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Research paper

Inland Saline Aquaculture – A hope for farmers

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Abstract: Soil salinity is one of the serious global problems telling upon economic utilization of land resources in arid and semi-arid environments. About one third of the cultivable land under irrigation in the world is presently known to be under the influence of salinity.

INTRODUCTION

Saline soils are classified based on electrical conductivity (EC) of the soil solution that detects osmotic problems and exchangeable sodium percentage (ESP) indicative of a physical dispersion problem. The soil with ≤15% ESP and ≤4 dSm^{-1} electrical conductivity is considered as Non-saline/ Non-sodic soils. Salt affected soils are classified as

Table:1. Classification of Salt affected soil

Salt affected soils	ESP (%)	EC (dSm^{-1})	pH
Saline soil	≤ 15	> 4	<8.5
Sodic soil	> 15	≤ 4	>8.5
Saline sodic soil	> 15	> 4	8.5

Saline soils have no effect on physical properties of the soil but it is harmful because elevated soluble salts in the soil solution reduce the availability of soil water to plants. Salt affected soils in inland areas have an accumulation of salt to an extent that they adversely affect yields of normal crops. Abrol, *et. al*., (1988) estimated that the whole world is losing at least 3 hectares of fertile lands every minute due to salinization or sodification. Salinization of the fertile agricultural lands and ground water is a common problem and increasing inland salinity due to anthropogenic activities (Williams, 2001) has major economic, social and environmental consequences, threatening the viability of various rural communities (Beresford *et. al*., 2001). The main cause of soil salinization in both coastal and inland states is water logging, indiscriminate use of inorganic fertilizers and over irrigation. Salt affected soils are categorized into two broad categories i.e. saline and alkaline (sodic).

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The rates of seepage is high due to the high percentage of silt in salt affected soil and have negative effect to develop aquaculture in this area. Water logging is also a main cause for inland salinity as defined by Rao *et. al*., (1991) water logging, the conditions when groundwater is at or near the ground surface at least for some time in a year. Salt affected soils and ground water salinity conditions prevail either in isolation or in combination with each other (Joshi and Tyagi, 1994). The inland and coastal saline soils located in the arid and semi- arid regions associated with poor quality ground water and coastal areas with frequent inundation of saline seawater.

Inland Saline Water

Saline groundwater can be found just below the surface, suitable saline groundwater can only be found at nearly 200 m depth. Inland saline ground water is widely distributed in semi- arid and arid regions where rainfall is less and the rate of evapotranspiration is high. Saline groundwater may also occur in regions of greater rainfall as a result of underground salt deposits, connate water of marine origin and saltwater intrusion in coastal areas (Boyd *et. al*., 2009). Thus, inland saline waters (ISW) have adversely influenced the agricultural outputs and environment in different parts of the world such as USA, Australia, India, China and Israel (Allan, *et. al*., 2001). Characteristics of saline affected land are described, with particular focus on Australia and India. Coastal salinity, caused by seawater intrusion and shallow saline water tables, is severe during the dry season. Saline and sodic soils are widespread in inland areas and are progressively expanding because of improper water management. Inland saline water differs from location to location in terms of both salinity and ionic composition. The salinity in the inland saline zone is varying from >0.5 to 165 ppt. The salinity of the inland saline water ranges from 10-25 ppt with high level of Ca^{2+} and Mg^{2+}, which has resulted in high water hardness (Jana, *et. al*., 2004). Saline groundwater is rich in nutrients, which do not contain unwanted marine organisms (pathogen free) and has a constant temperature. In some cases, the use of saline groundwater may be a solution to problems related to the use of open seawater. Several actions have been taken for the remediation of this problem, including attempts to use ISW for marine aquaculture as a remedial approach to reduce the cost of groundwater pumping and create economic opportunities for the farmers in the affected areas (Doupe, *et. al*., 2003). Thus, aquaculture in ISW provides the potential to turn an economic and environmental threat into an opportunity with both commercial and environmental benefits. It provides an opportunity for the diversification and expansion of aquaculture through a potentially productive use for land that can no longer support standard agricultural enterprises.

As inland saline waters are located in remote areas where land is cheap and water is disease free, there is potential for integration between aquaculture and agriculture (Gong, *et al.,* 2004). Salinity is one of the major physical factor influencing the survival, growth and metabolism of aquatic animals, most previous studies usually were conducted at constant salinity (Fielder, *et. al.,* 2001; Boyd, *et al.*, 2002; Boyd and Thunjai, 2003). Inland saline well waters (ISWW) do not have the same ionic composition as marine or brackish waters (Soaud, *et. al.,* 2003) but they can be made suitable for survival and growth of marine species, if chemically modulated. Inland saline waters differ from each other and variations in ionic profiles occur even in waters derived from the same saline aquifer. In general, except for low K^{+} concentration,

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ionic composition and concentration of ISW is similar to the ocean water. Although, K^+ concentration only contribute a small part of the total ions making up the ISW, it plays an important role in the functioning of the physiological systems of the aquatic animals (Shiau and Hsieh, 2001). Inland saline water is often deficient in potassium in comparison to marine water. In fish, potassium plays additional critical roles in osmo- and iono-regulation and acid/base balance (Marshall and Bryson, 1998; Evans, *et. al.*, 2005). The necessity of fortifying potassium-deficient inland saline water to allow penaeid shrimp culture has been demonstrated by several authors (Saoud *et. al.*, 2003; Prangnell and Fotedar, 2005; Rahman, *et. al.*, 2005). Naturally, saline surface water and groundwater often have different ionic proportionalities when compared with those seawater diluted to the same salinity. This is due to the differential precipitation of salts as water evaporates and removal of ions by reactions with soil and other geological material (Gong, *et. al.*, 2004). Fielder, *et. al.*, 2001 studied that the major ions found in seawater, in order of magnitude, chloride (Cl^-), sodium (Na^+), sulfate (SO^{2-}), magnesium (Mg^{2+}), calcium (Ca^{2+}) and potassium (K^+) (Spotte, 1979). Salt affected soils are distributed in various temperature zones ranging from Mild Hyperthermic (20-22°C) to Megathermic (>27°C). A significant area (75.7%) is occurring in strong Hyperthermic (25-27°C) region.

Global Status of Inland Saline Water

About 1000 million hectares of salt-affected soil (CSSRI, 2011; Sandeep, *et. al.*, 2013) is spread over in the world. Secondary salinity affects over 380 million hectares of land in over 20 countries throughout globe (Ghassemi *et, al.*, 1995; Lambers, 2003). Such lands are distributed in countries as Australia, China, Czechoslovakia, Denmark, Egypt, France, Germany, Hungary, India, Iran, Iraq, Israel, Italy, Mexico, Netherlands, North Africa, Pakistan, Romania, Turkey, U.S.A., U.S.S.R., Yugoslavia, and the coastal tracts of Britain (Singh, 1980; Singh and Singh, 2013). Australia has enormous underground water reserves and most of them are saline, rising water tables and increasing salt content causing loss of fertility and affecting agriculture. It is predicted that if land will not be utilized in significant manner then area will increase up to 3.5 million ha by 2050 in west Australia. In Asian context salinization is generally associated with irrigation areas. In China, more than half of the total lake area comprises inland saline water and most of them lying in the North- Western China while coastal salt pans or lagoons are distributed in Eastern China. (Wen and Zhi-Hui, 1999). Wen and Zhi-Hui (1999) studied 16 lakes of Zhangjiakou region of China and found that the salinity ranged between 0.98 to 175.2 ppt and observed that water type changed as salinity increased. In Thailand, inland salinity is distributed in the north- east of the country. Salinity in this region is associated with contact of ground water on a large scale with saline strata. Pakistan has largest irrigation system but excess irrigation with inadequate drainage system resulted in surface salinization.

However, one of the factors, that appears consistent worldwide is a deficiency of potassium, relative to equivalent salinity of seawater (Fielder *et al*., 2001; Partridge and Furey, 2002; Saoud *et al*., 2003; Zhu *et al*., 2004). This deficiency is primarily caused by the fact that potassium is preferentially taken up by cation exchange sites in clay soils (Stumm and Morgan, 1996). Saline groundwater can contain as little as 5% of the potassium (K^+-equivalence) found in equivalent salinity seawater (Fielder *et al*., 2001) to as high as 75% K^+-equivalence (Partridge and Furey, 2002); however, in a

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review of saline groundwater sources, Partridge and Creeper(2004) reported that most of those assessed for mariculture contain approximately 20% K-equivalence.

National Status of Inland saline water

In India salinization of inland waters, particularly in the north-west region is increasing at an alarming rate due to both natural and anthropogenic activities (Dhawan *et. al*., 2010). Increasing inland salinity at alarming rates in the country has major social, economic and environmental consequences. There are about 8.62 million ha of salt-affected lands and 1.93 million hectares kilometers area with ground saline water (Lakra, 2014; Lakra *et al*., 2014) prevalent mainly in the arid and semi-arid regions of Rajasthan, Haryana, Punjab, Gujarat, Uttar Pradesh, Delhi, Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Andaman & Nicobar. About 40 % of inland saline soil is contributed by Haryana, Punjab, Rajasthan and Uttar Pradesh. In Haryana, these are common in Jind, Hisar, Bhiwani, Mohindergarh, Sirsa, Rohtak and Jhajjar districts. South western districts of Punjab like Bhatinda, Faridkot, Firozepur, Mansa and Muktsar are also affected with ground water salinity (Dhawan*et al*., 2010). Dhawan *et. al*. (2009) reported salinity between 23- 165 ppt in some villages like Bhudda, Gujjar and Channu in Muktasar district of Punjab. Aligarh, Azamgarh, Bareilly, Etah, Etawah, Fatehpur, Faizabad, Ghazipur, Hardoi, Kanpur, Lucknow, Mainpuri, Meerut, Pratapgarh, Raibareilly, Sultanpur and Unnao are the districts of Uttar Pradesh affected with salt. In Gujarat, extensive area is found in Ahamadabad, Amreli, Banaskantha, Bhavnagar, Jamnagar, Kachchh, Rajkot and Surendranagar districts. In the East Coast, these soils are located in the East and West Godavari, Krishna and Srikakulam districts of Andhra Pradesh. Midnapur and 24-Parganas districts in West Bengal and Baleswar, Bhadrak, Ganjam, Jagatsinghapur, Kendrapara and Puridistricts in Odisha. Rajasthan located in Jalore, Bhilwara, Jodhpur, Bikaner, Luni, Jaisalmer, Ajmer, Churu, Barmer and Pali district. Such types of lands are also found in west Maharashtra primarily confined in Pune, Thane, Sangli, Karad, Satara and Rayagad districts and in Saran district of Bihar (Mandal, *et. al*., 2010). The saline soils of Maharshtra are quite different than Haryana and Rajasthan. Both the states have saline ground water whereas Maharashtra has rich sulphate soil with fresh ground water. In the island areas, these are strongly saline and located in the South and Middle Andaman and North Andaman and Mayabandar.

Inland Saline Aquaculture

Saline groundwater is abundant in India, and there is growing interest in developing commercial inland saline aquaculture. Salinity and ionic concentrations of the groundwater vary location wise. The salinity of the groundwater is also influenced by depth of the aquifer. Analysis of these areas at Lahli, Haryana indicated that the salinity of the groundwater increased at deeper zones. As an additional benefit, it can be used to reduce the amount of salt in underground water tables; leading to an improvement in the surrounding land usage for agriculture. Increasing demand for aquaculture combined with confined production from capture fisheries has led to the development of new production systems. However, high cost of coastal land and environmental concerns, have led aquaculture farmers to favour inland aquaculture. Inland saline aquaculture, defined here as land based aquaculture using saline groundwater. However, inland saline water could potentially utilize for aquaculture purposes, providing an income

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source from an unutilized (Trendall and Pitman, 1998; Beresford, *et. al*., 2001) or underutilized resource. Dwivedi and Lingaraju (1986) were the first to initiate fish and prawn culture in ground saline waters of semi-arid regions of Haryana in India. Saline water aquaculture was identified as a thrust area of research for ICAR-Central Institute of Fisheries Education in the X five years plan and proposed to set up an All India Coordinated Research Project (AICRP). Inland saline groundwater aquaculture relies on production strategies for growth and survival of salt-tolerant freshwater as well as estuarine/marine species.

Species suitable for culture in Inland saline area

Before the introduction of a species into the new environment, it is essential to assess the suitability of the ecosystem for the growth, survival and reproduction of selected species. It is also essential to know the suitability of inland saline water for the aquaculture activity of the selected species because it has been also reported that arid and semi-arid zones are different from coastal environments. Saline groundwater can differ in chemistry compared with coastal seawater and adjusting the chemistry or choosing species that are tolerant to the differences is one of the major challenges for expansion of inland saline aquaculture. The chemistry of different sources of water is described and common methods of adjusting the chemistry described. Finally, case studies of inland saline aquaculture are presented for Australia, India, Israel and the USA. Novel food production methods, such as inland saline aquaculture, are needed to increase aquaculture production and meet increasing demands for seafood. In recent years, interest in the possibility of utilizing inland saline waters for aquaculture, such as prawn farming, is growing due to their high availability in some regions of the world and relative isolation that offers bio-security against viruses that have plagued the penaeid prawn aquaculture industry (Gong, *et. al*., 2004; Pan *et. al*., 2006; Prangell and Fotedar, 2006; Sowers *et. al*., 2006; Roy *et. al*., 2007). Several finfish and crustacean species have been reared in inland saline water around the world (Fielder *et. al*., 2001; Ingram *et. al*., 2002; Saoud *et. al*., 2003; Allan *et. al*., 2009). For commercial mariculture, countries including Australia, China, India, Israel and the USA have demonstrated interest in utilizing their saline affected land and water (Ron *et. al*., 2002; McNevin *et. al*., 2004; Zhu *et. al*., 2004; Partridge and Creeper., 2004; Barman *et. al*., 2005). Over 60% of saline groundwater sources range from 5 to 45 ppt available in Australia, for the culture of many euryhalinespecies (Partridge and Creeper, 2004). Saline groundwater has been used successfully in the United States and the Middle East to culture a range of algae, crustaceans and finfish, such as tilapia, red drum, sea bream, eels and channel catfish (Forsberg *et. al*., 1996; Ingram *et al*., 2002; Samocha *et. al*., 2002). The culture of shrimp and marine fish in low salinity water is common practice in many countries throughout the world including China, Thailand, Vietnam, Ecuador, Brazil, Mexico, and the United States (McNevin *et. al*., 2004) and Israel, Australia and many other countries (Crespiand Lovateli, 2011). Allan *et al*. (2008) reported that in Australia, saline groundwater from shallow and deep aquifers has been suitable for growth and survival of crustaceans (Allan and Fielder, 1997) and euryhaline finfish, such as silver perch, *Bidyanusbidyanus*, Australian bass, *Macquarianooemaculeata*, barramundi, *Latescalcarifer* and Atlantic salmon, *Salmosalar*(Allan *et. al*., 2001). Numerous

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marine species including: red drum, *Sciaenopsocellatus*, white shrimp, *Litopenaeusvannamei* and tiger prawns, *Penaeusmonodon* have been commercially reared using moderate to high saline inland groundwater. These studies have opened up an avenue for the introduction of new candidate species. Barramundi (*Latescalcarifer*) tolerates salinities from freshwater (Rasmussen, 1991) to at least 55 ppt (Shirgur and Siddiqui, 1998) and has been identified as a suitable species for inland saline aquaculture in both Australia (Partridge and Creeper, 2004) and India.

Numerous marine species including: red drum, *Sciaenopsocellatus* (Forsberg *et. al*., 1996;Forsberg and Neil, 1997), white shrimp, *Litopenaeusvannamei* (Samocha*et al*., 1998) and tiger prawns, *Penaeusmonodon* (Cawthorne *et. al*., 1983; Flaherty and Vandergeest, 1998) have been commercially reared in moderately saline inland groundwater and inland culture of marine shrimp using saline well water is becoming more widespread throughout the world (Roy *et. al*., 2007).Depending on their source, inland water available for shrimp culture are usually of different salinities and possess different ionic compositions (Boyd and Thunjai, 2003). Singh *et. al*. (2012) recommended brackish water fin fish farming in inland saline area.

In India, ICAR- Central Institute of Fisheries Education, (Sultanpur and Rohtakcentre, Haryana, India) conducted several experiments in inland saline areas to find suitable marine (Dwivedi, 1984) and brackish water species like Milk fish, *Penaeusmonodon*, *Litopenaeusvannamei*, Pompano, Cobia, GIFT Tilapia, Red Tilapia. They also worked on freshwater species like *Macrobrachiumrosenbergii*, Pangas and Amur carp to find the suitability of species in low saline zones of the area. Earlier studies conducted by Dwivedi and Lingaraju (1986) reported good survival of *Chanoschanos*, *Mugilcephalus*, *Etroplussuratensis* and *Penaeusmonodon* in Sultanpur, Distt. Gurgaon (Haryana) at 8-10 ppt. In later studies, *C. chanos*and *P.monodon* cultured at 23 pptin saline ground water of Lahli (Distt. Rohtak), Haryana and high survival was reported for *C. chanos*and complete mortality for *P. monodon* (Jain *et. al*., 2003). Sharma (2002) reported the survival of *C.chanos*, *M.cephalus*and *L. calcarifer* in surface saline water of Lunkarnsar salt lake, (Bikaner, Rajasthan) during 1999-2000. He also reported salinity tolerance of these species was 0.2-48.0, 0.5-36.0 and 0.2-39.0 ppt respectively. It has been also observed that slowly acclimatization of fishes result to tolerate high salinity. Sudden introduction at higher salinity resulted in behavioural changes and mortality at last. In case of *P. monodon* complete mortality was observed at low and high salinities both. Systematic study of Rahman (2003) indicated the possibility of culture of *P. monodon*in inland saline water. He summarized that ionic ratio of inland saline water was varying from sea water and when these ratios were corrected by the fortification of potassium, magnesium and calcium salts the survival of *P. monodon*was improved (Rahman *et. al*., 2005; Fotedar *et. al*., 2011).Raizada *et. al*. (2015) reported the complete mortality of *P. monodon*in potassium deficient inland saline water while in potassium supplemented inland saline water survived well at the salinity of 5, 10 and 15 ppt. He also found best growth and survival at 10 ppt. The supplementation of potassium showed significant effect on the survival rates at different salinities. In polyculture of *M. cephalus* (4000 Fry) and *Macrobrachium rosenbergii* (2000 PL) stocked in 0.25 ha pond at Bharatpur, Rajasthan found average weight 209.8±278.7 g and 85.8± 29.2 g

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respectively after the culture of 198 days. Reddy and Harikrishna (2014) have developed technology for the commercial farming of *P. monodon* and *L. vannamei* in saline affected soils using inland ground saline water.

Several experiments have been conducted to evaluate the salinity tolerance of freshwater fish (Tewari *et. al*., 1994; Garg, 1996; Kumar, 2000; Pillai *et. al*., 2003; Dhawan*et al*., 2009; Kumar, 2013). Kumar (2000) reported that *Cirrihinusmrigala* can be culture in saline water of 8-10 ppt at Hisar. Tewari *et. al*. (1994) attempted culture of indian major carps in salt affected soils of Uttar Pradesh and summarized that salt affected soils treated with cow dung can be successfully utilize for the culture of these carps. Raizada *et. al*., 2005 reported that monoculture of giant freshwater prawn suitable in inland saline aquaculture. They found 1000 Kg/ha production in six months with average weight 40.66± 19.60 g. The seed production of the species was also reported from ICAR-CIFE, Rohtak centre in inland saline area. The preliminary studies conducted in Punjab revealed that the freshwater carps and prawn can be culture in inland saline area with salinity upto 10 ppt (Dhawan *et. al*., 2009; Dhawan *et. al*., 2010). Common carp showed satisfactory growth and maturity in water with upto 8 ppt. The successful breeding and seed production exposed a major breakthrough, as seed produced from broodstock reared in inland saline water will be more salt tolerant and will resemble the faster growth (Dhawan *et. al*., 2010).

Microalgae like *Spirulina* and *Dunaliella* are reported to present in salt water lakes of Rajasthan (Gopal and Sharma, 1994) have high economic importance throughout the globe and commercially produced in several locations of the world. Both the species have high salinity tolerance and the persistent sunshine provide the essential energy to convert nutrients to biomass. Sandeep *et al*. (2013) conducted an experiment in inland saline area of Rohtakto assess the suitability for mass cultivation of *Spirulinaplatensis* and found high growth in de-calcified inland saline water. The cultivation of *S. platensis* offers an added advantage for the reuse of the spent medium for agricultural and aquacultural purposes by removing calcium and salts from inland saline water. As mentioned above that salinity of this area varying from >0.5 to 165 ppt, so hypersaline water of inland area can be utilize for the production of *Artemia* cyst at commercial scale.

Table: 2. Species suitable for culture in Inland Saline aquaculture

S. N.	**Species**	**References**
1.	*Mugilcephalus*	Jana *et al*., 2004; Barman *et al*., 2005
2.	*Latescalcarifer*	Partridge *et al*., 2005; Patridge and Lymprey, 2008; Partridge *et al*., 2008
3.	*Chanoschanos*	Raizada*et al*., 2005; Jana *et al*., 2006
4.	*Etroplussuratensis*	Kumar *et al*., 2009
5.	*Oreochromisniloticus*	Limhang*et al*., 2011;Upadhyay, 2015
6.	*Argyrosomusjaponicus*	Doroudi*et al*., 2006; Partridge *et al*., 2005

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7.	*Pagrusauratus*	Fielder *et al*., 2001
8.	*Litopeaeusvannamei*	Davis *et al*., 2004; Samocha*et al*., 1998; Pathak, 2013; Reddy and Harikrishna, 2014, Paswan, 2015; Jahan, 2016
9.	*Sciaenopsocellatus*	Forsberg *et al*., 1996; Forsberg and Neill, 1997
10.	*Penaeuslatisulcatus*	Prangnell and Fotedar, 2006
11.	*Penaeusmonodon*	Antony, 2013; Reddy and Harikrishna, 2014; Antony *et al*., 2015; Raizada*et al*., 2015
12.	*Macrobrachium rosenbergii*	Raizada*et al*., 2005, Jain *et al*., 2007a, Jain *et al*., 2007b
13.	*Oncorhynchusmykiss*	Starcevich*et al*. 2003; Partridge *et al*., 2005
14.	Indian Major Carps	Garg, 1996; Pillai*et al*., 2003, Dhawan*et al*., 2009
15.	*Sparusaurata*	Appelbaumand Arockiaraj, 2009
16.	Red Tilapia	Kumari*et al*., 2015
17.	*Pangasiandon hypothalamus*	Kumar *et al*., 2013; Kumar *et al*., 2016
18.	Spirulina	Sandeep *et al*., 2013
19.	Rotifers	Walsh *et al*., 2008
20.	Molluscs	Lee, 1997
21.	Algae	Borowitzka, 1997; Awal and Christie, 2015
22.	Green Lip Abalone	Fotedar*et al*., 2008

Socio-economic Importance of Inland Saline Aquaculture

The inland saline states have strongly, moderately and slightly saline soils and water in nature. To resolve the problem of strong, moderate and slight salinity in the inland saline area aquaculture is the best way because it involves culture of various marine, euryhaline, diadromous or freshwater-salt tolerant fish species.Further research will help as remedial measure for the inland saline area development. Seed production of brackish water fishes by using inland saline water will be profitable venture and will help to reclaim this area. Inland Saline aquaculture research activities taken up in India confirm the suitability of resources for developing commercial aquaculture. Establishment of hatchery for the seed production of these species will help to raise the activities at another level. As no much work has been done on this aspect but Dwivedi (1984) have reported the natural breeding of *E. suratensis* in

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Sultanpur, Distt. Gurgaon (Haryana). Inland saline aquaculture is an alternate resource for marine as well as brackish water area and can be potentially utilize. The utilization of such lands will provide social, economical and nutritional security by culturing protein rich organisms to local people.

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