Local Ecological Knowledge and the Impacts of Global Climatic Change on the Community of Seaweed Extractors in Pisco-Perú

José C. Alvarez[1], Kelly Vodden[2]
[1]Pontificia Universidad Católica del Perú, Departamento de Ingeniería, Lima, Peru
[2]Memorial University of Newfoundland, Department of Geography, Canada

Abstract--Global climate change implies difficulties for coastal communities where activities are highly influenced by climate. This paper examines the case of seaweed harvesting in the community of Pisco-Perú. Aspects of environmental change that impact seaweed harvesting include global warming, "El Niño" events, pollution of marine space, declines of marine species, and the rupture of ecological cycles.

We look for relationships between local ecological knowledge (LEK) related to climate and other environmental change and strategies for coping with and adapting to current and anticipated change.

This project is developed through a participative methodology, with the participation of university researchers and the community of seaweed extractors, and builds on an ongoing study of collaborative approaches to research and development of the algae industry in this region.

Research questions include: the nature of the LEK held and shared; the extent to which LEK includes: the effects of climate changes on resources, harvesting and communities; and the contribution of LEK to industry resilience, harvester livelihoods and community well-being.

The results of the research provide insight into LEK accumulation about algae species, management, and impacts of global environmental change. Documenting methods of collecting, analyzing and sharing harvester knowledge is an additional contribution.

I. INTRODUCTION

Peru is an industrializing, lower-middle income economy, with 48% of its population still living in poverty despite economic growth (Trigoso [21], Stanford [18]). The country is considered to have a medium level of development using the Human Development Index [22]. Thomas and Twyman [20] point out that developing nations are generally considered to have lower capacity to adapt to climate change, and low system shock resilience. In this study the potential contributions of local ecological knowledge (LEK) in enhancing the capacity to adapt to environmental, particularly climatic changes, in coastal areas of Peru are examined. In particular, the authors explore this question using a case study approach in the Pisco area and within the algae harvesting and culture industry.

Goals of this study include enhanced understanding of the role of LEK in adaptation to environmental change, but also conversion of tacit knowledge, at least in part, into articulated knowledge, thus creating new learning and development opportunities [13]. The identification of LEK in fishing communities allows it to be more readily used for co-management actions and for solving and preventing marine environmental problems. Publishing LEK, however, also presents ethical issues that make a participative research approach critical.

Methods employed in this research included a combination of qualitative interview techniques, review of relevant documents, cumulative participative research through meetings and workshops

and compilation of a learning history. Ten semi-structured expert interviews were conducted in January and February 2009 for this paper, supplementing fifteen interviews conducted in 2008 on more general topics of algae growth and culture in the region. Respondents included representatives of associations of seaweed harvesters in the Pisco region, and members of the faculty of a local university that has it´s fishing faculty in Pisco. Six of ten respondents work and live in the Pisco region and were, therefore, considered sources of LEK. Their insights were complemented by four additional interviews held with academic, government and non-government scientific representatives based in Lima, that are researching the algae topics and/or environmental impacts (Table 1). Additional interviews are planned, with the goal of increasing the number of local interviews to fifteen, along with a focus group session in May/June 2009 to discuss findings.

This paper presents the findings of an initial analysis of interview results, combined with a review of studies related to environmental and climate change on the southern Peruvian coast. This is combined with continuing construction of a learning history and growing understanding of regional dynamics within the developing seaweed (macroalgae) industry through participation in a collaborative research and development project.

TABLE 1.INTERVIEW RESPONDENT PROFILE

Code	Occupation
P1	Harvester association
P2	Harvester association
P3	Harvester association
P4	Harvester association
P5	Professor (Pisco)
P6	Scientist (Pisco)
L1	Professor
L2	Professor
L3	Scientist
L4	Scientist

II. LOCAL ECOLOGICAL KNOWLEDGE AND THE MANAGEMENT OF RESOURCES, ECOSYSTEMS AND ACTIVITIES

Co-management models of managing coastal resources and activities offer advantages associated with both bottom-up and top-down approaches. Co-management, or collaborative governance, lies within the centralization/decentralization divide and is seen more consistent with the increasing complexity and interconnectedness of policy networks and sustainability problems (Taylor-Powell *et al*. [19], Henton et al [9]). Top-down governments provide access to jurisdictional powers, information and influence that cannot be matched at the local level, while local actors have strengths related to their way of life, familiarity with local issues livelihood, social and cultural traditions and local ecosystems. Local knowledge, therefore, is a form of community capital that can be combined with external, often more formal, knowledge sources [3]. Olsson & Folke [14] identify local ecological knowledge and its importance for the decision making by the association of fishermen of Lake Racken, Sweden, for example. These authors classify their knowledge as:

i) Structural knowledge about flora, fauna and its diversity.
ii) Knowledge about ecological process and functions at multiple scales temporal and spatial, as the existing links between these processes.

According to Baird [4] an important component of LEK is the knowledge transmitted from generation to generation.

As their involvement in decision-making has grown, stakeholders such as local communities and conservation groups have become more sophisticated and often more powerful, forcing conventional powerbrokers, which are often information poor, to acknowledge that their knowledge deserves recognition and validity and that even the most sophisticated science can be proven wrong. Each kind of knowledge has strengths and weaknesses, similarities and differences. By triangulating among them knowledge is enhanced. Differences exist in scale and specificity, for example. Western science may look at a very specific characteristic of larger systems where local knowledge has a more holistic understanding of a smaller-scale local area. Identified advantages of incorporating local knowledge in resource use planning include: increased observation scope and depth over long time periods, tendency to take an integrated, holistic view, cost savings by pointing researchers "in the right direction," maximizing local involvement and buy-in, and capturing vulnerable historical knowledge. Case studies in cooperative resource management demonstrate that community members often bring quality of life objectives forward in planning processes and represent a more complex suite of values than other interests.

Sims [17] points out, however, that local actors can also benefit from conventional science in improving their understanding of specific issues but also from the more theoretical knowledge and perspectives often brought to the development process by actors at broader scales:

> *"There is a system of cause and effect. If all people feel is the effect, without understanding the cause, they are powerless…the exercise of citizenship calls for a deeper understanding of the workings of human society"*

McLaren et al [12] suggests that knowledge-sharing combined with stewardship can have significant social and environmental outcomes, empowering local actors to mobilize their local knowledge, values and motivations to protect the natural environment, improve knowledge quality and flow and create trust and goodwill when information and knowledge is shared in an appropriate manner.

Effective incorporation of all available knowledge forms into decision-making processes, following principles of transparency and clear communication, is identified as particularly important in fisheries and marine and coastal management [8].

Davis & Wagner`s [5] research suggests that this requires:

i) Policies and institutional structures for local resource management.
ii) Methods for specifying and use of local ecological knowledge.

Some programs of co-management have strong predominance of government provide very little decision power to users and limited consideration of LEK [4]. Henton *et al.* [9] suggest that collaborative governance approaches, such as coastal planning and co-management of coastal resources, can be evaluated on the degree to which they are representative, deliberative, offer concrete ideas, are taken seriously by decision-makers, sustainable (vs. occasional) and tied to implementation. The extent to which local knowledge and input is considered and translated into concrete actions are key questions of this ongoing research.

III. STUDY AREA AND SPECIES

The study area is delimited by the work area of the members of the four algae harvesters associations that have been participants in an algae cultivation project in the Pisco area since 2007, discussed further below. The considered study area begins at the Pisco river exit in the Caucato zone and continues, until Santo Domingo in the beginning zone of the Reserva de Paracas where it is possible to do research but production activities are banned.

Pisco, the project region, shown in Figure 1, is south of the Peruvian capital of Lima, is one of the five Ica provinces. The population of Pisco is 107,000 inhabitants, living in eight districts. The Pisco port has a locational advantage in relation to Lima, only 250 km away from the capital city. It also has a pleasant climate and an airport that facilitates the transportation of the regional products. Pisco is also the site of both a marine terminal and fractioning plant for the

Camisea gas project, which has a strong impact on the regional economy. Pisco also has tourist attractions such as the Reserva Nacional de Paracas, Ballestas Islands, the ancient city of Tambo Colorado.

In the August 15, 2007, however, a strong earthquake of 7.9 degrees in the Richter scale destroyed Pisco and resulted in over 500 fatalities. Since that time the reconstruction process has demanded considerable effort and resources effort.

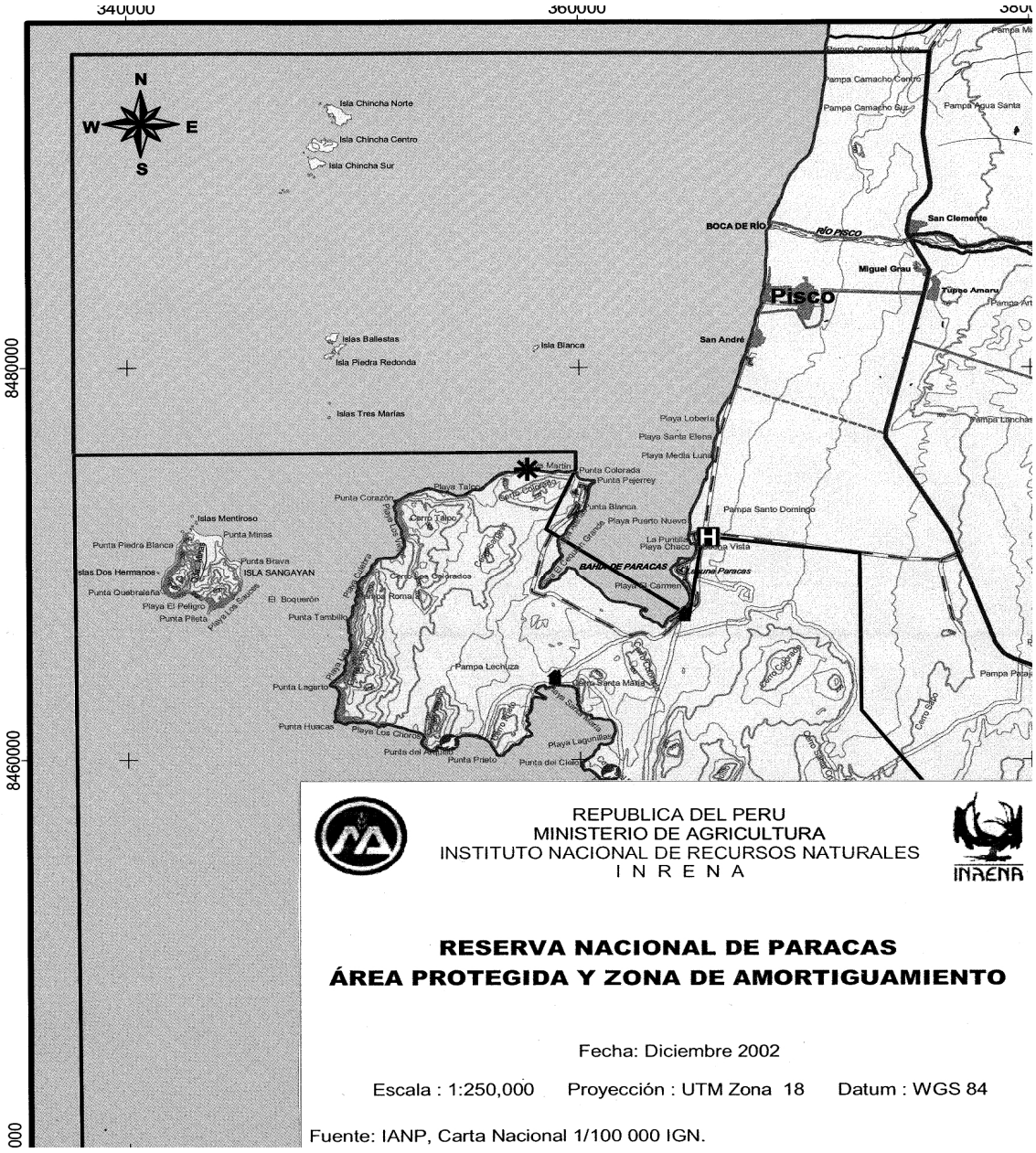

Fig. 1 Map of Pisco and Paracas research project areas.

In the study area there are many different algae. In this case we work only with the *Chondrocanthus chamissoi* algae (fig No2), because in the culture project was defined to begin with this type of algae that involves the greatest number of harvesters within the four associations.

Expressing codified knowledge related to the species *Chondrocanthus chamissoi* Acleto [1] state that:

"The thallus in this species, is characterized for being the membrane form, of 1 mm of width in the chauvinii forms; its height varied since 6 to 45 cm. Its color is so varied as its form and size, frequently is green dark, green violet, iriscente, brown, red or black. It is constituted by many axial axes that they derive from a small basal disc".

According to Acleto & Zuñiga [2] marine algae are of two kinds: plankton (floating in suspension) and benthic (fixed to the marine substrate). Speaking of *Chondrocanthus chamissoi* they add:

> *"The species of these sorts grow in the zone through branches, adhered to rocks of the different levels. In our means G. chamissoi (Chondrocanthus chamissoi) is more widely distributed and is used as a human food source with the name of ´yuyo´ or ´cochayuyo"*

Fig. 2 Algae Chondrocaunthos chamissoi
Source: IMARPE [10].

According to these authors the ecological factors that influence benthic algae such as the *Chondrocaunthos chamissoi* are: temperature, illumination, salinity and substrate.

IV. THE INDUSTRY, HARVESTERS AND THEIR ASSOCIATIONS

The total algae harvest registered in Pisco, according to Produce [16], was 630 ton in 2004; rising to 657 ton in 2005 and 2,960 ton in 2006. This growth is matched nation-wide, with exports of Peruvian algae jumping from 4,191 tons in 2001 to 10,688 tons in 2007, and a predicted 20,000 tons for 2008. Concerned about impacts of over-harvest on fish species and oxygen generation, a ban was placed on the extraction, processing and commercialization of sea algae in Peru in October 2008 by the country's Ministry of Production [15].

An interviewed professor (L2) emphasizes the importance of considering the origin of the extractors of seaweed:

> *"Remember that the algae harvester had came to Pisco for harvesting cotton and after that they begin to harvest algae"*

According to Defensoria del Proyecto Camisea (2008) the members of these associations have an average income of S/500 (US$ 160) per month during the nine month harvesting period (April to December). While incomes are below the Peruvian average, as cotton production fell, the algae industry provided an important livelihood alternative for those in the cotton sector or migrants from Andean agricultural communities.

It is common for small-scale Peruvian fish harvesters to organize in guilds, trade unions, associations and other organizations [11]. Likewise algae harvesters of the Pisco area have formed democratic associations with presidents and directors elected by all members. The harvesting and cultivation associations involved in this study are: Señor del Mar, San Andres, Alto Puno, and Beatita de Humay. A total of 400 members belong to these four associations (aproximately 100 in each), while others that work independently

The associations communicate and negotiate with other actors on behalf of their members. The interaction between the algae associations and other human actors is illustrated in fig.3.

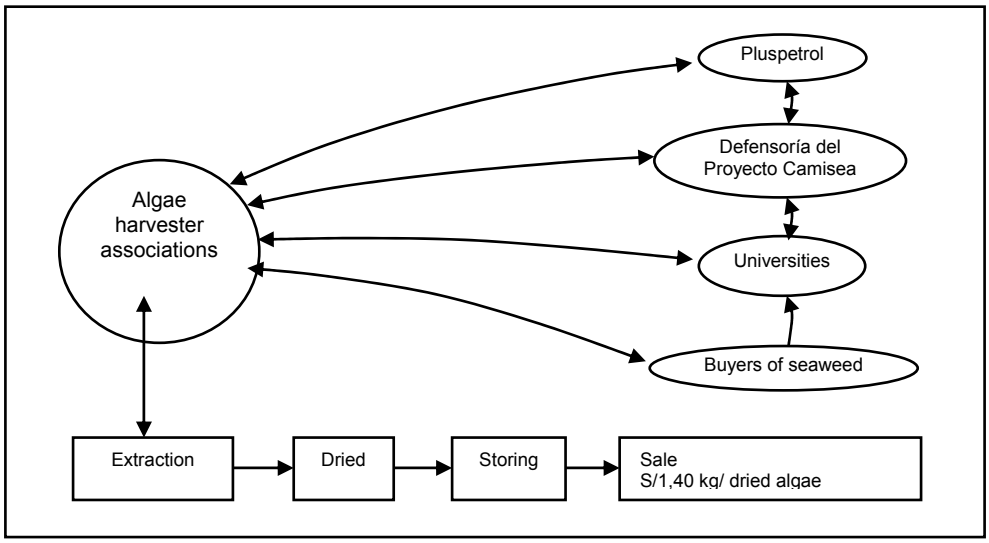

Fig.3 Human actors and process of algae harvesting.
Source: interviews and site visits

These harvester communities characterize themselves as relying on strong vows of sharing and common aid. As the majority are migrants of the high Andean zones of the south like Ayacucho and Puno where they traditionally worked in agriculture they have limited knowledge and experience with enterprise and organizational management. Defensoria del Proyecto Camisea and the Pontificia Universidad Católica del Perú, (PUCP) are facilitating participative meetings and encouraging the building of collaborative knowledge networks that respect and include LEK to assist in building local capacity for sustainable development within the sector.

V. LEK EN PISCO

A. LEK identified in Pisco

Weather, climate and ocean conditions

Interview respondents suggest that the most significant challenge faced by the sector is reduced water quality and product contamination (noted by four of ten respondents and 50% of those from Pisco), followed by resource decline and conflicting uses of marine space. Sources of contamination mentioned ranged from the 2007 earthquake to fishing and natural gas development.

Occasional wind conditions carrying "dust clouds" that are deposited in the product were also noted by P1, while L7 elaborates:

> *"There are seasons of Paracas winds. Very strong winds can transfer sediments that produce changes. There is greater water turbidity and therefore a reduction of photosynthesis and in some cases detachment or loosening from the substrate."*

Due to contamination P2 suggests harvesters have to travel further for suitable algae and require more and better boats to do so.

All types of respondents discussed the importance of marine currents in shaping ocean conditions, with implications for the growth and abundance of algae and other marine species. About the importance of the region for the encounter of two marine currents, a professor and consultant to the harvester association (P5) states:

> *"In the coast between Lagunillas and San Andres the Humbolt Current forms a dome. The geographic flexion of San Gallan forms. By Cerro Azul the current of Bjerknes enters (current of equatorial waters) that gives the Bay of Paracas its tropical atmospheric condition. Because of this, in Paracas it has hot waters and in Lagunillas cold waters. When there is a heating, by Paracas zone it begins to enter prawns…"*

According to one association member (P2) talking about the San Andres waters, in front of the Huayuna water channel:

> *"In this zone the water is lukewarm, while in Mendieta is cooled. Cultivation in this zone will not be successful."*

Efforts in conjuction with Defensoria del Proyecto Camisea and the PUCP have also permitted the codification of LEK about marine bottoms in Bahia de Paracas and San Andres - Pisco area. In this work Diaz [7] also assessed marine habitats by diving in areas, north to south in direction: Playa San Andres, Playa Loberia, Playa Santa Elena, Playa Puerto Nuevo, Playa Punta Colorada. Results are presented in the following table.

TABLE 1: MONITORING MARINE INDEPTH OF THE MARINE BOTTONS.

Marine area.	Marine depth.	Algae *Chondrocanthus chamissoi* quantity.	Fixation at the marine floor in the substrates.	Algae culture.
Playa San Andres.	4,5 m	Few	Not	Not
Playa Loberia.	4 a 5 m	Few	Not	Not
Playa Santa Elena.	3 m	Only in the border.	--	Not
Playa Puerto Nuevo.	4 a 5 m	More presence.	Yes	Experimental
Playa Punta Colorada.	3 a 4,5 m	More presence.	yes	Not

Source: adapted from Diaz [7]

The 2007 earthquake was noted by P5 as having caused damage to substrate habitats.

Local knowledge about climatic change

Local participants expressed little knowledge expressed related to long-term climate change, although P2 suggests that ``these Paracas winds never occurred at this time of summer. They always happened in August. There is a change. Further, "there was fog, there was humidity, and the Paracas winds were stronger and made the fishing task difficult."

Respondents focused on cycles of "El Niño" and "La Niña" events. The participants noted that the phenomenon of "El Niño" (heating of waters) of the years 1982-83 and 1997-98 have negatively impacted the algae *Chondrocanthus chamissoi*. During "El Niño" algae demonstrate loss of growth and color, with a substantial reduction and delay in its recuperation after these periods, they suggest.

This aspect is described by respondent P5):

"The algae got to disappear with "El Niño", there was a drastic reduction of the algae. El Niño is lethal for the algae… Those most notables of 1983 and 1998 they drastically reduced the algae prairies whose recovery was delayed more than a year before achieving profitable production for the extractors".

P1 adds ``All the plants don't die, some resist the climatic changes.`` Because there are less seaweed during this event the existing extractors exert major pressure on remaining natural seaweed prairies.

P5, a local professor adds:

"During the phenomenon of "La Niña", the cold waters increase the production of seaweed and then the number of extractors of the seaweed is tripled, causing a disorderly extraction."

One harvester representative adds that ``the duration of La Niña is of little time.,` another adding that the high number of harvesters remain after La Nina events, contributing to excess harvesting pressure.

The systemic impact of many factors in the algae *Chondrocanthus chamissoi,* as described by interview respondents, can be seen in the fig.4 and incorporate both the

structural knowledge about algae characteristics, types of algae and growth according temperature and water quality and knowledge about ecological process and its interactions referred to by Olsson & Folke [14] above,

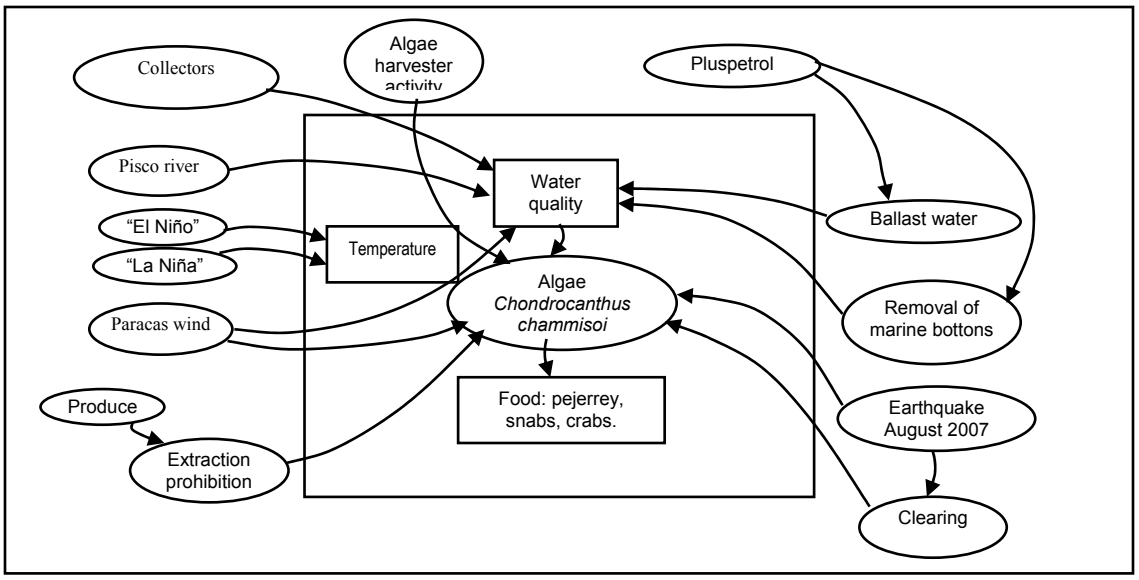

Fig. 4 Impact of the Pisco marine ecosystem in the algae *Chondroacanthus chamissoi.*
Source: interviews and site visits

B. Missing LEK.

A researcher who works and lives in Pisco (P6) points out the necessity for more research at the local level**:**

"In Pisco there are not quantification of the contribution of nutrients to marine means"

A professor of the local university (P5) suggests some applied research:

"The investigation must be promoted to obtain resistant stocks to the climate change effects."

Another scientist (L4) suggests that sea level rise is likely to result in a reduction in suitable habitat. Salinity is a factor in algae health, yet no respondents referred to implications of changing water flows in the Pisco River.

Local knowledge about El Nino and La Nina impacts may inform this research, although Trigoso [21] observes that, while accustomed to ENSO events, coastal residents are ill-prepared to deal with increases in sea surface temperature and fluctuations in temperature and precipitation.

A major Peruvian researcher in biology of algae (L3) expresses his doubts about interest in such research:

"Who will want to study the impact of the "El Niño" phenomenon in the algae?"

One method of enhancing local knowledge and knowledge sharing is meetings, and courses like one organized recently (February 6-7, 2009) by the Defensoria del Proyecto Camisea (Camisea Ombudsman). This course was taught by a professor of the fishing faculty of Universidad san Luis Gonzaga de Ica and of Universidad Nacional Federico Villarreal. The actions developed during this course appear in the learning history below (table 2).

VI. MANAGEMENT OF RESOURCES, ECOSYSTEMS AND ACTIVITIES IN PISCO.

Incorporating local knowledge into Peruvian management systems is challenged by existing governance systems strongly dominated by the government, considered from Lima in general form and without the specificities for each region. Trigoso [21] suggests that "centralism permeates the Peruvian political structure and constraints local decisions."

Currently LEK is not considered in decisions that have a top-down characteristic such as the recent algae extraction prohibition [16] that was determined only with a participation of the technicians of the Produce department and IMARPE scientists without consideration of the opinions of the algae harvesters and the social problems that it would generate.

In the interviews (January - February 2009) almost the totality of the interviewees think that the climatic change is not considered in the planning of future algae culture/extraction activities in Pisco. Respondents also consider that there aren't actions taken for organizations linked to the culture and/or extraction of algae to adapt to climatic change.

LEK in Pisco could be useful for formulate regulations as part of a future program of co-management such as occurs in other regions and incorporating research related to climate change.

Through efforts such as the participation of the Defensoria del Proyecto Camisea and the PUCP in promoting participative meetings, encourage the building of participative knowledge and the networking changes can, however, occur. The authors continue to build on knowledge collaborations such as the learning history from Alvarez and Vodden [3] and below and by inititating discussion on issues such as climate change through interviews and a workshop planned for June 2009.

Recent reflections on methods of collecting, analyzing and sharing harvester knowledge and recommendations for future management action are captured in the following portion of an accumulating learning history being documented by the authors (table 2).

TABLE 2. LEARNING HISTORY

Analysis and comments	The course permitted the relationships with participants to be maintained in addition to contributing continued learning. Also it reinforced the necessity to solicit and count areas of cultivated algae. Condensed texts on the themes discussed will be prepared and distributed among the algae growers.
Actions	February 6-7, 2009 a workshop on environmental issues was delivered, including techniques of cultivation, and product health. Participants realized the importance of these workshops in gaining knowledge and of counting on a designated area to secure production (zoning). P2 demonstrated that indiscriminant algae harvest would be avoided if each organization had its own concession area. He expressed the importance of establishing parcels for maintained and planned cultivation; with monitoring of areas. P1indicated that they do not count on an assigned area and the necessity to count on support. Having itself managed these areas, they still haven't had any answers from the State. Esteban spoke about air contamination for the zone's business gas emissions, indicating that neither the mayor nor the regional president are preoccupied with the problem of contamination of marine space and asked how this participation could be demanded. The importance of the relations of confidence in the whole productive chain was emphasized, along with norms on conservation and biodiversity through sustainable use. . She presented aspects of the law on the recognition of traditional ecological knowledge for its use in sea cultivation. It treated the subject of biological biodiversity in the sea as part of the ecosystem. She discussed the subject of control of the harmlessness of foods, also on the law of harmlessness (innocuousness). Sanipez, Senasa, and Digesa form the national system of food innocuity. Sanipez controls fish products and aquaculture, including algae. . is in charge of issuing certificates for aquaculture products and for sanitary control of aquaculture environments. Monitored areas exist where control is realized by governmental agencies. One strategy would be to use less chemical additives. The bases of the system of Securing quality that requests Codex has been accepted for the country (before, during and after the process). There have been no certificates for algae emitted yet. Before initiating the drying it would be necessary to verify that there is no contamination in algae from monitored areas. The university can credit methods. Cases of sanitation control were presented along with types of the algae. Factories should treat their waste water before it is emitted into the sea. Monitoring of Environmental control indicators such as the quantity of microorganisms, the presence of heavy metals, oil discharge, chemical indicators with a weekly frequency. International organizations could help. The importance of projects with the support of universities was discussed. After monitoring of harvest for example, it is necessary to control each lot, across the declaration of resource extraction. Plans for good manufacturing and good hygiene practices to control the processing area were discussed, including documentation and registry and rotation in the warehouse to prevent cross-contamination. Finally, the processes that produce waste products that can be utilized in some other way were identified.

VII. CONCLUSIONS

In this paper we investigate relationships between human actors and the processes of algae harvesting, as well as the impact of the Pisco marine ecosystem on the algae "*Chondrocanthus chamissoi*".

There is a disorderly extraction that is exacerbated by the "El Niño" and "La Niña" phenomenon and the pollution of the marine space. This disorderly extraction generates reductions in resource that could be exacerbated with climatic change. The designation of marine areas for the culture of algae could be a partial solution, requiring dialogue and planning related to conflicting demands for marine space, along with more collaborative research related to climate change impacts and adaptation.

Areas of existing and missing knowledge necessary for the efficient use and conservation of the "*Chondrocanthus chamissoi*" resource was identified. Creative forms for developing and capturing this knowledge should be implemented. The participative work promoted by the Defensoria del Proyecto Camisea and PUCP is one of these.

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