions throughout Spain, France and Italy during the 1970s and 1980s (Henttonen and Huner, 1999).

ii. Biological control:

In Kenya attempts have been made to use *P. clarkii* as a biological control agent to reduce the numbers of snails that act as intermediate hosts for the disease-causing organism that causes schistosomiasis (*Bilharzia*) (Hofkin *et al.*, 1991). This may have encouraged the spread of *P. clarkii* within the Africa (Holdich, 1999).

iii. Live food trade:

Commerce in live crayfish from neighboring Spain and more distant countries including the Far East have been responsible for some of the introductions of *P. clarkii* into England, the Netherlands, France, Germany and Switzerland (Henttonen and Huner, 1999).

iv. Pet/aquarium trade:

The habit of selling *P. clarkii* alive as an aquarium or garden pond pet may have accelerated the spread of the species through natural waterways in Europe (Henttonen and Huner, 1999).

v. Self-propelled:

Natural dispersal from Spanish waters is thought to have facilitated the spread of *P. clarkii* into southern Portugal (Henttonen and Huner, 1999).

vi. Smuggling*:*

The crayfish that now occur in African freshwaters are thought to have been introduced without the knowledge and permission of the relevant authorities (Mikkola, 1996, in Holdich, 1999).

vii. Other:

P. clarkii can spread to new areas by anglers using them as bait. Popular as a bait species for largemouth bass, this is believed to have been the most likely cause for their introduction into Washington (Washington Department of Fish and Wildlife, 2003).

ECONOMIC IMPACT WORLD WIDE

The introduction of alien freshwater crayfish in new habitats, mainly as food value, has been practiced since 1746 (Hobbs *et al*., 1989). The Louisiana red swamp crayfish, *Procambarus clarkii* (Girard, 1852), has been introduced almost everywhere, with exceptions for Australia and the Antarctic (Huner, 1981). Resulting negative impacts over the ecosystems have been since recorded (Thompson, 1990).

Procambarus clarkii is undoubtedly a good example to illustrate the problems from a non-controlled introduction of alien species (Holdich, 1987). In general, this species reveals a high adaptive capacity to new available habitats, with good tolerance to a wide range of environmental conditions (Hobbs *et al*., 1989). A high growth rate (Culley & Duobinis-Gray, 1987) associated with a well succeeded reproductive strategy is responsible for the development of extremely large populations. These populations can have a severe negative impact over agriculture areas in wetlands (Ocete & Gallego, 1985).

Increasing populations of *Procambarus clarkii* are present in very different regions, namely (Huner & Avault, 1979; Holdich, 1987; Hobbs *et al*., 1989):

1. **Africa:** Kenya, Nigeria, Sudan, Uganda, and Zimbabwe;
2. **South America**: Brazil, Costa Rica, Ecuador;
3. **Continental Asia**: Popular Republic of China;
4. **Pacific**: Hawaii Japan, Thailand;

5. **Caribbean**: Dominican Republic.

1. POSITIVE IMPACT

Its ability to grow and mature rapidly and to adapt to seasonal waters enabled the establishment of *P. clarkii* as the most dominant freshwater crayfish in the world during the 20th century (Henttonen and Huner, 1999). In fact, it is considered to be the most ecologically plastic species of the entire Decapoda order. In Louisiana (USA) this has created a multi-million dollar industry, with more than 50 000 ha under cultivation. In Europe, the introductions especially benefited Spain, creating a flourishing crayfish industry and revitalising the local economy in certain districts. The commercial success of *P. clarkii* is partly due to its ability to colonise disturbed habitats and resist the crayfish fungus plague, *Aphanomyces astaci*, which native European crayfish (Lindqvist and Huner, 1999).

2. PROBLEMS

When introduced into a suitable habitat *P. clarkii* may quickly become established and eventually become a keystone species (a primary contributor to the ecosystem it inhabits). Its introduction may cause dramatic changes to occur in native plant and animal communities (Schleifstein & Fedeli, 2003). For example, *P. clarkii* has contributed to the decline of native European crayfish (in the family Astacidae) by introducing interspecific competition pressure and acting as a vector for the transmission of the crayfish fungus plague, *Aphanomyces astaci*. *P. clarkii* has also been associated with the crayfish virus *vibriosis* in crayfish farms, and is an intermediate host for numerous helminth parasites of vertebrates (Hobbs *et al.*, 1989).

P. clarkii also reduces the value of the freshwater habitats in which it occurs by consuming invertebrates and macrophytes and degrading river banks by its burrowing activity (Holdich, 1999). A successful coloniser, *P. clarkii* employs an r-strategy, exhibiting a short life cycle and high fecundity. In comparison, native European species (such as *Astacus astacus*) employ a k-strategy, exhibiting a long life cycle and low fecundity. As a result, *A. astacus*, is more competitive in mature ecosystems, while *P. clarkii* is more competitive in disturbed habitats (including those areas modified by humans such as rice fields). If present in irrigation structures (such as reservoirs, channels or rice fields) *P. clarkii* may cause significant economic loss.

This is both due to its burrowing activity, which alters soil hydrology and causes water leakage, and its feeding, which causes damage to rice plants (Correia, 1993). The reproductive success of *P. clarkii*, its ability to tolerate environmental changes and its ability to feed on almost anything contribute to its huge potential to colonise new locations and exploit natural resources (Momot, 1995).

CASE STUDIES IN SOME COUNTRIES

1- Portugal and Spain

In Spain, this species was firstly introduced in 1973 in the Badajoz region. In 1974 a similar action was accomplished in the Seville province, in the Guadalquivir hydrological basin (Gaudée, 1984; Habsburgo-Lorena, 1986; Velez, 1980). Since then the population is expanding, and its distribution already reaches the Salamanca region.

The goal of this introduction was to get a double production of rice and crayfish, copying the U.S.A. situation, where crayfish production usually attains very high values (e.g. 55 thousand tons in 1985, about 85% of the world market volume). But six years after its introduction in Spain, crayfish populations have increased without control, invading all the rice fields in the Seville region (Velez, 1980), considered by the FAO as one of the most important rice production regions world wide. The population became one of the most abundant world wide, allowing a yearly capture of about three thousand tons (Habsburgo-Lorena, 1986), but as in other cases crayfish infestation also caused serious damages to drainage systems and rice crops, as consequence of digging activities (Gaudé, 1984).

The first record of *P. clarkii* in Portugal, in 1979, is from the Caia River, in the Guadiana hydrological basin, but the precise date and the aim of its introduction remain unknown. May be it just arrived from a natural infestation in the Guadiana basin after the fast expansion in the south of Spain. In 1986 this species were already widely distributed in the south of Portugal, namely in the Guadiana, Tagus and Sado hydrological basins. In 1987 it was detected in the lower Mondego river region, and in 1990 and 1991, like in other rice areas, *P. clarkii* was the cause of important losses on rice yield (mainly in the lower Mondego and its tributaries Arunca and Pranto regions). Again, the problems are related to digging behaviour, with the consequent damage of the irrigation systems. Additionally, rice plants were physically damaged, and observations suggested that light penetration be obstructed by resuspension of sediments. Apparently, this process affects primarily rice offshoots.

Additionally, it was assumed that crayfish could also have impact over the aquatic ecosystems. In fact, the species introduction might have caused a trophic impact over other populations. For all these reasons, in Spain and Portugal, farmers took this species as a pest and repeatedly tried to get rid of its populations by means of very toxic xenobiotic chemicals, such as Malathion, Parathion, Dimetoate, and Pyrethroids. Such methods proved nevertheless to be ineffective, owing to high resistance of crayfish to toxic compounds, causing on the other hand a severe impact over useful species and the environment (Velez, 1980; Roqueplo & Hureaux, 1989).

Finally they develop an integrated model for the management and production of *P. clarkii* in rice fields, assuming that crayfish populations size will be controlled by their use as a resource, and potential damages mitigated through the application of a non harmful chemical procedure. They develop a non-harmful chemical procedure to control the physiological activity of crayfish populations, in order to assist the rice farming, and simultaneously to allow crayfish production in rice fields, taking profit of both activities.

2- USA

The red swamp crawfish is native to fresh waters from northern Mexico to the Florida panhandle and north to southern Illinois and Ohio. It has been introduced into at least 15 states (Hobbs, 1972; Table, 1). This species and one other, the white river crawfish (*P. acutus*), comprise over 90% of the crawfish produced in the U.S. Both species are very similar. In California, wild populations of the red swamp crawfish eat rice crops (Pennak 1989). They have also been found to prey on California newts (*Taricha torosa*) and may be responsible for their decline in some areas. In Louisiana (USA) this has created a multi-million dollar industry, with more than 50 000 ha under cultivation.

The geographical range of this species is present in table (1) and divided into two categories:

1. Native range: Northeastern Mexico and the south central USA (Henttonen and Huner, 1999).

2. Known introduced range: inter-state introductions into at least 15 other states in the USA (Holdich, 1999).

Table(1).Information on distribution of *Procambarus clarkii* in some locations in United States (USA)

Location	**Source**	**Occurrence**	**Status**	**Invasiveness**
Alabama	Benson and Fuller, 1999	Established	Native	Not invasive
Arizona	BISON, 2000	Established	Native	Not invasive
Arkansas	Benson and Fuller, 1999	Established	Native	Not invasive
California	Holdich, 1999	Established	Alien	Invasive
Florida	Benson and Fuller, 1999	Established	Native	Not invasive
Hawaii	Benson and Fuller, 1999	Reported	Alien	Invasive
Idaho	Benson and Fuller, 1999	Reported	Alien	Invasive
Illinois	Benson and Fuller, 1999	Established	Native	Not invasive
Kentucky	Benson and Fuller, 1999	Established	Native	Not invasive
Louisiana	Benson and Fuller, 1999	Established	Native	Not invasive
Maryland (US	Benson and Fuller, 1999	Reported	Alien	Invasive
Mississippi	Benson and Fuller, 1999	Established	Native	Not invasive
Nevada	Benson and Fuller, 1999	Reported	Alien	Invasive
New Mexico	BISON, 2000	Established	Native	Not invasive
New Mexico	Benson and Fuller, 1999	Reported	Alien	Invasive
North Carolina	Benson and Fuller, 1999	Reported	Alien	Invasive
Ohio	Benson and Fuller, 1999	Reported	Alien	Invasive
Oklahoma	Benson and Fuller, 1999	Established	Native	Not invasive
Oregon	Benson and Fuller, 1999	Reported	Alien	Invasive
South Carolina	Benson and Fuller, 1999	Reported	Alien	Invasive
Tennessee	Benson and Fuller, 1999	Established	Native	Not invasive
Texas	BISON, 2000	Established	Native	Not invasive
Utah	Benson and Fuller, 1999	Reported	Alien	Invasive

Virginia	Benson and Fuller, 1999	Reported	Alien	Invasive

3- Kenya:

P. clarkii was introduced into Kenya between 1966 and 1970 for farming in an attempt to broaden the range of the commercial fishery in the lakes and dams. It has become widespread in all the major drainage systems. Attempts have also been made to use *P. clarkii* as a biological control agent to control the snails that act as intermediate hosts of the organism that causes schistosomiasis (*Bilharzia*) (Hofkin *et al.* 1991).

Impacts:

Different impacts were done on Kenyan waters, *P. clarkii* has interfered with the existing gill net fisherys (for bass and cichlids) by damaging nets and fish, competing with tilapia for food and reducing the number of submerged macrophytes (Brummett and Alon, 1994). The introductions of *P. clarkii* into Kenya caused many economic and social problems. For example the local people did not eat crayfish and lacked the economic and technical means to catch and export them properly.

MANAGEMENT INFORMATION

Possible management options include the elimination (or reduction) of alien crayfish via mechanical, physical, chemical or biological methods, the restocking of native crayfish populations (threatened by the crayfish plague fungus and interspecific competition with alien species), the development of plague-resistant strains of native crayfish and the use of legislation to prohibit the transport and release of alien crayfish.

Preventative measures:

Legislation designed to prevent the spread of crayfish has proven difficult to enforce due to the presence of conflicting social motivations (such as the desire to propagate the species for recreational or commercial purposes). Political barriers, particularly in Europe, may hinder conservation goals; for example the free trade policy backed by the European Union has hindered the attempts of European countries to prohibit the importation of live crayfish from other countries within the EU (Holdich *et al*., 1999).

Physical:

Reduction may be possible by physical methods, although eradication is unlikely unless the population is particularly resitricted in range and size. All physical methods have environment costs, which should be weighed up against the environmental benefits of employing them. Mechanical methods to control crayfish include the use of traps, fyke and seine nets and electro-fishing. Continued trapping is preferrable to short-term intensive trapping, which may provoke freedback responses in the population such as stimulating a younger maturation age and a greater egg production. Bait, such as roach, bream, bleak or white bream, may increase the number of crayfish caught in traps, although freshwater fish should be avoided to prevent spread of the crayfish plague fungus (which may be transmitted on their scales) (Rogers, 1999). Physical methods of control include the drainage of ponds, the diversion of rivers and the construction of barriers (either physical or electrical).

Chemical:

Chemicals that can be used to control crayfish include biocides such as organophosphate, organochlorine, and pyrethroid insecticides; individual crayfish are differentially affected depending on their size, with smaller individuals being more susceptible. Since no biocides are crayfish-specific other invertebrates, such as arthropods, may be eliminated along with crayfish, and may subsequently have to be re-introduced. There is cause for concern about toxin bioaccumulation and biomagnification in the food chain (although this is less of a problem with pyrethroids). Another chemical solution lies in the potential to use crayfish-specific, or even species-specific, pheromones to trap animals. This has been used to control insect populations, but has not been researched with respect to crayfish, although crustaceans do use similar pheromones.

Biological:

Possible biological control methods include the use of fish predators, disease-causing organisms (that infect crayfish) and use of microbes that produce toxins, for example, the bacterium *Bacillus thuringiensis* var. *israeliensis* (Holdich *et al*., 1999). Only the use of predaceous fish has been used successfully; eels, burbot, perch and pike are predators are all partial to crayfish. The amount of cover, type of fish predator used and location are all important variables in determining the success of such an approach, and in general reduced coverage is correlated with increased predation rates.

INVASTION TO EGYPTIAN WATERS

P. clarkii seems to have been introduced latterly in Egypt. Within the last few years, it has been successfully established in various sites of the river Nile and its branches. Although *P. clarkii* has been recorded in Sudan (Huner, 1977), there is no clear evidence that it has migrated from the Sudan northward. There are no records of this species from the most southern parts of Nile or Lake Nasser.

The only available explanation is that the initial access and colonization of *P. clarkii* started a commercial aquaculture in Giza (Manial- Sheiha), in the early 1980's, when the first immigrants of this species were introduced from USA. This project was shortly terminated due to administrative failure, but, meanwhile, *P. clarkii* proved to have definitely been transported in Egyptian waters (Hamdi, 1994).

IMPACTS ON EGYPTIAN WATERS

Negative impact:

1. *P.clarkii* had a destructive impact upon the local biota and might lead to considerable stress on the freshwater ecosystems. They have affected many water courses in Giza and Qalyoubiya governorate and caused a marked decline in species diversity, where it is exploited, it may cause unacceptable damage to the irrigation system, primarily through burrowing in poorly constructed levees and canal banks.
2. They attack fish inside nets, on the other hand, trammel nets used by fishermen in the Nile River were frequently torn by wrongly entrapped crayfish and cause loses for fishermen.
3. *P. clarkii* was found to be a host for some protozoa and may act as an intermediate host for some parasitic helminthes consequently it may create new public or

veterinary health problems when successfully introduced to or transported into new localities. Ramadan (1997) found that three types of protozoa were detected either in the gills or in the connective tissues underneath the carapace. On the other hand, this crustacean animal can be infected with several microbial and helminthic diseases.

4. Some diseases can be transmitted to human by eating the uncooked infected animals. *P. clarkii* host for the rate-lung nematode *Angiostrongylus cantonesis* by harboring its third larval stage causing meningoencephalitis to human (Soliman, 1998). Nassar *et al.* (1991) provided that many predaceous colonial water birds are attracted to crayfish ponds, especially herons, ibises and gulls.

Positive impact

1. *P. clarkii* has shown definite possibilities in the biological control of snails transmitting blood and liver flukes. Also, the results provided encouraging indications of the possible use of it as a biocontrol agent against local aquatic weed pests. A positive note in the selectivity of these species for aquatic, semi aquatic snails which are vector for human pathogens such as Schistosomiasis
2. The flesh of *P. clarkii* is recommended to stand as a source of animal protein for Egyptian citizens and its carapace can be used as forage for animals
3. Crayfish can be used as bio-indicator of trace metals pollution in aquatic environment because they tend to accumulate metals in their tissues**.**

LITERATURE REVIEW IN EGYPT

Hamdi (1994) studied the biology of *P.clarkii* as a new invader in Egypt. Her study included habitat, behavior, food and feeding habits, morphometry, breeding season and life cycle. She recorded this species in Delta region, Cairo and Giza Governorates.

Emam and Khalil (1995) recorded that the estimated average annual yield of *P. clarkii* in the River Nile was found to be about 4.6 tonnes/ year. However, trap size, design, placement, density, and frequency at which they are emptied, in addition to environmental. Factors, such as water circulation, depth, temperature have an important role in determining the real stock and yield. Also, the study indicates that the stock of *P. clarkii* is so far under exploitation. The yield per recruit at the current ages of the first capture and recruitment by using traps was higher that that by using nets. Moreover, using traps as a fishing gear for crayfish will help and save the biomass per recruit rather than using nets.

Ibrahim *et al* (1995) inspected the gut content of forty different size groups of crayfish, *P. clarkii* and studied their feeding behavior in Egypt, and they found that very young stages (0.5 – 0.9 cm carapace length) depend mainly on plankton as the main diet, in addition to a little amount of the aquatic plant**.** Medium-sized crayfish (2.0 – 4.9 cm carapace length) prefer animal organisms in addition to the plant sources. Fish scales were found abundantly in the large-sized individuals (over 5cm carapace length) indicating its main dependence on fish as food on the other hand, the snails *Biomphalaria alexandrina, Bulinus truncates, Limnaea cailliaudi* and *physa acuta* were reported easier preys to be attacked by the crayfish.

Ibrahim *et al* (1996) made a survey for *P. clarkii* along River Nile and its main tributaries at 25 sites from Qena to outlet of the Nile Delta. They stated that *P. clarkii* and *P. zonangulus* were distributed and established viable populations in the aquatic ecosystem of Cairo, Giza and some Nile Delta Governorates. It was not recorded in the Nile at Upper Egypt.

Mubarak (1996) studied the life history, growth curve and mode of living for *P. clarkii* at two localities, Cairo governorate and other in Qalyoubiya gvernorate and found that no significant differences was observed between growth rate of the two population. *P. clarkii* exhibited a well defined 2-years life cycle with two separate breeding stocks, one in the mid spring (April) and the other in late autumn (November). The crayfish active season began in late March when the temperature increases and the water level in different channel and ditches was raised (after winter closure).

Ibrahim *et al.* (1997) carried out a survey for *P. clarkii* and *P. zonangulus* for the first time in Egypt along the River Nile and its main tributaries at 35 sites, from Qena to the outlets of the Nile Delta, during the period from September 1993 to September 1994 , they found that, the two species coexist in mixed populations throughout most of the examined localities though *P. clarkii* indicated remarkable predominance over *P. zonangulus,* and they are more frequent in Qalyoubiya, Cairo and Giza governorates than in El-Menoufiya and El-Sharkiya In Geza governorate, crayfish were found frequently in the main Nile and Ibrahimia Canal. All water cources in this governorate near to Nahia, Warrak El-Arab, Abou-Rawash region, El-Zumur and El-

Marouteya canals were variably populated with the crawfish. This high density decreased gradually southward, until the crawfish became very rare at El-Aiat and Banha. *P.clarkii* had invaded most of the governorates of Upper and Lower Egypt.
Its distribution has extended from northern Delta to Assiute (Saad & Emam, 1998).

Ramadan (1997) found that three types of protozoa were detected either in the gills or in the connective tissues underneath the carapace. On the other hand, this crustacean animal can be infected with several microbial and helminthic diseases.

Sharshr and Geasa (1998) studied the light microscopy examination of hemocytes in *P.clarkii* and indicated the presence off two types of hemocytes namely hyalinocytes and granulocytes. The study also revealed that the concentration of blood levels may be changed according to concentration of the medium surrounding the crayfish.

Shaker and Ibrahim (1998) reported the distribution of *P.clarkii* using geographic introduction system (GIS) in Nile Delta.

Soliman *et al* (1998a) investigated the habitat and distribution of *P.clarkii.* They revealed that this species completely colonized Cairo, Giza and Delta waters. They described also the behavioral patterns of this species.

Soliman *et al* (1998b) stated that *P.clarkii* is known to cause a lot of damage to the fisheries of the Nile possible by eating the fry and the young fish and damaging the nets of fishermen.

Soliman, (1998) studied the diseases can be transmitted to human by eating the uncooked infected animals.

Garo & Saad (1999) studied the histological and ultra structural studies on haematopancreatic hermal space of the *P.clarkii.* They revealed the presence of two cell types (Hematocyst and fixed phagocystes).

Tolba (1999) studied the oxygen consumption (as bio-indicator for water quality) of *P. clarkii* under controlled conditions. His results indicated that *P. clarkii* may be suitable as a bio indicator for total water quality as well as copper and cadmium toxicity.

Heiba (1999) studied the histopathological alterations induced in the hepatopabcreas of the *P.clarkii* exposed to the insecticide diazinon. The results indicated that alterations are dependent on both the insecticide concentrations and the exposure time.

Aly (2000) studied the effect of jojoba seed oil and fenthion on the histology of hepatopancrease, ovary and muscle of *P. clarkii.* The results indicated that the treatment of jojoba oil caused hydropic degeneration of digestive cells and increased the dark brown bodies in the secretory cells of the hepatopancreas. However, fenthion produced pronounced effect on the digestive cells and reduced the size of yellowish granules and dark brown bodies in the secretory cells. On the other hand, fenthion was more destructive than jojoba oil to ovary.

Mona *et al* (2000) studied the composition of freshwater crayfish , *P. clarkii* and its nutritive value in Egypt and found that average chemical composition of flesh of male was to be 7% moisture, 3.1% fat, 10.2% ash, 17.5% carbohydrate, 62.2% protein, calcium 2843mg/100g, phosphorus 343.6 mg/100g ,iron 11.7mg/100g, zinc 15.1mg/100g, selenium 0.9 mg/100g. They concluded that the flesh of *P. clarkii* is recommended to stand as a source of animal protein for Egyptian citizens and its carapace can be used as forage for animals.

Hamdi (2001) studied the physiological changes in the haemolymph, hepatopancreas and muscles of the red swamp crawfish *P.clarkii* exposed to the organophosphorus pesticide malathion in acute and chronic doses during different intervals.

Salah El-Deen *et al* (2001) studied the physiological changes in the haemolymph, hepatopancreas and muscles of the red swamp crawfish *P.clarkii* exposed to the malathion.

Mobarak (2001) studied the distribution of *P.clarkii* in the irrigation canal system of the River Nile.

Sayed (2002) studied the anatomy and histology of both digestive and reproductive systems of *P.clarkii.* He stated that this crayfish is highly resistant for sever conditions and tolerates high doses of pesticides especially bayluscide.

Abdel Mageed (2004) assessed the accumulation of some heavy metals in different tissues of *P.clarkii* collected from the River Nile. He showed that the chronic exposures of fenitrothion caused histpathological changes in hepatopancreas, tests and ovary of *P.clarkii.* The degree of change in these tissues depended on the time of exposure and the ability of animal to overcome the toxicity of fenitrothion.

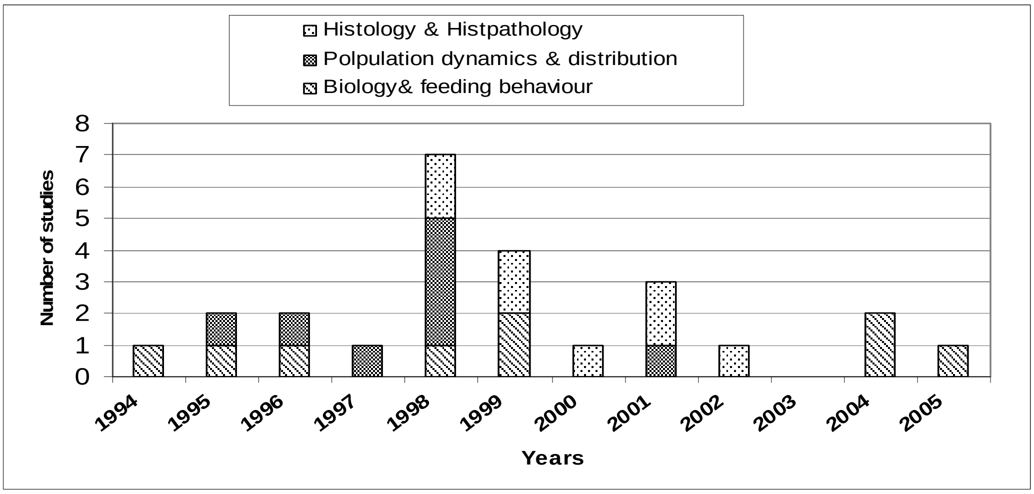
Habashy (2004a) studied the effect of wide range of temperature on survival and growth rate of *P. clarkii* under laboratory conditions, and found that survival was (90%) at 20°C, and the highest weight gain at 30 °C (for about two months rearing experiment). She studied the response of juvenile crayfish *P. clarkii* fed on different fresh diets from available agriculture and freshwater ecosystem, {sweet potato tuber, fresh leaves of lettuce, fresh fish meat (mosquito fish meat)}. The differences were not significant between the other treatments. These results revealed that a diet based on animal source might significantly improve the growth rate of crayfish

Habashy (2004b) studied the response of juvenile crayfish *P. clarkii* fed on different fresh diets from available agriculture and freshwater ecosystem, {sweet potato tuber, fresh leaves of lettuce ,fresh fish meat} and all the possible combinations of those ingredient, result showed that a significant higher growth rate in crayfish fed on fresh fish meat. The differences were not significant between the other treatments. These results revealed that a diet based on animal source might significantly improve the growth rate of crayfish.

Ibrahim *et al* (2005) studied the toxicological impact of the organophosphorus insectside fenthion on *P. clarkii.* Their results showed that LC_{50} of the Fenthion after 12 houres was 1 µg\L. They stated also that the survival of *Oreochrmus niloticus* was directly proportional to its concentrations and inversely proportional to fish size. The study showed that this insectside could be caused nuisance and used for reduces activity of *P. clarkii* in only closed aquatic habitats or some fish ponds (not in Nile or its irrigation).

Analysis of results:

Although the crayfish is widely distributed in the Egyptian freshwater systems, there is a little information about its population dynamics and ecology Nile and its canals. Fig (2) shows that most of results carried on this species are mostly academic and focused on its histology, histopathology and effect of some chemicals on its organs and muscles. Also, no studies was carried on methods for controlling this crayfish or benefit from it. The distribution and quantity of this species is still unknown in spite of some field observations from fishermen stated that it was recorded in Upper Egypt at Qena (not documented).


Histology & Histpathology
Polpulation dynamics & distribution
Biology& feeding behaviour
Number of studies
0
1
2
3
4
5
6
7
8
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Years

RECOMMENDATIONS

To protect our freshwater ecosystem from the impact of the crayfish *P. clarkii* and there is no recent studies on its distribution, it is very important to establish a program to determine the population dynamics, distribution and geographical extent of this species in River Nile and irrigation canals.

According to the results of such program the research activities put the best possible strategy for solving the problems through 2 scenarios:

Scenario 1: Elimination of crayfish from River Nile and irrigation canals

Scenario 2: Use of crayfish as a resource of animal protein for Egyptian people, many of them suffering from malnutrition, where the crayfish muscles contain higher values of protein (58.6 g/100g for female and to 62.6g/100g for male). While the dried carapace can also act as a rich constituent of poultry food.

The two scenarios will used the following steps:

1. Developing methods for eradicating them using a natural biocide, harvest it and export frozen it to Scandinavia as the Iranians do with their natural stocks of narrow-clawed crayfish
2. To develop an integrated model for the management and production of crayfish (*Procambarus clarkii*) in River Nile, assuming that crayfish population's size will be controlled by their use as a resource, and potential damages mitigated through the application of a non harmful chemical procedure.
3. To define based on the model results, a "best possible strategy" for crayfish populations management in River Nile, using a combination of crayfish harvest and the non harmful chemical procedure.

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الملخص العربى

يعتبر أوستاكوزا الماء العذب من نوع بروكمبارس كلاركى (القشريات عشرية الأقدام: فصيلة كامباريدى) أكثر أنواع عائلة كامباريدى انتشارا بصورة عامة ويمثل حوال 90% من حجم المحصول السنوى العالمى لهذا النوع من القشريات فى ولاية لويزيانا بالولايات المتحدة الأمريكية.
وقد ظهر هذا النوع من الأوستاكوزا فى مصر منذ اوائل الثمانينات عن طريق عدة مئات من أفراده تم استيرادها من الولايات المتحدة الأمريكية لاستزراعها فى أحد المزارع السمكية فى منطقة منيل شيحا بمحافظة الجيزة. ورغم أن هذا المشروع قد توقف بعد قليل إلا أن قدرات هذا النوع غير العادية وقدرت الفائقة على التأقلم اتاحت له أن يستقر وينتشر خلال السنوات التاليه فى نهر النيل وقنواته ومصارفه.

وقد تضمنت الدراسة وصفا للحيوان وصفاته البيولوجيه (طرق التكاثر والتطور الجنينى ودورة حياته) وكذلك الخصائص البيئية لهذا الحيوان مثل سلوكه الغذائى والبيئات التى يعيش فيها.

بالإضافة إلى ذلك قدمت الدراسة وصفا شاملا لطرق غزوه للأماكن الجديدة وهى:

أ- الإستزراع:
هذه الطريقة من أهم طرق انتشار هذا الحيوان حيث يستورد للإستزراع فى مزارع خاصة ومنها ينتشر فى حالة عدم وجود طرق للتحكم وهى الطريقة التى دخل بها مصر

ب- المقاومة البيولوجية:
حيث تم إدخالة إلى كينيا للمقاومة البيولوجيه للقواقع التى تسبب مرض البهاريسيا

ت- تجارة المواد الغذائية:
يعتبر تصدير هذا الحيوان حيا للمطاعم من أهم طرق انتشاره خصوصا فى انجلترا وفرنسا وهولندا وسويسرا والدول الإسكندنافية التى تستورده من اسبانيا والبرتغال

ث- أسماك الزينه:
يتم إدخال هذا النوع فى بعض الأحيان لهواه أسماك الزينة

ج- التهريب:
تم أنتشار هذا النوع فى بعض بلدان أفريقيا عن طريق تهريبه بدون موافقات رسمية أما للتجاره فيه أو لإستزراعه

الأهمية الإقتصادية:

أ- **<u>الإيجابيات:</u>**

- يعتبر استزراع هذا النوع من اقشريات عشرية الأقدام من أهم مصادر الدخل فى العديد من دول العالم ففى الولايات المتحدة الأمريكية تيم استزراع أكثر من 50000 هكتار من المزارع تدر عائدا يقدر بمئات الملايين من الدولارات وفى اسبانيا أيضا يتم استزراعه وتصديره إلى معظم الدول الأوربية.
- من فوائد هذا النوع أنه يتغذى على قواقع البلهاريسيا وبذلك يقلل من نسبة الإصابه بهذا المرض بقضائها على العائل الوسيط لها.

ب- **السلبيات**:

- تتسبب هذه الأستاكوزا فى هدم جسور شبكة الرى والصرف الزراعى بسبب الحفر التى تحفرها فى الجسور والشواطىء مما يؤدى إلى تهدمها.
- يشكل هذا النوع تهديدا للثروة السمكية لأنه يتغذى على الزريعة والأسماك الصغيره.
- يتسبب هذا النوع فى أختفاء العديد من الأنواع النباتية والحيوانية الأصيلة والموجودة فى البيئات المائية التى يغزوها ويرجع ذلك لقدرته الشديده على التكيف وشراهته الغذائيه.
- يتسبب هذا النوع فى خسارة اقتصاديه كبيرة لمزارع الأرز خصوصا عندما يتواجد فيها بكميات كبيرة كما حدث فى البرتغال.

قامت الدراسة أيضا بمسح لوضع هذا الحيوان فى بعض البلدان مثل البرتغال (فى أوروبا) والولايات المتحدة الأمريكية وكينيا (فى أفريقيا). ففى البرتغال تم ادخالة للإستزراع فى مزارع الأرز ولكنه سرعان ما سبب مشكله كبيرة للمزارعين بسبب سرعة تكاثره والتهامه لإنتاج الأرز نفسه وهو ما دعاهم إلى عمل برنامج مقاومه برشة ببعض المواد الكيميائيه التى تضعف حركته وهو ما يساعدهم فى جمعه وتجميد وتصديره إلى الدول الأخرى. وفى الولايات المتحدة الأمريكية لا توجد مشكلة حيث أنه يستخدم فى الإستزراع ويعتبر موردا هاما من موارد الدخل القومى فى هذا المجال. أما فى كينيا فقد تم إدخال هذا الحيوان كمحاولة للمقاومة البيولوجية للقواقع الناقله للبلهاريسيا ولكن قدرته الفائقة على التكاثر والإنتشار سبب لهم مشكله كبيره مازالت قائمه.

قدمت الدراسة أيضا مسحا تفصيليا لمعظم الدراسات التى تمت على هذا الحيوان منذ دخوله مصر وحتى الان وتم تحليل هذه البيانات. وقد اثبتت نتائج هذا التحليل أن معظم هذه الدراسات تأخذ منحى أكاديمى ولم يتطرق معظمها لطرق الحد من انتشار هذا الحيوان أو رصد توزيعه فى نهر النيل والقنوات المائية فى مصر أو تقدير المخزون وكميات هذا الحيوان والمدى الفعلى للأضرار التى يسببها.

ولذلك اقترحت الدراسة مايلى:

<u>أولا</u>: عمل دراسه تفصيليه تتناول الوضع الحالى لانتشار هذا النوع فى نهر النيل والقنوات المائية فى مصر أو تقدير المخزون وكميات هذا الحيوان والمدى الفعلى للأضرار التى يسببها سواء للصيادين أو للجسور أو للثروة السمكية.

<u>ثانيا</u>: بناء على نتائج الدراسة التفصيلية يتم وضع استراتيجية المقاومة بعده طرق:

1. استخدام مواد كيميائية غير ضارة لنوعية المياة تقوم بإبادته أو إضعافة وتقليل أضراره
2. إستخدام وتطوير نماذج رياضية للحد من انتشاره
3. محاولة تصنيعة وتقديمه للمستهلك المصرى فى صوره يتقبل أكلها
4. تشجيع المستثمرون لصيده وتجميده وتصديره للدول التى تأكله مثل الدول الإسكندنافية