FISHERMEN ECOLOGICAL KNOWLEDGE AND COMPLEX ADAPTIVE SYSTEMS: AN INTERPRETATIVE MODEL FOR SMALL-SCALE FISHERIES[1]

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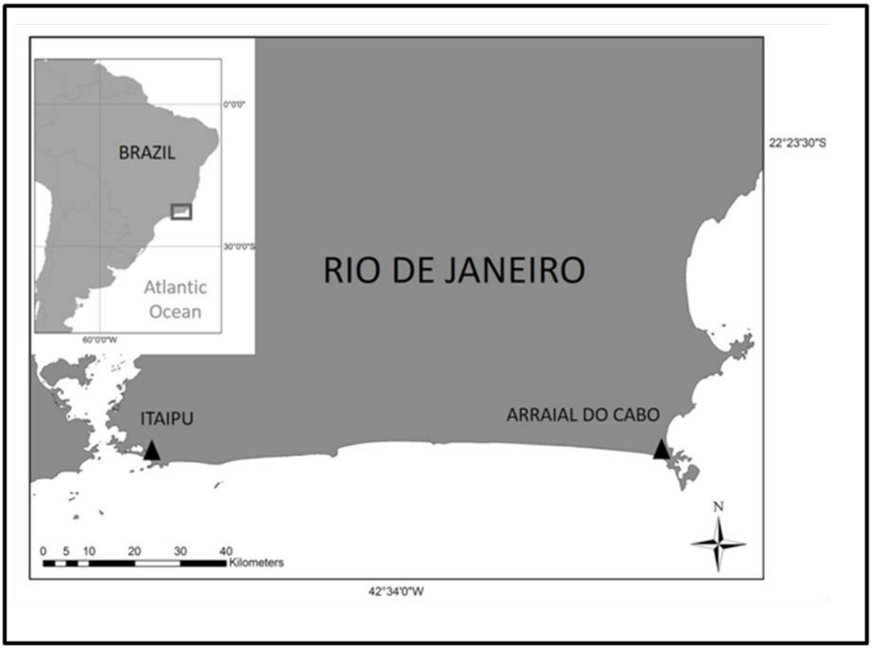
Introduction

The Traditional Ecological Knowledge has been identified in the last 20 years as a system that can contribute for the conservation of protected areas (JOHANNES, 1998; LEITE; GASALLA, 2013; RUIZ-MALLÉN; CORBERA, 2013) and the sustainable use of renewable natural resources (BERKES, 2012; MISTRY et al., 2016). Traditional Ecological Knowledge may be seen as a model of adaptive management, because it responds and manages processes and functions as a complex system (BERKES; COLDING; FOLKE, 2000; FARR; STOLL; BEITL, 2018; PELOQUIN; BERKES, 2009).

This research aims to apply the concepts of the Complex Adaptive Systems (CAS) theory of John H. Holland (1995) for the interpretation of a particular Traditional Ecological Knowledge: the Fishermen Ecological Knowledge (FEK). The first part of this research will describe the ecological knowledge of artisanal fishermen and its importance for the reproduction of their social structure. This will be discussed in the light of anthropological data, previously published during the 90's about the localities of Arraial do Cabo (BRITTO, 1999) and Itaipu (LIMA; PEREIRA, 1997) in Rio de Janeiro (Brazil) (Figure 1). In the second part, the CAS structure (HOLLAND, 1995, 1999) will be described focusing on its characteristics, components, proprieties, and mechanisms. The third part will propose the interpretation and structuring of the FEK as a type of CAS. The last section will discuss the epistemological significance and suitability of this approach.

Figure 1. Map of Brazil indicating the geographical location (▲) of Arraial do Cabo and Itaipu, within the state of Rio de Janeiro.



Source: Based on *google* images and modified by the authors.

The ecological knowledge of artisanal fishermen from Arraial do Cabo and Itaipu (fishery communities established in Rio de Janeiro State, Brazil) synthesizes their understanding on migratory movements of a large number of fish species and climatic and oceanographic information, all of them related with the emergence of fish schools within their used fishing grounds. Furthermore, FEK is codified in a complex language of signs, which are used for communication among companions during their fishing activities, especially those occurring at the beach by "pescarias de cerco" (beach seine fishery). Based on empiric observation (therefore, built on a try-and-error process), FEK is orally transmitted from one generation to another, being constantly updated by the day-by-day experience of fishermen (BRITTO, 1999; LIMA; PEREIRA, 1997). In this sense, FEK may be defined as a Complex Adaptive System.

The theory of Complex Adaptive System (CAS) was developed by Holland (1995, 1999) with the purpose of mathematical modeling. A complex adaptive system (CAS) is complex because it is composed by different elements with distinct natures, and it is adaptive because it has the ability to change over time learning from experience. In this study, one of the aims is to evaluate the scientific usefulness of interpreting the knowledge of artisanal fishermen from Arraial do Cabo and Itaipu as a CAS, and in sequence, try to use anthropological knowledge produced on their activity to organize their FEK in the structure of a CAS.

It is supported that this approach can help to establish a more horizontal communication between scientists enrolled in formal science, and also among scientists and fishermen. Scientific fields in formal sciences such as anthropology, marine biology, oceanography etc. are interested in the study of marine and coastal environments. Fishermen are engaged in activities concerning fisheries and their management, requiring "knowledges" about the natural environmental cycles and biological cycles of the fishery resources. Thus, one of the main aims of this study is to discuss a methodology that can promote an interdisciplinary approach to studies related to fisheries ecology and sustainability, overcoming problems related to incommensurability among different sciences and knowledge (KUHN, 1998).

However, in this study, CAS will not be used for the purposes of mathematical modeling, but as a key for studying and describing FEK. Therefore, theory and concepts of CAS will be used as a structuring metaphor. The uses of metaphors have been considered for some as a problem in science practice (CARDOSO, 1985; FERREIRA, 2009; FRANCELIN, 2015; MINETTI, 2018). At this point, the use of metaphors in science will be discussed using the epistemological framework of the French philosopher Gaston Bachelard (BACHELARD, 2000).

Methodological statements

This research is characterized by the procedures undertaken by a theoretical assay which includes:

1) A documental analysis with data compilation, systematization and interpretation regarding the Traditional Ecological Knowledge (TEK) (BRITTO, 1999; LIMA;

PEREIRA, 1997) of traditional fishermen communities from Rio de Janeiro state, but also an exegesis of the texts regarding the theory of Complex Adaptive Systems (HOLLAND, 1995, 1999);

2) The establishment of a framework (structuring metaphor) which combines data and theory in an unified corpus (THIS ASSAY); and

3) The use of epistemology (BACHELARD, 1972, 2000) to discuss the benefits and limits of using the proposed framework of structuring metaphor.

The use of empirical data in a dynamic model is beyond the scope of this assay, which has the main aim of structuring the compiled data on TEK in a way that supposedly can surpass its epistemological incommensurability with other forms of knowledge. However, despite of not putting forward a dynamic model (function) in this assay, it is trusted that the proposed framework (structure) is the first step towards such endeavor.

Ecological Knowledge (EK)

Arraial do Cabo (22º58'18"S, 42º01'48"W) and Itaipu (22º53'14"S, 43º22'48"W) are located in the state of Rio de Janeiro, Brazil (Figure 1). Both locations harbor artisanal fishery communities in which traditional fishing practices are conducted with large dugout canoes carrying beach seines of a few hundred meters. Fishermen adopt two different fishing strategies: "cerco-com-vigia", a strategy that relies on visual school targeting (mostly pelagic migratory fishes wandering closer to the shore) and waiting for fish schools to come within fishing grounds; and "lance-à-fortuna" in which the beach seine is cast on a by-chance manner, without any specific target (may include the capture of pelagic and demersal species) (BRITTO, 1999; LIMA; PEREIRA, 1997; LOTO et al., 2018; TUBINO et al., 2014). The fishing operation may include six to seven fishermen with defined roles, in the moment of encircling the schools. This productive unit is called "companha" (the fellowship), and "companheiros" (companions) responsibilities are defined as follows:

"Vigia" (watchman) – who has the function of spotting the arrival of fish schools within a certain fishing area. The watchman usually sits on the top of a hill, where he can see the schools coming into the area. His expertise enables him to recognize the composition (predominant species) and size of the school ("magote" - up to 100 fish; "cardume" - schools with 100 to 500 fish; and "manta" - above 500 fish). The watchman also defines the school trajectory, based on the swimming behavior of each species, and establishes how and when to set the seine for capturing the school. This procedure also relies on the knowledge of environmental variables such as currents and wind directions. His communication with the "companha" is maintained through a set of particular hand signs made to each "companha", using a white cloth or handkerchief. This practice is currently being complemented by radio communication by most of the watchmen.

"Mestre" (master) - the skipper and owner of the dugout canoe, he interprets the signs of the watchman, steers the boat, with the help of a small oar, finding the right path to encircle the school, guides the oarsmen regarding the boat speed, and commands the other fishermen on the right time to set the net. The master is also responsible for passing the warp to the warp-man, once the canoe gets back to shore.

"Remeiros" (oarsmen) - four oarsmen are responsible for powering the boat ahead. They observe the signs of the watchman and follow the orders of the master to keep the desired direction and speed, rowing strongly or lightly, sometimes on the port side, other times on the starboard side, or both at the same time.

"Chumbeiro and Corticeiro" (Leadline-man and floatline-man) - they are responsible for setting the beach seine in the water during the fishing operation, and also for hauling it back into the boat, in the right place, after the catch is finished. They control how the seine is lowered in the water maintaining the proper tension according with the boat speed. Both the leadline and floatline men are able to interpret the signs of the watchman, but they respond only to the orders of the master.

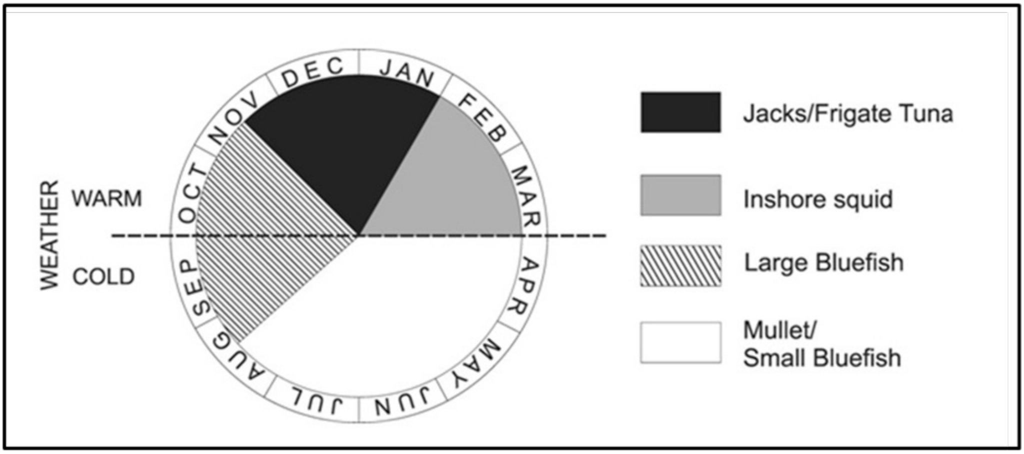
"Cabeiro" (warp-man) -who is responsible for tending the hauling rope (warp) on shore. As the canoe approaches the beach, the warp-man swims closer, gets the warp from the master, and swims back to shore, waiting for the signs to start hauling the beach-seine.

The whole operation demands knowledge and synchronism on the part of every crewmember, as well as acceptance and understanding of the master's and watcher's instructions. Furthermore, when hauling the seine to the shore, other fishermen and people on the beach may help on the task. The successful fishing process depends on a series of knowledge that enable prognostics related to the arrival of fish schools within fishing grounds. Their importance of the capture is usually defined by the market value of the target species.

Some of the fishermen knowledge on the natural variables involved in the process has been systematized by anthropological studies. In this way, some diagrams called "wheels" (BRITTO, 1999) where produced which represent a combination of biological and environmental factors that organize the fishery social production. For the fishing processes in Arraial do Cabo four wheels were defined:

"The fish wheel" -defines the occurrence of fishery resources within two weather categories: hot (October to March) and cold (April to September). For instance, jacks (*Caranx* spp.), frigate tuna (*Auxis thazard*) and the inshore squid (*Doryteuthis* spp.) appear in the hot weather, from November to March. Mullet (*Mugil liza*) and small bluefish (*Pomatomus saltatrix*) are present in colder months from April to mid August. Large bluefish appear late in the colder months (late August) and remain in the area until mid November, in the beginning of the hot weather (Figure 2).

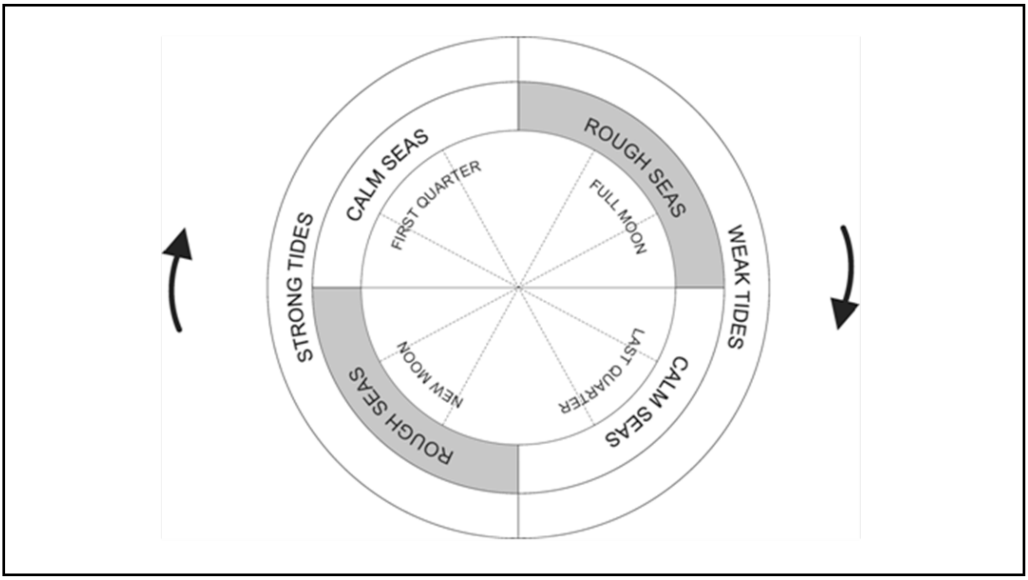
Figure 2. "The fish wheel", defining the predominant fishery targets (fish species) over the year.



Source: Adapted from Britto (1999).

"The moon wheel" –summarizes the information about tides, wave height and sea state, which are influenced by the phases of the moon. Thus, periods of weak and strong tides may also have rough and calm seas. This information is constantly updated by observation (Figure 3).

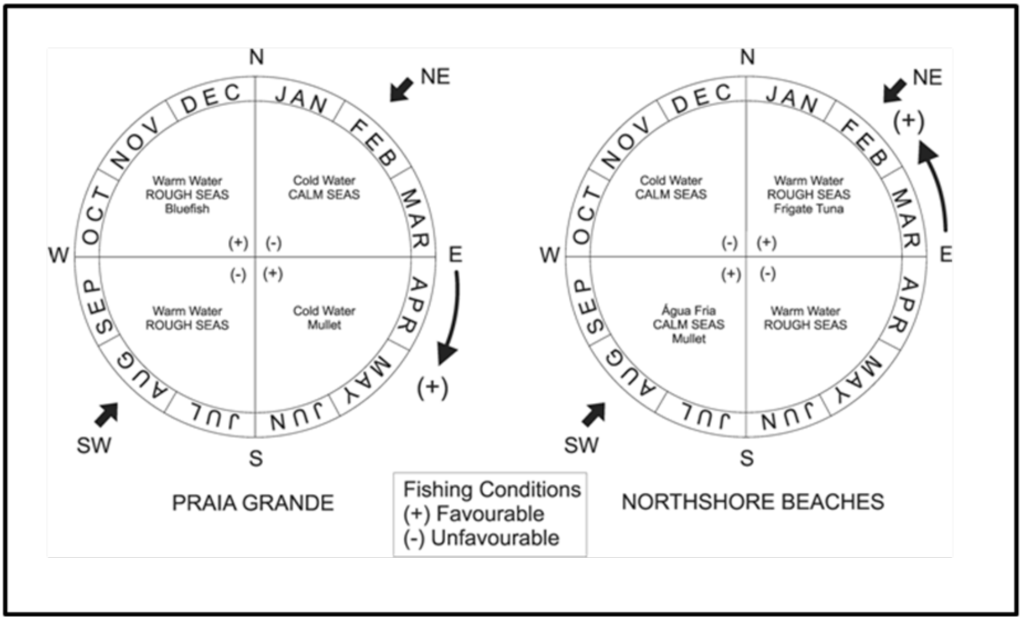
Figure 3. "The moon wheel", defining sea conditions based on the influence of the moon.



Source: Adapted from Britto (1999).

"The sea wheel" – defines sea conditions including water temperature and sea state, following the wind direction and indicating favorable or unfavorable sea conditions for fishing (Figure 4). The sea wheel is also constructed for specific localities such as "Praia Grande" and other beaches to the North ("Praias do Norte").

Figure 4. "The sea wheel", defining good or bad sea conditions for the fishery, based on wind direction.



Source: Adapted from Britto (1999).

Hence, the fishery success depends on a hierarchical structure based on technical knowledge and a unique language code used among members of the "companha", and also a series of understandings that permit the prediction of the arrival of fish schools in the area (FEK). Supported by all these elements, fishermen are capable of having successful fish captures, besides a series of reasonably reliable predictions regarding natural conditions that may interfere in the whole fishing process. Nevertheless, fishermen are aware that this "concrete science" has a short, local validity, and is based on a social context that is not capable of achieving a more holistic goal. In regards to the limitation of their practices, fishermen affirm, "*it is not possible to know the sea*" (BRITTO, 1999). Thus, FEK is based on a large set of understandings and practices, and it also presents great epistemological awareness.

Complex Adaptive System (CAS)

A complex adaptive system is a complex set that has the capacity to change and learn from experience (HOLLAND, 1995). This concept was produced originally aiming to mathematically understand and model problems that include aspects in biology, such as the origins of life, the evolution of species, the functioning of the immunological system and of the central nervous system. Among the social sciences, the notion of CAS has been used in mathematical models to solve problems related to economy, as for example, market behavior. According to Holland (1995), a CAS may be defined by seven basic characteristics classified into four proprieties (diversity, aggregation, flux, and non-linearity) and three mechanisms (labeling, construction blocks, and internal models).

Diversity, or in other words, the presence of different elements, is the basic characteristic of any complex system. These elements are constantly interacting with each other and, therefore, may be considered as agents, which are able to affect the other agent behavior in the system. Thus, reciprocal interactions may produce changes leading to agent adaptations in a defined system. The changes and the adaptations performed by the agents improve their roles inside the system. Furthermore, a variety of agents may work together as an aggregate maintaining a unique identity. This property called **aggregation** is mediated by a **labeling** mechanism, which enables the identification of affinities among agents. Aggregates maintain different kinds of interactions such as addictive, multiplicative, or synergic. Aggregated behavior has the advantage of anticipating new situations created by the simultaneous actions of the agents.

The challenge found in the analysis of aggregate behavior is to be able to understand the relationship among individual action (of each agent) and the collective emerging activity. This understanding may be especially difficult to acquire, once the result of the interaction is usually **non-linear**. This means that the knowledge of the activities of each agent does not lead to the direct understanding of the aggregate activity itself. Despite of that, the proprieties and mechanisms described, lead to an intuitive comprehension of another characteristic that defines a CAS: the **fluxes**, which can be both of resources and information. These fluxes generate unexpected effects, such as recycling and multiplicative effects.

The description of CAS provided so far is basically structural and static, showing very little dynamic. However, the great advantage of CAS is its capacity of adaptation. The structural scheme described, when placed in time, enables the possibility that different snip-profiles may be taken in the system in order to act based on its parts (larger or smaller divisions) or functioning (emerging effects). Therefore, from these different snip-profiles, it is possible to identify a large variety of structures, which in turn, can be reorganized in other systems. What is being described is the CAS mechanism recognized as **construction blocks**. The operation of the whole system in time produces a more intriguing aspect of the CAS, which is the **internal model**, or in other words, a set of rules that permits the system as a whole to become predictable.

A complex adaptive system creates choices among a set of possibilities. At one extreme this process produces the exploitation, which is a way of working when all the operating rules are established and used in all possible manners. On the other extreme is placed a behavior of full exploratory research, when the system is continuously searching for new rules, without even testing them — suggesting that the system does not always use the successful information which is generated by its operation. A successful Complex Adaptive System will be established between these two extremes, although in its history it alternates between order and chaos. The order is the completely predictable development of the system, whereas the chaos is its constant change.

The greatest innovation of CAS structured models is that they incorporate time (or history). In other words, adaptation is a phenomenon that occurs overtime, under the influence of the environment, system operation and history. That is what is called a learning process that generates anticipation. However, it is important to bear in mind that adaptation is not an optimizing process. Adaptation generates only the best result possible under the historical circumstances, based on the available resources. Thus, in a CAS there is not an absolute optimal state, as the system is in continuous evolution (novelty is perpetual at any time scale in which the system is operating). The anticipation capacity arises from the selected system of rules because the result was able to guarantee the evolutionary success of the system till the present time.

Ecological Knowledge as a Complex Adaptive System

The ecological knowledge of artisanal fishermen from Arraial do Cabo and Itaipu have changed over time in order to keep up with the time transformations. These changes over time include but are not limited to demographic growth, physical changes on the beach and within the limits of their fishing areas (BRITTO, 1999; LIMA; PEREIRA, 1997), depletion of fishery resources on traditional fishing grounds (LOTO et al., 2018; TUBINO et al., 2014), and most of all the establishment of a marine protected area known as “Reserva Extrativista Marinha” (marine extractive reserve, which is a kind of marine protected area defined by the Brazilian system of conservation units) (LOBÃO 2010*a*; ORENSANZ; SEIJO, 2013). The changes in FEK includes the reorganization in the number of “companhas”, rearrangement of “companheiros” from one “companha” to another, the introduction of additional fishing gears and technologies such as different apparatus than the beach seine as well as changes in their traditional fishing methods. Hence, there is a constant process of learning which adapts FEK for time transformations. Thus, under changes in circumstances the system is constantly selecting rules that match the expectancies of the system itself determining a feedback process.

These changes do not de-characterize FEK, since it is still used as such today by groups of artisanal fishermen, also being a fundamental aspect of their identity (which is very much defined by the hierarchy between the members of the “companha”, their sign language, and their use of a forecasting system). Therefore, these overtime changes in the ecological knowledge simply demonstrate the continuous dynamics of changes and adaptation of the system. Thus, it is possible to identify in the FEK system a dialectical logic of fixedness and changes which is in accordance with characteristics and proprieties of a Complex Adaptive System: a dynamic system in constant adaptive development.

Hereafter in the next paragraphs this interpretation of FEK as a kind of CAS will be discussed under the light of proprieties and mechanisms previously defined before.

Regarding the seven basic characteristics, the mechanism of **construction blocks** is the one that presents an interesting parallel, once it is from the **agents** (fishermen) that is possible to perceive other units in FEK, such as the functions (watchman, master, oarsman, cork man, lead man and cable man), or the "companhas" themselves. At the same time, the proprieties of **diversity** and **aggregation** are evident taken the description which was given to **construction blocks**. The **labeling** mechanism is performed by local identities and tradition, since they are the labels which define the group's identity. For instance, fishermen from Arraial do Cabo are used to say that *"not all fishermen in Arraial do Cabo are fishermen from Arraial do Cabo" ("nem todos os Pescadores em Arraial do Cabo são pescadores de Arraial do Cabo*"; BRITTO, 1999). In other words, what they are saying is that only individuals who share the complex codes of the ecological knowledge, typical for that place, are recognized as true fishermen, therefore, fishermen from Arraial do Cabo are only recognized as such by other Arraial do Cabo's fishermen.

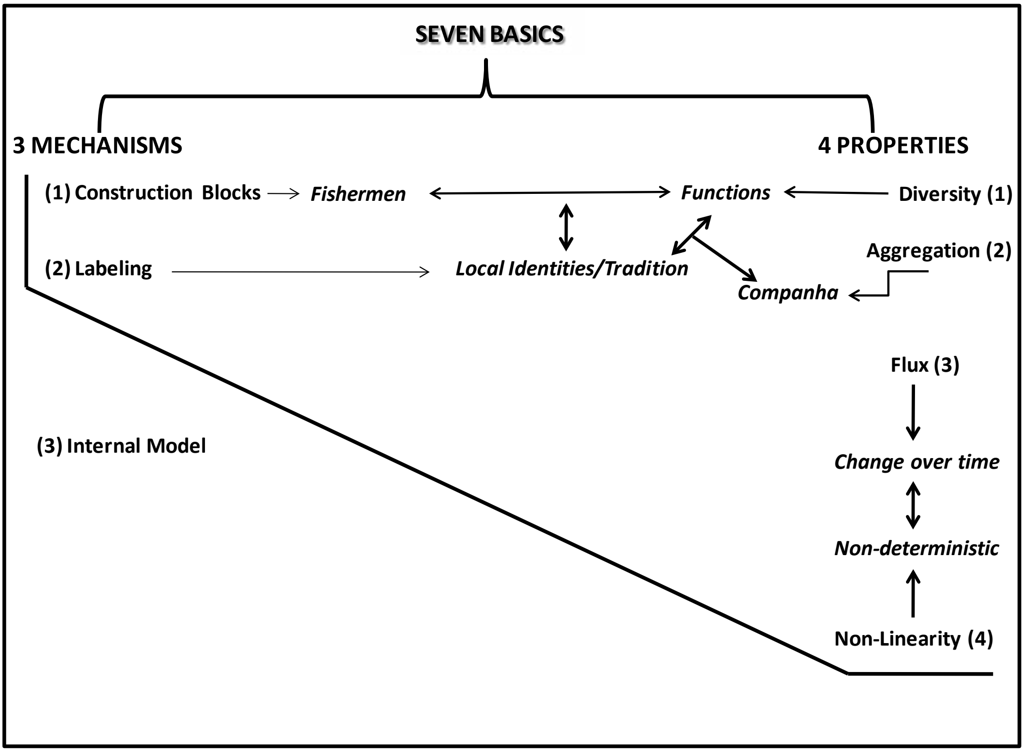
The **non-linearity** is a property inherent to the collective activity of FEK agents in their different construction blocks (fishermen, functions, and fellowships). More than that, it is an epistemological requirement, since is limited within the framework of predictions that are produced by synthesis of knowledge placed in the three "wheels" diagrams. However, understanding this process of anticipation is only possible if the **internal model** of the FEK is identified and analyzed.

The last property of FEK as CAS is the **flux** within the system. For instance, both in Arraial do Cabo and Itaipu there have been a flow of knowledge and know-how on techniques across generations at least in the last one hundred years (BRASIL, 1876). However, the extension of these fluxes is severely limited spatially, since its effectiveness is circumscribed to the local level. Thus, the ecological knowledge inherent to Arraial do Cabo is useless at Itaipu, even if they were developed based on ecosystems which are very much analogous.

As an example of the fast adaptability of FEK, depending on local conditions, is the change occurred in traditional inshore squid fishing (*Doryteuthis* spp.) in Arraial do Cabo. This fishing was conducted at night, using kerosene fueled lamps, but recently, cold fluorescent battery powered lamps were introduced to this fishing, changing much of the know-how associated with the traditional fishing. Another example is regarding the system of prognostics, which is based on a limited number of elements such as those that show changes in the sky (presence and type of flying of seagulls) or arrival of the fishing schools. In this case, a small Number of elements (wind, sea condition, sea bottom) produce prognostics that are quite sophisticated, however, subjected to rapid changes as a consequence of specific circumstances such as small environmental changes.

In summary, FEK systematizes understandings from ancient times, moving across time and being updated constantly, from one generation to another through oral tradition. These understandings involve how to "kill" fish in the moment they get closer to the shore, a decision which is taken based on the understanding of the behavior of certain fish schools, sea states and meteorological conditions (winds, currents etc.), and the results of previous fishing events. Tradition and innovation, change and permanence, experience and adaptation, are the evolutionary part of the Complex Adaptive Systems and also of the Fishermen Ecological Knowledge. Therefore, taken the structure of CAS to interpret FEK seems to be adequate to assist the communication between different areas of the formal sciences, as well as to enable a greater horizontality in the relationship between the formal sciences and FEK. Figure 5 presents clearly the proposition that FEK can be considered a CAS.

Figure 5. Diagramatic representation of FEK as CAS showing the seven basics defined by Holland (1995), which means a dynamics of rules selection that determines a dialectic of change which keeps FEK always different although the same.



Source: Original figure idealized and designed by the authors.

CAS as a structuring metaphor of FEK

The Complex Adaptive System was originally proposed as a genetic algorithm and a model to study the dynamics of such systems. Therefore, CAS was developed fundamentally in an effort of mathematical modeling of aspects from biological and economical systems (HOLLAND, 1995, 1999).

Mathematical models present useful particulars from a scientific point of view, such as a concise language that enables a simple description of the world and its phenomena, enabling the test of hypothesis by comparison between data and facts. However, even simple modeling can go higher in complexity as the demand for realistic tests increases. The realism of models and tests are on dependence of a growing number of parameters. An immediate consequence of this demand of realism/complexity is the necessity to acquire data to feed the model, as well as the output, which becomes difficult to interpret. As a consequence, the developing of a suitable mathematical model for a given circumstance is under the need of a good balance between how much the model represents the reality and how many parameters are necessary for doing the job (the complexity of the model).

When analyzing the EK of fishermen of Arraial do Cabo and Itaipu as a CAS as was done here, it was not the intention to reduce an anthropological object to the demands of the mathematical modeling. Differently, the proposal was to use CAS structure as an organizing metaphor and by then to operate procedures of analysis-synthesis in the arc of induction-deduction. On the other hand, the term "metaphor" faces some epistemological restrictions.

According to Bachelard (2000), the metaphors are an "epistemological obstacle" to the progress of scientific thinking: "*The progress of scientific thinking occurs due to the transposition of such obstacles and the practice of epistemological acts*". This means that Bachelard differentiates the pre-scientific spirit from a scientific one, being the scientific character of the spirit acquired from the surpassing of these epistemological obstacles. Yet, according to this author, it is in the course of a psychological analysis of the science and its progress that is achieved the conviction that this problem must be approached by a framework which consider history of scientific progress as a history of surpassing particular obstacles in the way of scientific advance: "*…it is during the moment of learning intimately when the stupor and the confusion rise, as a type of functional necessity*".

For a pre-scientific spirit, one single word can be converted to an adequate explanation. It is in this sense that the metaphors represent an obstacle to the construction of thorough explanations. They are images that become robust enough to block the operation of reason. Metaphors drive the thought, tend to match other metaphors and complete one another, and giving the kingdom of imageries the power to impede a more autonomous thinking (BACHELARD, 2000).

In this study, however, the CAS metaphor did not operate as an image, but as an organizational structure. In this sense, the CAS structure intended to fulfill two functions: first, it organized the anthropological object (FEK) in order to facilitate the discussion between different areas of formal sciences over it — or in other words, it intended to promote an interdisciplinary discussion. Second, once the object was structured, it is trusted that the possibilities of communication between knowledge from different sources are enhanced, for example, between formal science and FEK. Along these lines, what is being proposed is a conception of metaphor that aims to create a rupture over the obstacle role of the terminology and to establish a unique advantage to facilitate the communication between distinguished areas of the sciences and between knowledge of different sources.

Hence, the metaphor associated to the structuring adjective is attached to a bridge that surpasses the abyss of incommensurability (KUHN, 1998).

Bachelard (2000) stated that "*the empirical thinking is clear, immediate, when supported by the apparel of reasoning. When facing a past of errors, the truth is found in a state of intellectual regret. In effect, it is recognized that 'against' a previous understanding, destroying wrongly acquired knowledge, or overcoming those ideas, which in spirit impede the spiritualization*". It is based on this position that this study is supported, searching for an approximation between empirical and scientific knowledge, in the moment in which the focus is an artisanal fishing system, where it is possible to identify these both formats of understanding.

Lobão (2010b) observed that both types of knowledge transit over the sphere of prognostics. Both are linked to empirical demonstration, however, in distinct temporal poles: the ecological knowledge of traditional fishermen of Arraial do Cabo is based on their past, the present time is an externality, and the future is a prognostic or indeterminable set, depending on the temporal scale used. The scientific knowledge is supported by the present: the past is an externality, and the future a scenario that can be anticipated in the present. Thinking on this interpretation on the different models of knowledge, the author proposes the use of CAS model as a possibility to combine the horizons between science and tradition, with the objective to contribute to a sustainable management of the artisanal fishing systems (BERKES, 2012; JOHANNES, 1998; PITA et al., 2016; ROUX; TALLMAN; MARTIN, 2019).

Bachelard (1972) also proposes that it is necessary to use all philosophies to achieve a full notion in form of a spectrum in a particular knowledge: "*Only one philosophy is insufficient to cover a specific knowledge. Then if this is the objective, according to different spirits, exactly the same question regarding a specific knowledge, you will observe the singular increase the philosophical plurality is capable of building under the idea of a notion*". Continuing, "*Each philosophy provides only one edge of the full notion in form of a spectrum*" (BACHELARD, 1972).

In summary, this study proposed the use of the model of Complex Adaptive System as a structuring metaphor. The main aim was to generate a dialogue between what can be considered two philosophies: science and tradition. Moreover, the concept of structuring metaphor surpasses the role of an epistemological obstacle to become a way to engage different knowledge in an interdisciplinary dialectics.

Conclusion

In this research, the proposal of Lobão (2010b) was implemented using the terminology "structuring metaphor". Or in other words, the CAS structure was used to organize the anthropological object of artisanal fisheries and the FEK involved in them. However, the term metaphor when applied to science has generally a negative meaning related to the epistemology of Gaston Bachelard (2000) who defines "metaphors" as one of the main obstacles for the establishment of an objective knowledge. Thus, the terms "metaphor" and "epistemological obstacles" were discussed in order to give to the new proposed term "structuring metaphor" a positive meaning related to an interdisciplinary perspective which favors the dialogue between different forms of knowledge.

The ideas here developed followed those proposed by Lobão (2010b) as a second moment in a larger scientific-epistemological project, which aims to open the gates for an interdisciplinary perspective which can facilitate the dialogue among different scientific areas such as Anthropology and Marine Biology, as well as between scientific knowledge and the FEK. Beyond the use of CAS as organizational/structuring metaphor, the next step in this endeavor is the study of the dynamics of this system (FEK), which allows the understanding of the internal model under operation. These are the tasks to be performed on the next contributions to this topic.

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FISHERMEN ECOLOGICAL KNOWLEDGE AND COMPLEX ADAPTIVE SYSTEMS: AN INTERPRETATIVE MODEL FOR SMALL-SCALE FISHERIES[1]

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FISHERMEN ECOLOGICAL KNOWLEDGE AND COMPLEX ADAPTIVE SYSTEMS: AN INTERPRETATIVE MODEL FOR SMALL-SCALE FISHERIES

***Abstract*:** The fishermen ecological knowledge (FEK) encompasses information on biology of species and climatic and oceanographic changes, all related with schools of fish and its capture. It incorporates a complex set of codes and signs, which are constantly updated and transmitted orally thorough generations. In this sense, FEK presents characteristics such as diversity and ability to learn from experience, which are in conformity with the definition of a complex adaptive system (CAS). Based on this assumption, this work proposes to structure and interpret FEK as a CAS. It is supported that such approach can promote the exchange of information among areas, which are other way considered incommensurable (anthropology, oceanography, marine biology, meteorology etc.), and also among formal sciences and the FEK. However, CAS is a structure designed with heuristic goals associated with mathematical modeling what is beyond the aims of this work, which uses CAS only as a structuring metaphor.

***Key-words*:** Traditional Ecological Knowledge, Artisanal Fisheries, Interdisciplinarity

CONHECIMENTO NATURALÍSTICO E SISTEMAS ADAPTATIVOS COMPLEXOS: UM MODELO INTERPRETATIVO PARA PESCARIAS DE PEQUENA ESCALA

O conhecimento naturalístico (CN) resume a compreensão que os pescadores têm tanto da biologia das espécies, quanto das mudanças climáticas e oceanográficas relacionadas com a identificação de cardumes e sua captura. Ele é composto de uma linguagem complexa de códigos e sinais atualizada constantemente e transmitida oralmente através das gerações. Nesse sentido, o CN está em conformidade com a definição de sistema adaptativo complexo (SAC), ou seja, apresenta diversidade e aprende com a experiência. Com base nesse pressuposto, este trabalho se propõe a estruturar e interpretar o CN como um tipo de SAC. Acredita-se que tal abordagem pode reduzir a incomensurabilidade entre as diferentes ciências formais relacionadas ao estudo dos ambientes costeiros (antropologia, oceanografia, biologia marinha, meteorologia etc.), bem como entre as ciências formais e o CN. Entretanto, o SAC foi desenvolvido com objetivos associados à modelagem matemática, nesse trabalho ele é usado apenas como uma metáfora estruturante.

***Palavras-chave*:** Conhecimento Naturalístico, Pesca Artesanal, Interdisciplinaridade

EL CONOCIMIENTO NATURALISTA Y SISTEMA ADAPTATIVO COMPLEJO: UN MODELO INTERPRETATIVO PARA LA PESCA EN PEQUEÑA ESCALA

***Resumen*:** El conocimiento naturalista (CN) resume la comprensión que los pescadores tienen de la biología de las especies, y de los cambios climáticos y oceanográficos relacionados con la identificación de cardúmenes y su captura. Se compone de un lenguaje complejo de códigos y señales, en constante actualización y transmitido oralmente a través de las generaciones. En este sentido, el CN está en conformidad con la definición de sistema adaptativo complejo (SAC), o sea, presenta diversidad y aprende con la experiencia. Sobre esta base, este trabajo se propone estructurar e interpretar el CN como un tipo de SAC. Se cree que este enfoque puede reducir la inconmensurabilidad entre las diferentes ciencias formales relacionadas con la pesca (antropología, biología, etc.), así como entre las ciencias formales y el CN. Sin bien el SAC fue desarrollado con objetivos asociados al modelado matemático, en ese trabajo se utiliza el SAC solamente como una metáfora estructurante.

***Palabras-clave*:** Conocimiento natural, Pesca artesanal, Interdisciplinariedad