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REVIEW ARTICLE

The suggestion of integrated trout-crayfish culture in Turkey

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Abstract

The rainbow trout (*Oncorhynchus mykiss*) has been cultured in Turkey since 1969 and Turkey has become one of the top trout producing countries in Europe with an annual production of 85,000 tons (inland+sea) amounting to 51% of the Turkish aquaculture production. *Astacus leptodactylus*, the narrow-clawed crayfish (popular name "Turkish crayfish"), is the native freshwater crayfish species in Turkey. Due to overfishing, pollution and the crayfish plague (*Aphanomyces astaci*), the total annual production of crayfish dramatically reduced from 8,000 to 320 tons between 1985 and 1991. However, in recent years (1996-2004), there has been a gradual increase of production. Aquaculture is important not only for food supply but also for purposes of restocking (including endangered species) and recreational fisheries. This study describes a suggestion which can reduce the nutrient outflow from trout farms. The basic construct is an aquatic ecosystem consisting of one or several water bodies comprising an integrated food web. Horizontal integration of trout and crayfish aquaculture represents a technically viable opportunity for aquaculture producers to reduce environmental impacts and enhancing production efficiency. The study outlines the basic principles in this integrated system.

Keywords: *Oncorhynchus mykiss*, *Astacus leptodactylus*, integrated aquaculture.

Introduction

Inland Fisheries of Turkey

Turkey's fish production in 2010 was about 653,080 tons. Of this figure, 39,187 tons come from inland capture fisheries and 78,568 tons come from inland aquaculture production. The major commercial freshwater fisheries in Turkey are concentrated on inland lakes and the coastal lagoons. Turkey is rich in terms of inland resources compared with many countries in Europe, and capture fisheries occur in all freshwater ecosystems. Turkey has 200 natural lakes with

906,118 ha area, 206 dam lakes with 342,377 ha area, 953 small dam lakes with 15,500 ha and 33 rivers, 177,714 km long and many streams. Main species of inland capture fisheries are common carp (*Cyprinus carpio*), tarek (*Alburnus tarichii*), sand smelt (*Atherina boyeri)*, mullet (*Mugil* sp.), Pike perch (*Lucioperca lucioperca*), catfish (*Clarias lazera*), tench (*Tinca tinca*) and crayfish (*Astacus leptodactylus*). Three species, common carp, tarek and sand smelt dominated the catches with 71% of total inland production in 2010 (TurkStat 2010).

Aquaculture in Turkey is a relatively young industry; it started with rainbow trout culture (*Onchorhynchus mykiss*) in the early 1970s. However, aquaculture production has increased rapidly. The main development took place during the 1990s. Over the past ten years, the volume of aquaculture production has increased by a factor of 10, from 16,000 t in 1996 to 167,141 t in 2010. The industry has developed to such an extent that Turkey is currently the third largest finfish aquaculture producer (i.e. excluding shellfish) in Europe, and the second largest producer of both sea bass and sea bream and of rainbow trout (after Norway). The following species are mainly cultured commercially: rainbow trout (*Oncorhynchus mykiss*), seabass (*Dicentrarchus labrax*), gilthead Seabream (*Sparus aurata*), carp (*Cyprinus carpio*), bluefin tuna (*Thunnus thynnus*) and Mediterranean mussel (*Mytilus galloprovincialis*). Production from marine (including brackish water) aquaculture in 2010 was 88,573 tons which was 53% of total aquaculture production while inland (freshwater) aquaculture production was 78,568 tons (47%). Today both freshwater and marine aquaculture plays significant roles in Turkish fishery production, contributing 25% to total fisheries production. Currently, there are 1,470 fish farms, of which 1,159 are freshwater fish farms and 311 are marine fish farms (FAO 2008; TurkStat 2010).

Trout Farming in Turkey

The rainbow trout (*Onchorhychus mykiss*) has been cultured since the early 1970s and Turkey has become one of the top trout producing countries in Europe with an annual production of 85,244 tons, or 51% of country's total aquaculture production. Of this figure, 78,165 tons come from inland aquaculture and 7,079 come from sea water production. There are 222 fisheries cooperatives and 3,325 fishing vessels engaged in inland fisheries while 1,159 farms are involved in inland aquaculture and mainly rainbow trout production. A great majority of the farms are small (<50 tons/year) scale family-owned enterprises, but the producers have considerably increased their capacity in recent years. A great majority of the trout farms have their own hatchery. Trout farms are mainly localized in the Aegean, Black Sea and Mediterranean regions. The main freshwater aquaculture production system in Turkey is the cold water flow through system for trout production. The most common rearing system used in freshwater trout production is concrete raceways except some larger farms having modern circular concrete tanks; earthen ponds are also used for the intensive rearing of trout. Cages used in reservoirs for trout are generally simple wooden structures locally constructed. The system is mainly used where good quality water is available and environmental regulations are not overly strict. There are several streams especially in mountainous (coastal and inland) areas with very favourable water and temperature condition which is very convenient for trout farm. Distance between farms is a very conflicting matter and a scientific solution has not been found for this yet. At present practice, the distance between ongrowing farms using same stream is minimum 500 m and 5 km between hatcheries. In cage culture the distance is 1,000 m (Kılıç 1999; Kılıç *et al.* 2010; TurkStat 2010).

The Status of Crayfish in Turkey

The only native crayfish species in Turkey, *A. leptodactylus*, is widely distributed in lakes and ponds in many parts of the country. It originates in western Asia and Eastern Europe. It was widely introduced into many countries, e.g. Poland, Italy, Germany, England, Spain and France, where it escaped into the wild and established large populations in a number of localities (Harlıoğlu 2004). At present, it can be found in 27 countries, 14 of which it has been introduced into (Skurdal and Taugbol 2001). In Turkey, there are 42 recorded crayfish harvest populations, but harvesting is not carried out regularly on these populations every year (Figure 1). In addition to these harvested populations, there are many crayfish populations that are not harvested because of their low economic value, for example, some populations observed to have crayfish plague, and those from waters into which crayfish have only been recently introduced (Harlıoğlu 2008). After the presence of *Aphanomyces astaci* in Europe, Professional management support, conservation studies and action plans have been put in place to protect the European native crayfish (*A. astacus* and *Austropotamobius pallipes*) populations. These management activities include producing disease free juveniles under controlled conditions for stocking, providing shelters and food, catching regulations, protecting crayfish from harmful animals (predators), preventing the spread of diseases and alien crayfish introductions, outreach to inform governments, fisherman and the public on the importance of native crayfish species population protection and removing plague infected crayfish from wild habitats (Laurent *et al.* 1993; Rogers and Holdich 1997; Von Lukowicz 1999). With the exception of the above regulations, no population management or conservation strategies have been put in place for the populations of *A. leptodactylus* in Turkey.

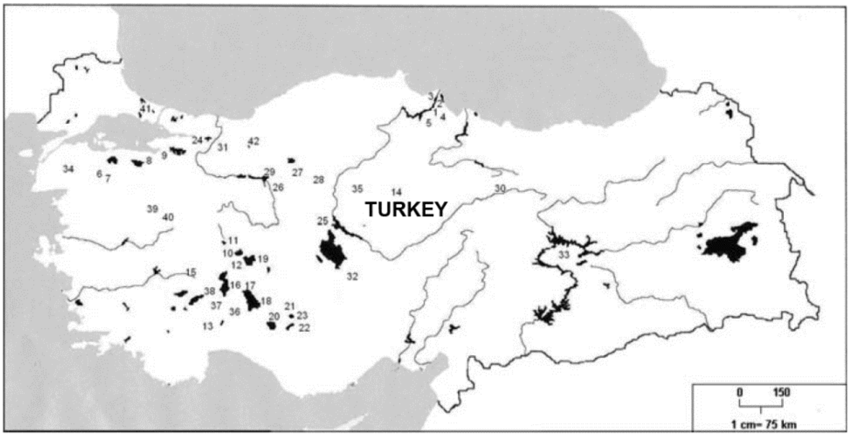

Figure 1. Distribution of waterbodies from which *Astacus leptodactylus* is harvested in Turkey (Harlıoğlu 2008)

Harvest of *A. leptodactylus* from nature in Turkey varied from 3,885 to 7,936 tons between 1977 and 1984 (Köksal 1988). Because the domestic demand of crayfish was very low in Turkey, it was exported to Western Europe from 1970 (or possibly earlier) until 1986 (Köksal 1988; Harlıoğlu 2004). The production of *A. leptodactylus* after 1985 decreased dramatically from 7,936 to 320 tons in most Turkish lakes as a result of the crayfish plague reported in several studies. As a result of severely reducing the harvest of *A. leptodactylus* in Turkey, crayfish harvesting was forbidden by law between 1986 and 1990. After the occurrence of crayfish plague in Turkey, in order to increase crayfish stocks, uncontrolled *A. leptodactylus* stockings have been carried out in many waterbodies throughout Turkey. These introductions have caused an increase in the number of *A. leptodactylus* populations, but exploitation of *A. leptodactylus* is still under the pressure of the plague, although there has been a steady increase in crayfish production in recent years. In the early 1990s, the annual harvest was around 300-500 tons and reached 1,500 tons in 1998, but the plague was still present at some localities (Diler *et al.* 1999). The total harvest has gradually declined to approximately 1,372 tons in 1999, however, it increased slightly to 1,681 tons in 2000 and 1,634 tons in 2001. In 2002, the harvest was 1,894 tons. After 2002, there was a gradual increase in the amount of *A. leptodactylus* harvested, i.e. 2,183 tons in 2003 rising to 2,317 tons in 2004, but the harvest was recorded 809 and 1030 tons in 2005 and 2010, respectively (Figure 2).

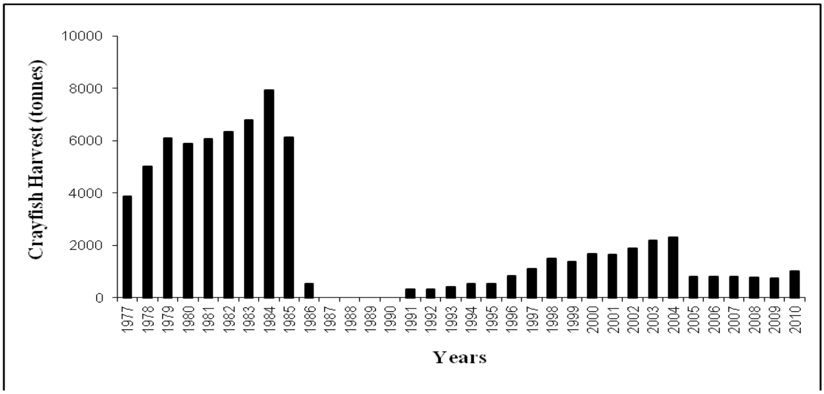

Figure 2. Crayfish harvest in Turkey between 1977 and 2010. Data summarized from Köksal (1988) and TurkStat (1990-2010)

Discussion

Aquaculture is a very fast developing branch of food production. However, this fast development, usually focused only on one species being involved, might be very harmful for environment and cause serious damages. Sustainable development in aquaculture means such system of production which is environmentally non-degrading, technically appropriate, economically viable and socially acceptable, which conserves land, water and animal resources (FAO 1995, 1997). Also, future development of the aquaculture industry is limited by resources, such as water, land, fishmeal, and other factors, such as environmental pollution. The negative impact of aquaculture derives mainly from particulate and dissolved nutrients from animal excretion and uneaten food. Nitrogen (N) and phosphorus (P) are the two main pollutants of intensive aquaculture (Lemarie *et al.* 1998). Different methods have been tried to minimize the effects of nutrient loading. Minimizing the impact on the environment should be a priority in any project. Current techniques for the reduction of particulate matter in wastewater involve mechanical removal by sedimentation and micro saving, but removal of particular matter by sedimentations alone is inefficient and microsieves are relatively expensive and require regular maintenance. Integrated aquaculture is a feasible method to reduce the environmental impacts of by-products from fish culture. Moreover, in integrated systems, nutrients are converted into harvestable products. Recently, different authors such as Seawright *et al.* (1998), Bunting (2001, 2008) and Neori *et al.* (2004), have outlined "Diversification" and horizontal/integrated aquaculture like one of the basic principles of sustainability and it should be kept in mind by the countries in planning and future development of aquaculture sector. The projects with a wide range of species culture contemplated in the same installation (polyculture or multicomponent system) should be a priority.

The freshwater farming industry envisions that, with their existing water supply, it can produce more fish with a greater biomass than they are currently licensed for, with no increase in environmental impact (Warren-Hansen 2001). In this context, depending on the capacities of enterprises, necessary arrangements related to the distance between them should be made and limitations to effluent and its load should be set and put into practice in Turkey. Nutrient polishing risk in the trout farms using the same stream area. Bulut *et al.* (2010) investigated physicochemical and microbiological parameters of Kanlıçay Stream in Denizli located on the western part of Turkey to determine the effects of trout aquaculture facilities on water quality. Along this stream, there were 93 trout aquaculture facilities, many of which did not have any clearing pool systems. In general, it was found that the water quality in the upstream stations was appropriate for trout aquaculture and water was not polluted. On the other hand, in the downstream stations, organic pollution was observed on account of intensive trout culture activity. Aquaculture is important not only for food supply but also for purposes of restocking (including endangered species) and recreational fishing.

The objective of this study is to develop a project that enable to reduce the effects of outflow nutrient from trout farms to environment and to construct aquatic ecosystem consisting of one or several water bodies like wetland, with an integrated food web utilizing nutrient rich wastewater to culture crayfish. The main dependent of horizontally trout-crayfish culture is capability of water criteria of these two species. Horizontal integration represents a technically viable opportunity for aquaculture producers to reduce environmental impacts whilst apparently enhancing production efficiency and gaining from economies of integration. Sindilariu *et al.* (2010) studied effluent treatment concepts for trout aquaculture in dependence on production intensity in Germany. In outflow, the nutrient concentrations from 13 German trout farms were monitored. The farms had a significant effect on the effluent quality and the macro-invertebrate fauna. Finally a constructed wetland showed the highest treatment efficiency compared to the other treatment options with nutrient reduction rates of > 35% for TP (total phosphorous), COD (chemical oxygen demand), BOD (biological oxygen demand), TSS (total suspended solids) and total ammonia nitrogen (TAN).

Trout is cold-water fish. Although the optimum temperature for rainbow trout metabolism is about 15°C, in practice, the water temperature is the critical discriminating factor on the production style of trout farms. In Turkey, facilities having 8-12°C water temperature are in use of gamete and fry production in hatcheries and 15-17°C in breeding. Temperature can rise to 17-22°C in some facilities in summer (Table 1). The crayfish requires water temperature of 14-22°C and they can establish a regular population in which they are stocked. The main dependent of integrated trout and crayfish farming is the compatibility of water criteria of these two species (*O. mykiss* and *A. leptodactylus*). According to the suitable geographical conditions and field type, crayfish can be live stocked in lakes or ponds if the drained water has no other commercial or ecological boundaries. When these conditions are satisfied crayfish production could be operated.

Crayfish demand for human consumption in Europe is as much as 10,000 tons per annum (Huner *et al.* 1992). There is a steady increase in demand in Europe, because the production of most native (*A. astacus*) species continues to decline. On the other hand, *A. leptodactylus* is equal in taste to the related and highly esteemed *A. astacus*. In addition to this, optimal growing conditions which will help to establish healthy stocks of *A. leptodactylus* may achieve growth rates that are comparable with other astacid crayfish species and thus provide crayfish farmers with a useful supplementary or alternative species for culture. Turkey has already a great freshwater potential to do this (Harlıoğlu 2004).

Table 1. Some water parameters in trout farm (950 tons/year) in different seasons in Turkey (Anonymous 2002)

Parameters	Spring Inflow/Outflow	Summer Inflow/Outflow	Autumn Inflow/Outflow	Winter Inflow/Outflow
Turbidity (NTU)	0.4 / 0,4	0,36 / 0,5	0,32 / 1,4	0,36 / 0,4
Temperature (°C)	14.4 / 14,9	14,8 / 17,9	13,9 / 15,0	13,4 / 14,2
pH	7,99 / 7,85	7,91 / 7,68	7,69 / 7,73	7,79 / 7,67
DO (mg/l)	10,45 / 6,3	9,36 / 6,2	10,60 / 6,3	9,93 / 7,4
Total hardness (mg/l)	400 / 420	406 / 433	393 / 390	403 / 466
NO_2-N (μg/l)	1,88 / 15,2	Nd / 9,07	11,21 / 4,62	Nd / 13,7
NO_3-N (μg/l)	31,10 / 35,4	89,90 / 115,3	30,75 / 40,5	8,47 / 11,2
NH_4-N (μg/l)	7,1 / 131,2	9,0 / 298,9	4,9 / 196	11,89 / 123,2
PO^{-3}_4-P (μg/l)	1,99 / 19,9	1,37 / 17,45	15,25 / 58,9	6,65 / 15,96
Organic Matter (mg/l)	13,7 / 22,1	9,48 / 15,77	18,87 / 26,31	29,4 / 36,86
Flow Rate (m^3/sc)	3,46 / -	2,22 / -	2,54 / -	4,04 / -
BOD (mg/l)	0,1 / 1,3	1,36 / 4,03	1 / 1,5	2 / 1,16

Moreover, there is a danger to import non-native crayfish species into Turkey in order to expand crayfish production in recent years. It is thought that the introduction of non-native crayfish species into Turkey must be strictly forbidden because of the observed negative impacts of non-native crayfish species introductions carried out in many parts of the world. The introduction of the crayfish species from North America into Europe had negative impacts on the native species populations. Since 1883, crayfish plague (*A. astaci*), has devastated Finland's most productive populations of the native crayfish (*A. astacus*), causing great loss to once very valuable fisheries and exports. After efforts to halt the spread of the plague having failed, it was decided in the late 1960s to attempt to revive crayfish production and fisheries by introducing the plague-resistant North American signal crayfish (*Pacifastacus leniusculus*), into infected waters. So far, this crayfish has been stocked in 300 lakes and it has reproduced in many of them. In some lakes, the two crayfish species cohabit. The fact that both species have lived side-by-side for 30 years in Slickolampi, a small lake in southern Finland, without any signs of crayfish plague *A. astaci*, indicates that the *P. leniusculus* population must be plague-free. The native crayfish was clearly dominant up to 1980, but since 1990, the signal crayfish has completely replaced native crayfish. In three decades, signal crayfish have almost completely replaced native crayfish (Westman *et al.* 2002). For these reasons, to increase crayfish production of Turkey, before thinking the introduction of any non-native crayfish species, it is necessary to increase studies scientifically on the biology, ecology, reproduction, feeding, especially robust juvenile rearing to stock (or re-stock) freshwaters and conservation of populations of *A. leptodactylus* (Harlıoğlu and Yonar 2007).

Culture of *A. leptodactylus* in captivity is not carried out in Turkey. Supply of this species is only from crayfish fisheries and nearly all the production is exported. This species is not only important for its economic value but also for its important role in inland aquatic food web. Crayfish aquaculture relies on control of pond hydrology to simulate optimal wet and dry conditions occurring in natural riverine and wetland habitats. In a natural ecosystem, crayfish feed omnivorously on detritus, algae, plants, invertebrates, and vertebrates. Low-protein resources such as plants, detritus, and algae are important energy sources for maintenance. Usually, fully grown adults feed almost entirely on vegetal matter, either fresh or detritic (Rudnick and Resh 2005). Detritus, decomposing organic material, is the base of the complex, self-sustaining food system required in crayfish culture. As organic matter decomposes, it becomes "coated" with bacteria, other microorganisms, and small invertebrates that increase its nutritional quality. Larger aquatic fauna such as insects, worms, clams, snails and zooplankton feed on the enriched decomposing vegetation. It is these animals that make up the major part of the crayfish diet. Crayfish production can use planted or voluntary natural vegetation. Many aquatic plants provide detritus to the underwater foodweb consistently throughout the growing season.

Natural voluntary vegetation is usually the least expensive to establish and can sometimes be satisfactory as a forage crop; however, it is often unreliable and insufficient for maximum crayfish production. When flooded, voluntary terrestrial grasses and sedges usually decompose rapidly. This reduces water quality and provides short-lived detrital sources. Aquatic and semi-aquatic plants such as alligatorweed (*Alternathera philoxeroides*) and smartweed (*Polygonum* spp.) are superior to terrestrial grasses because they continue to live when flooded. During much of the season little material is cast from these plants to form detritus. However, during the winter the emergent parts of the plants die and form large amounts of detritus, usually at a time when low water temperatures reduce feeding by aquatic organisms. Ponds with an appropriate mixture of aquatic, semi-aquatic and terrestrial vegetation do occasionally produce good crawfish crops. After trout farm, constructed wetlands should be constituted, in the places where terrain enables. These areas can encourage the growth of naturally occurring vegetation, thus may be managed exclusively for crayfish. The system results in reduced waste discharge and resources use. In horizontally integrated trout-crayfish culture in a water body or a pond system, waste serves as nutrient for phototrophic and detrivorous/heterotrophic conversion into plants, bacteria, and invertebrates, on which crayfish are feeding. At the same time, agricultural lands unsuited for growing grain crops because of poor drainage or soils are sometimes used for naturally vegetated crayfish ponds. These kinds of ponds can sometimes be effective low-input production systems. Experimental watercress-crayfish polyculture system was described by Rundquist *et al.* (1977). The watercress bed receives nutrient-rich effluent from a connecting trout hatchery and effectively strips nitrates, ammonia, and phosphorous from the waters. The harvested watercress also provided a clean and easy food source for crayfish.

The quality of water required to produce crayfish is similar to that required by most warm-water aquatic animals. Important water quality variables are dissolved oxygen, pH, total hardness, total alkalinity, ammonia, nitrite, iron and hydrogen sulphide. Dissolved oxygen is the most important factor in water quality. It should be maintained above 3 parts per million (ppm) for optimal crayfish production. Water pH should range from 6.5 to 8.5 at dawn; both total hardness and total alkalinity should range from 50 to 250 ppm as calcium carbonate (100 ppm is optimal). Un-ionized ammonia and nitrite are toxic to crayfish at concentrations higher than 2 and 4 ppm (as nitrogen), respectively. Iron and hydrogen sulphide are toxic to crayfish at concentrations often found in well water, but the two compounds may be lowered to non-harmful concentrations when well water is oxygenated (Avery *et al.* 1998).

Cool water crayfish species (principally Astacidae) such as *A. leptodactylus* grow slowly. Most of astacid crayfish mature in two to four years. They produced rather few large eggs in autumn at temperatures below 10°C, and their eggs hatch up to nine months later. Female growth is restricted as they cannot moult because of carrying eggs up to nine months (Reynolds 1989). However, manipulation of reproductive cycles has been accomplished with crayfish species based on physiological studies of gonadal development and abdominal egg development. For example, in astacid crayfish species, abdominal egg development can be rapidly shortened by increasing incubation temperature to around 20°C (Huner 1990). The artificial temperature regimes and incubation techniques have been used to induce early hatching of juveniles for *A. leptodactylus* by Köksal (1988) and Harlıoğlu (1996). It has been observed that *A. leptodactylus* mated and spawned at water temperature 8-11°C. Meanwhile, we assume that the water condition in wetland area can contribute to reduce hatching time of eggs.

After the wetland (water body) is prepared and filled, spawners and juveniles without disease can be collected from natural dam-lakes and reared under controlled conditions in tanks or ponds up to a certain size. The prepared crayfish is used for farming in ponds up to a marked size or for re-stocking of natural water bodies in the country. Stocking can be done from May to July. Bloodstocks generally consist of an equal number of males and females. Stocking density for extensive rearing should be 200 to 1,000 crayfish/hectare

(Lee and Wickins 1992). Crayfish held for longer periods of time are subject to stress and may have significant post-stocking mortality. Bloodstocks should be transported in mesh sacks and packed densely enough to minimize movement. The transported crawfish should be kept cool and moist, but not have direct contact with ice. If sound management practices that ensure good survival are followed, crawfish should not have to be restocked annually. The unharvested population remaining in the area should be sufficient to sustain consistent levels of production from year to year. Restocking is recommended when annual production in the area is significantly lower than when it decreases by 25 to 30 percent over time. Bloodstocks should be restocked at a rate proportional to the decrease in production. There will be no problem in case fish escape from trout farm into constructed water body area. Rubin and Svensson (1993) studied predation by the indigenous crayfish *Astacus astacus* (Linnaeus) on trout eggs and fry and found no evidence of this species ability to consume trout eggs laid in reeds. Stenroth and Nyström (2003) studied the effect of signal crayfish on brown trout using enclosures in a Swedish stream and found no impact on growth or survival of juvenile trout. Degerman *et al.* (2006) studied the effect of native noble, *A. astacus* and introduced signal crayfish *P. leniusculus* on fish population densities in temperate stream communities and found no effect on fish population including brown trout *Salmo trutta*. This situation can help to establish recreational fishing at the same time. The trout fishing (specimen specific) is a remarkable potential for angling tourism, a spectacular attraction for the fishing enthusiasts and an economic value for the community in both local and national level. Recreational fishery and related tourism will play a key role in multipurpose aquaculture, as angling provides high economic value to the society.

We have concerns and expectations on this suggestion, such as;

Concerns:
- Interaction diseases between trout and crayfish
- *A. leptodactylus* still under the pressure of the plague
- To obtain disease-free stock
- Legislative support

Expectations:
- Mutual benefits achieved ecologically
- Bio-solution for a sustainable trout culture
- Conversion into biomass
- To protect crayfish gene resources
- To culture crayfish

The objective of this study is to draw attention to the quality properties of the effluent of trout farm in aquaculture production and environmental interaction and to produce crayfish both for consumption and for stocking into the nature to support the wild populations. To perform the crayfish farming into profitable branch of aquaculture and enhance and protect the natural resources of crayfish, several issues of farming technology have to be solved. The development of integrated trout-crayfish culture is ecological and economically promising because of two valuable outputs - cleaner water and crayfish.

Türkiye'de entegre alabalık-kerevit yetiştiriciliği önerisi

Özet

Türkiye'de gökkuşağı alabalığının (*Oncorhynchus mykiss*) yetiştiriciliği 1969'dan beri yapılmakta olup, 85,000 tonluk alabalık üretimi (içsu ve deniz) ile Türkiye su ürünleri yetiştiriciliğinde %51'lik paya sahiptir ve alabalık yetiştiriciliği yapan ülkeler arasında Avrupa'da ilk sıralarda gelmektedir. *Astacus leptodactylus*, ince kıskaçlı kerevit (popüler ismiyle "Türk Kereviti"), Türkiye'nin doğal kerevit türüdür. Aşırı avcılık, kirlilik ve kerevit vebası (*Aphanomyces astaci*) nedeniyle toplam yıllık kerevit üretimi 1985-1991 yılları arasında 8,000 tondan 320 tona kadar gerilemiştir. Bununla birlikte son yıllarda (1996-2004) üretimde aşamalı bir artış gerçekleşmiştir. Su ürünleri yetiştiriciliği besin kaynağı açısından olduğu kadar aynı zamanda stoklandırma (nesli tükenmekte olan türler için) ve rekreasyonel (turizm/sportif amaçlı) balıkçılık açısından da önemlidir. Bu çalışma alabalık üretim işletmelerinden nütrient çıkışını azaltmayı öngören bir öneriyi ortaya koymaktadır. Temel yapı bir veya birkaç entegre besin ağını içeren sucul ekosistemdir. Alabalık ve kerevit yetiştiriciliğinin yatay entegrasyonu, su ürünleri üreticilerine çevresel etkiyi azaltan ve üretim verimliliğini arttıran teknik uygulama imkanları sunar. Çalışma, bu entegrasyon sisteminde temel ilkeleri ana hatlarıyla belirtmektedir.

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