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Research Article

Socio-ecological analysis of the artisanal fishing system on Easter Island

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ABSTRACT. This paper introduces a socio-ecological analysis of the artisanal fisheries system on Easter Island (27º07′S, 109º22′W) through the identification and interaction of stakeholders. It also comprises a structural analysis of the system aiming to identify any key issues and then propose research and development programs for multiple fisheries that will contribute to their sustainable development. The methodology is divided into four stages: i) identification of issues with stakeholder (fishers, government workers and expert scientists) participation, ii) analysis of a structural matrix consisting of a direct causality study of the symmetric, structural and binary matrix based on socio-ecological issues allowing the calculation of the level of influence and dependence of each issue, iii) identification of key issues with an influence/dependency diagram, and iv) proposal of research and development programs according to the needs and opportunities identified in the previous stages. The Easter Island artisanal fishing system is used as a case study for this methodological approach. Thus, the fishers identified 108 issues, which were then grouped by similarity, reducing the number to 27 global issues, of which seven were identified as key. Surveyed local and central government workers and expert scientists identified 7, 2 and 5 issues, respectively. Finally, research and development programs are proposed that will encourage a series of changes to the fisheries situation on the island, in order to resolve issues and promote their sustainable development.

Keywords: fisheries management, sustainable development, socio-ecological system, artisanal fishing, Easter Island.

Análisis socio-ecológico del sistema pesquero artesanal de Isla de Pascua

RESUMEN. Este artículo presenta un análisis socio-ecológico del sistema pesquero artesanal de la Isla de Pascua (27º07'S, 109º22'W), mediante la identificación e interacción de los actores sociales (stakeholders). También comprende un análisis estructural del sistema con el objetivo de identificar los problemas clave del sistema para la posterior propuesta de programas de investigación y desarrollo para múltiples pesquerías que contribuyan a su desarrollo sustentable. La metodología se divide en cuatro etapas: i) identificación de los problemas con la participación actores sociales (pescadores, trabajadores del gobierno y expertos científicos), ii) análisis de la matriz estructural que consiste en un análisis de causalidad directa de la matriz simétrica, estructural y binaria construida con problemas socio-ecológicos que permiten el cálculo del nivel de influencia y dependencia de cada problema, iii) identificación de los problemas clave con un diagrama de influencia/ dependencia, y iv) propuesta de programas de investigación y desarrollo de acuerdo a las necesidades y oportunidades identificadas en las etapas anteriores. El enfoque metodológico se aplica al sistema pesquero artesanal de Isla de Pascua como caso de estudio. De este modo, los pescadores identificaron 108 problemas, los cuales fueron agrupados por similitud, lo que redujo el número a 27 problemas, de los cuales siete fueron identificados como problemas clave. También fueron encuestados funcionarios del gobierno local y central y expertos científicos, que identificaron 7, 2 y 5 problemas clave, respectivamente. Por último, se proponen programas de investigación y desarrollo que fomenten una serie de cambios en la situación de la pesca en la isla, para resolver los problemas y promover su desarrollo sustentable.

Palabras clave: gestión pesquera, desarrollo sustentable, sistema socio-ecológico, pesquería artesanal, Isla de Pascua.

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INTRODUCTION

Easter Island, or Rapa Nui, is located at 27º9′S, 109º26′W, almost 3.700 km off the Chilean coast and equally far from Tahiti in the west. Therefore, it is considered the most remote inhabited island on the planet (Mieth & Bork, 2005). World famous for its remarkable monolithic human figures, or moai, Easter Island is also recognized for its unique marine life (Glynn *et al.*, 2003; Randall & Cea, 2011). Its waters support wide-ranging populations of migratory fish species such as yellowfin tuna (*Thunnus albacares*), albacore (*Thunnus alalunga*), bigeye tuna (*Thunnus obesus*), and swordfish (*Xiphias gladius*), among others. These fish form a fundamental part of Rapa Nui culture, which has a God of Tuna, represented by the stone statue "Pou Hakamononga" (Ferrer, 1990). The exploitation of marine resources on Rapa Nui is mainly subsistence and artisanal in nature (Randall & Cea, 1984), *i.e.*, small-scale fishing in near-shore waters (Muñoz, 2011). Coastal fishing is conducted on boats no bigger than 15 m long, and generally occurs within the first five miles from the coast. The fishing system is composed of 56 active and inactive fishers in the five artisanal coves of Hanga Roa, Hanga Piko, Vaihu, Hotu Iti and Hanga Ho'onu (Yáñez *et al.*, 2007). According to statistical yearbooks, the main fisheries resources exploited that have significant positive socio-economic impacts on Easter Island are yellowfin tuna, nanue (*Kiphosus sandwicensis*) and sierra (*Thyrsites atun*), which comprise 50%, 14% and 8% of total landings, respectively (SERNAPESCA, 2010). Other coastal fisheries include shoreline fishing with line and bait, costal diving with harpoons and the collection of seaweed, crustaceans and mollusks in the intertidal zone and coral from the sub-tidal shallows (Ayres, 1979, 1985; Yáñez *et al.*, 2007). However, a series of issues, such as insufficient relations with public institutions in the central government, the high demand for marine products from inhabitants and tourists on Easter Island and the irregularity of fisheries activities, have led to a constant sensation of abandonment and shortages in marine resources by the islanders (Yáñez *et al.*, 2007; Ramírez, 2010).

In order to mitigate the above issues and achieve sustainable development of the fisheries system on Easter Island, it is necessary to consider the island as a Socio-Ecological System (SES), as its existence and development over time will depend on how key factors (economic growth and social equity) interrelate with one another and with the ecosystem. An SES is understood as a system with a social (or human) component in interaction with an ecological component (Berkes & Folkes, 1998; Perry *et al.*, 2011). In recent years, several scientific research projects have shown the importance of approaching fisheries systems from a socio-ecological perspective (Murray *et al.*, 2008; McClanahan *et al.*, 2009; Berkes, 2011; Yáñez *et al.*, 2011). This approach was applied in a diagnostics project about the fishery industry on Easter Island funded by the Under Secretary of Fisheries and Aquaculture, National Fisheries Service V Region and the Provincial Government of Easter Island (Yáñez *et al.*, 2007). The project was executed during 2007 by the School of Marine Sciences at the Pontificia Universidad Católica de Valparaíso and provides a full report on artisanal fisheries on the island, using workshops and surveys of all stakeholders (artisanal fishers, government workers and expert scientists) in order to identify issues in the fisheries system and other aspects relevant to sociological issues (Yáñez *et al.*, 2007).

In order to identify the population needs on Easter Island in connection to the fisheries sector and also to get primary information of their concerns and perspectives for the development of the sector, an innovative, participative and multi-methodological approach was used to create a vision of the fisheries sector in a socio-ecological context (Gunderson & Holling, 2002; Berkes *et al.*, 2003). The analysis of the socio-ecological system presents the reality on the island based on the perspectives of all the stakeholders and gives rise to a multi-referential situational explanation (Matus, 1987), using perceptions of the people who interact with the fisheries sector, both locally on Easter Island and on continental Chile.

The methodology of this study includes an initial phase of identifying the issues in the fisheries system with the participation of the stakeholders themselves, followed by a structural analysis (matrices and diagrams) to identify the key issues that must be resolved in order for the institutional organization of the fisheries system to function. The objective of the study is to provide a socio-ecological analysis that uses the identification and interactions of the stakeholders to conduct a structural analysis of the system to identify the key issues, propose research and development programs for the fisheries system, and contribute to its sustainable development.

MATERIALS AND METHODS

This study conducted a socio-ecological analysis of the stakeholders of the Artisanal Fisheries System on Easter Island (AFSEI). The stakeholders include fishers, public administrators (local and central government) and expert scientists. A set of five clusters of minimum knowledge

(environment, technology and infrastructure, economics, social knowledge and governance) was used to understand the structure and function of the AFSEI (Fig. 1, adapted from Yáñez *et al.*, 2011). The fifth cluster refers to the system's governance: it influences all other clusters and includes the knowledge required to understand the approaches, methods and instruments needed for the sustainable development of fisheries (Fig. 1).

The study was conducted following a four-stage process. First, a collection of socio-ecological information about fishers and public administrators (local and central government) was performed based on participatory activities, including workshops and surveys carried out during June 2007. The socio-ecological information generated was used to create a situational explanation from fishers and public administrators and to identify and define an initial list of issues that hinder the sustainable development of the fisheries system. Additionally, a bibliographical review was conducted to characterize the present status of the AFSEI in the context of the five clusters of minimum knowledge. The bibliographic analysis served as input for the expert scientists to generate an *a priori* situational explanation of the AFSEI and to identify and describe an initial set of issues. Secondly, using the initial issues identified by stakeholders, a structural matrix analysis, based on Godet (1994), of these issues as related to fisheries development was conducted to estimate their influence and dependency on the system and to identify key issues. A direct causality analysis of the symmetric, structural and binary matrix built with socio-ecological issues allowed for the calculation of the level of influence and dependence of each issue (Fig. 2a). In workshops the stakeholders estimated the degree of influence of each issue (driver) on the other issues (dependence). The influence (driving force) was calculated for each issue as follows:

$$Dr_{ij} = \Sigma_j\, e_{ij}$$

$$Dr\%_{ij} = (\Sigma_j\, e_{ij})*100/(\Sigma_j\, Dr_{ij})$$

where Dr_{ij} is the sum of influences of driving force i to issue j; $e_{i,j}$ is a binary value which can be 0 (no influence) or 1 (influence) of the issue i (driver) to issue j (dependence); i = 1….8 is an identifier of corresponding issue (driver); j = 1….8 is an identifier of corresponding issue (dependence); $Dr\%_{ij}$ is the driving force of issue j as percentage of contribution over the sum of Dr_{ij}. The dependency was calculated for each issue as follows:

$$Dep_{ij} = \Sigma_i\, e_{ij}$$

$$Dep\%_{ij} = (\Sigma_i\, e_{ij})*100/(\Sigma_i\, Dep_{ij})$$

where Dep_{ij} is the sum of dependence j to issue i; $e_{i,j}$ is a binary value which can be 0 (no dependence) or 1 (dependence) of the issue j (dependence) to issue i (driver); i = 1….8 is an identifier of corresponding issue (driver); j = 1….8 is an identifier of corresponding issue (dependence); $Dep\%_{ij}$ is the dependence of issue i as percentage of contribution over the sum of Dep_{ij}.

Thirdly, based on this matrix analysis an influence (driving force) - dependency diagram was constructed using ($Dep\%_{ij}$, $Dr\%_{ij}$) to identify the key issues and facilitate the analysis of the issues in terms of their roles and relative importance or specific weight in the functioning of the AFSEI (Fig. 2b). The driving force-dependency diagrams are the basis for determining the shape and strength of the relationships between the socio-ecological issues. The diagram is a Cartesian plane, divided into four zones that are defined as: power or forcing issues (quadrant I); conflict or forcing-but-forced issues (quadrant II); autonomous or non-forcing issues (quadrant III); and outcome or consequence issues (quadrant IV). The diagram is divided into four zones using the average contribution of each issue, *e.g.*, with eight issues the average is 100%/8 = 12.5% (Fig. 2a). The forcing issues are those that have a great influence on the rest of the issues, but experience little or no influence from them. The conflict zone identifies the issues that have a significant level of influence on the system and receive a similar amount of influence from the system. Outcome issues are those receiving great influence from the system while being unable to influence it. Autonomous issues are those that, even though able to show some level of forcing or dependency with the system, seem to be relatively independent of the system. The key issues are those plotted in quadrants I (forcing issues) and II (conflict issues).

Fourthly, keeping in mind the key issues detected by stakeholders, a proposal for research and development programs was designed, showing which aspects (ecosystem, technology and infrastructure, economics, social aspects and governance) are in need of sustainable development.

RESULTS

Application

In this section we report the case study of AFSEI where the application of each stage of the approach was critical to explore, model or analyze the social-ecological system of concern.

Issues identified by stakeholders

In 2007, an *in situ* survey was conducted with different stakeholders (fishers, local government, central govern-

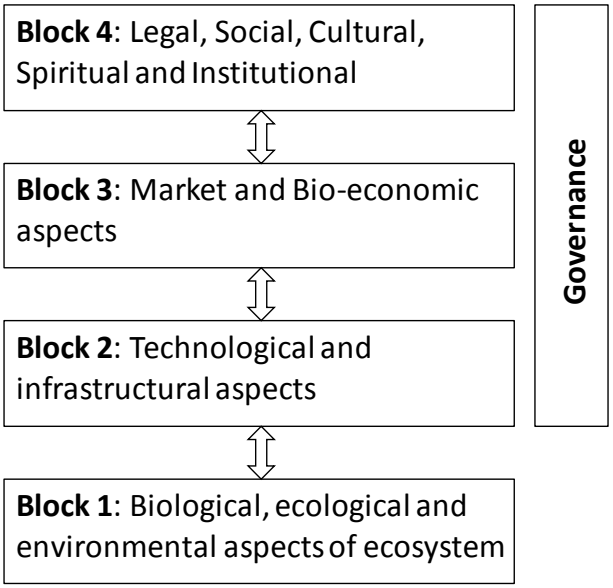


Figure 1. Cluster of minimum knowledge used to understand the fisheries system (adapted from Yáñez *et al*., 2011).

ment and expert scientists) in order to capture their perceptions about the needs and projections of artisanal fisheries activities on Easter Island. The following question was put to the interviewees: in your opinion and based on your own experience as a fisher on Easter Island, central government worker, local government worker or scientist, what do you believe are the main issues that hinder the functioning of fisheries activities? Briefly describe each issue.

In 2007, artisanal fishers and boats on Easter Island numbered 56 and 38, respectively (Yáñez *et al.*, 2007). A total of 37 fishers (male) received and answered the survey question. Of the total surveyed fishers, 25 were from Hanga Piko, 8 from Hanga Roa, 3 from Hanga Ho'onu and 1 from Hotu Iti. Only 12 of the fishers surveyed were registered in the Artisanal Fishing Register (AFR). Of the fishers who responded, 15 indicated that they declared catch information about the species harvested. Around 68% of the fishers surveyed indicated that they were fishing boat owners and captains and 32% indicated they were crew. All fishers were male with an average age of 50.3 years. In total 108 issues were identified by fishers, which were then grouped by similarity to find a resulting 27 general issues (Table 1).

In addition, 6 central government and 8 local government workers were surveyed, identifying 12 and 14 issues, respectively (Table 1). Of all the central government workers interviewed, 3 were from the National Fisheries Service, 2 from the Under-secretary of Fisheries and Aquaculture and 1 from the Chilean Economic Development Agency. Local government surveyed included the Municipality Mayor, the National Property Manager, the Maritime Governor of Hanga Roa, 2 workers from the Provincial Office of the National Fisheries Service, 2 from the Provincial Office of the National Tourism Service and 1 from the Ministry of Publics Works.

Finally, 6 scientists were surveyed identifying 18 issues (Table 1). Recognized Chilean scientists with expertise in fisheries, biology and ecology of the Eastern Island marine ecosystem were surveyed and included researchers from Instituto de Fomento Pesquero, Universidad Austral de Chile and Pontificia Universidad Católica de Valparaíso.

Structural analysis: identification of key issues

The list of issues identified by the stakeholders formed the basis for constructing the interaction matrices for the structural analysis (Fig. 3). The degree of influence of each issue (driver in rows) on the other issues (dependence in columns) was estimated by the stakeholders in participatory workshops. For example, it is evident that Fisher's issue#1 (driver), accumulation of sediments in the harbor basin, influences issue#11 (dependence), small space for mooring small and large boats. Thus, fishers assigned this a dependency of "1" (Fig. 3a). However, the issue#1 (dependence), accumulation of sediments in the harbor basin, is only influenced by issue#5 (driver), poor road access to the harbors, according to fishers' perceptions. The highest forcing issue estimated by fishers was the lack of credibility in the central government (issue#16, Fig. 4a). After the matrix was filled, the influence-dependency analysis for fishers was then used to select the key issues that finally went into the preparation of research and development programs for the sustainability of the fisheries system (Fig. 4a). The following key issues (forcing and conflict zones) for fishers were selected: difficult access to credit, poor associativity of fishers, lack of training in the use of new technologies (GPS, Sounder), accumulation of sediment in the harbor basin, lack of credibility in the central government and high variability of marine currents.

The key issues (forcing and conflict zones) for local government workers were selected. For example, the highest driving power or influence (driving force) issue estimated by local government was the lack of fisheries projects by extant organizations (issue#14, Fig. 4b). Three higher driving forces issues were estimated by central government workers (Fig. 3c): Rapa Nui people do not recognize the fisheries authority and the General Law on Fisheries and Aquaculture of Chile, no adherence to fishing law and cultural barrier (issues#6,

a)

	E1	E2	E3	E4	E5	E6	E7	E8	Dr_{ij}	$Dr\%_{ij}$
E1		0	1	0	0	0	0	0	1	5,6
E2	0		1	0	0	0	1	0	2	11,1
E3	0	0		1	0	0	1	1	3	16,7
E4	1	1	0		1	1	0	0	4	22,2
E5	1	0	1	1		0	0	1	4	22,2
E6	0	1	0	0	0		0	0	1	5,6
E7	1	1	0	0	0	0		0	2	11,1
E8	0	1	0	0	0	0	0		1	5,6
Dep_{ij}	3	4	3	2	1	1	2	2		
$Dep\%_{ij}$	16,7	22,2	16,7	11,1	5,6	5,6	11,1	11,1		

Driver = $Dr_{ij} = \Sigma j\ e_{ij}$

$Dr\%_{ij} = (\Sigma j\ e_{ij})*100/((\Sigma i\ \Sigma j\ e_{ij}))$

Dependency = $Dep_{ij} = \Sigma_i\ e_{ij}$

$Dep\%_{ij} = (\Sigma_i\ e_{ij})*100/((\Sigma_j\ \Sigma i\ e_{ij}))$

	$Dep\%_{ij}$	$Dr\%_{ij}$
E1	16,7	5,6
E2	22,2	11,1
E3	16,7	16,7
E4	11,1	22,2
E5	5,6	22,2
E6	5,6	5,6
E7	11,1	11,1
E8	11,1	5,6

b)

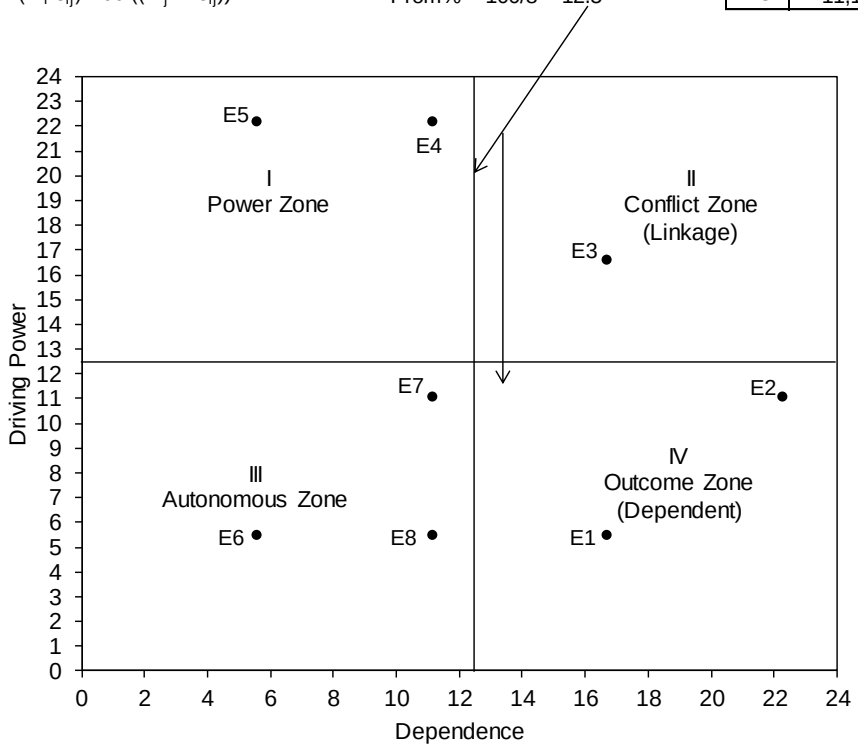


Figure 2. Example of stages 2 and 3 of the methodology: a) structural analysis of issue matrix, and b) driving power and dependence diagram (adapted from Godet, 1994).

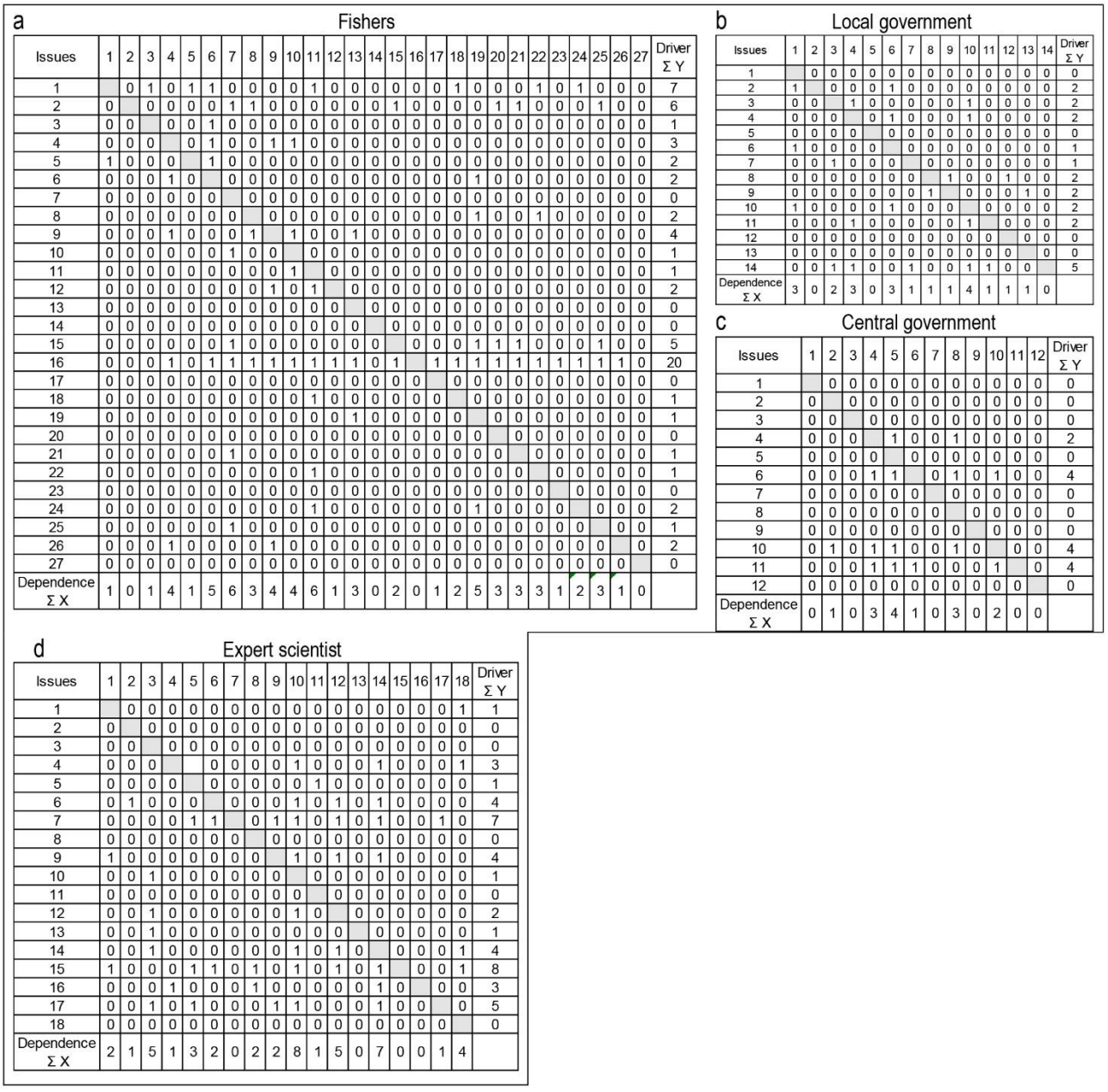
#10, #11, Fig. 4c). These three forcing issues together with issue#4, fishers and boats are unregistered in the AFR (Chilean Artisanal Fishing Register), were selected as key issues by the central government.

Recognized Chilean scientists built a structural analysis matrix (Fig. 3d). The following key issues (forcing and conflict zones) were detected by scientists (Fig. 4d): lack of dock infrastructure, lack skilled island manpower, Rapa Nui people and culture, lack in adaptation of suitable fishing technologies, "more than a problem I see a general balance in the use of fishing resources," absence of a legal framework of incentives for the development of fisheries in this isolated place, lack of facilities for maritime berthing, loading and protecting boats, and idiosyncrasies of the islanders, who have other means of subsistence or more profitable jobs than what they would obtain from fishing.

Key issues detected by stakeholders were then grouped according to similarity, leading to 8 categories within the framework of knowledge clusters (Fig. 1): legal, cultural, institutional, economic, technological, infrastructure, governance and ecosystem. Table 2 shows the key issues by stakeholder and by category.

Table 1. Set of issues identified by stakeholders.

	Fishers		Local government
1	Accumulation of sediments in harbor basin	1	Lack of analysis of what is available and what can be done
2	High variability of marine currents	2	Lack of technological upgrading of the existing fishing fleet
3	Inexistence of closure on perimeter of harbor	3	The unwillingness of fishers to formalize his professional activity
4	Poor associativity among fishers	4	Expand the fishing area
5	Poor access road to the harbors	5	Organization of the fishers (cooperative, trade unions)
6	Poor service facilities for fishers (bathrooms, boxes, rooms)	6	Poor relations of fishers with the National Fisheries Service
7	Lack of knowledge of new fishing zones	7	Lack of training to improve standard of fishing
8	Motor wear due to weight of stones used in fishing	8	Poor relationship of Rapa Nui Fishers with Chilean Under-secretary of Fisheries and Aquaculture, no statistical information
9	Difficult access to credit	9	No boats with sufficient autonomy and equipped with advanced technology
10	Boats unsuitable for ocean fishing	10	Increasing tourists and there are no fish to offer. Landing tends to decreased
11	Small space for mooring small and large boats	11	High prices of fish on local markets
12	Too many fishers for the number of boats available	12	Lack of fish on local market
13	Lack of supply of fishing materials and at low cost	13	Lack of new ideas for fishing
14	Poor relations with the National Fisheries Service representative	14	Lack of fisheries projects by organizations currently constituted
15	Lack of training in the use of new technologies (GPS, Sounder)		**Central government**
16	Lack of credibility in the central government	1	No adequate supply of seafood products for local needs
17	Lack of policing of boats that enter the ZEE set up by the island	2	Easter Island fishers have no awareness or actions regarding conservation and protection of marine resources
18	No ramp or crane to get boats out of the water	3	The characteristics of the island, its limited space and vulnerability
19	Lack of motor maintenance service	4	Fishers and boats are unregistered in the AFR (Chilean Artisanal Fishing Register)
20	Lack of technology to increase catches	5	No information on fishing catches by coastline collectors and divers
21	Lack of technology for communication and navigation	6	Rapa Nui people do not recognize the Fisheries authority and the General Law on Fisheries and Aquaculture of Chile
22	Inconvenient fuel supply	7	Absence of a cohesive organization with members registered on the artisanal fishing register
23	Sales method (whole, no head and gutted) affects local consumer	8	No information regarding unloading of boats
24	Dock is deficient for fishing operations	9	No knowledge of the reality of the fishing sector on the island
25	No diversity in fishing systems	10	No adherence to fishing law
26	No policing by the National Fisheries Service	11	Cultural barrier
27	No income from use of dock	12	No information or diagnostics of the situation in the sector and its production and organizational potential
	Expert researchers		
1	Lack of fishing prospecting	10	No interest in increasing amount of fishing
2	Informality in fishing systems	11	Bad relations with Chileans from the continent
3	Informality in sales methods.	12	Lack of adaptation of *ad-hoc* fishing technologies
4	Lack of dock infrastructure	13	Non-established internal demand
5	Island culture has strong disconnection and lack of sense of belonging with rest of the country	14	"More than a problem I see a general balance in the use of fishing resources"
6	Lack island skilled manpower.	15	Absence of a legal framework of incentives for the development of fisheries in this isolated place
7	Rapa Nui people and culture	16	Lack of facilities for the maritime berthing, loading and protecting boats
8	Poor supply, availability or access to raw materials	17	Idiosyncrasies of the islanders, who have other means of subsistence or more profitable jobs than what they would obtain from fishing
9	Lack in adaptation of suitable fishing technologies	18	Apart from tuna, lack of knowledge on other resources that fishing could be based on



a Fishers

Issues	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	Driver Σ Y
1		0	1	0	1	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	1	0	1	0	0	0	7
2	0		0	0	0	0	1	1	0	0	0	0	0	0	1	0	0	0	0	1	1	0	0	0	1	0	0	6
3	0	0		0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
4	0	0	0		0	1	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
5	1	0	0	0		1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
6	0	0	0	1	0		0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
7	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	2
9	0	0	0	1	0	0	0	1		1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
10	0	0	0	0	0	0	1	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
11	0	0	0	0	0	0	0	0	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
12	0	0	0	0	0	0	0	0	1	0	1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
13	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	1	0	0	0	0	0	0	0		0	0	0	1	1	1	0	0	0	1	0	0	5
16	0	0	0	1	0	1	1	1	1	1	1	1	1	0	1		1	1	1	1	1	1	1	1	1	1	0	20
17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0		0	0	0	0	0	0	0	0	1
20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	1
22	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0		0	0	0	2
25	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	1
26	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	2
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Dependence Σ X	1	0	1	4	1	5	6	3	4	4	6	1	3	0	2	0	1	2	5	3	3	3	1	2	3	1	0	

b Local government

Issues	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Driver Σ Y
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	1		0	0	0	1	0	0	0	0	0	0	0	0	2
3	0	0		1	0	0	0	0	0	1	0	0	0	0	2
4	0	0	0		0	1	0	0	0	1	0	0	0	0	2
5	0	0	0	0		0	0	0	0	0	0	0	0	0	0
6	1	0	0	0	0		0	0	0	0	0	0	0	0	1
7	0	0	1	0	0	0		0	0	0	0	0	0	0	1
8	0	0	0	0	0	0	0		1	0	0	1	0	0	2
9	0	0	0	0	0	0	0	1		0	0	0	1	0	2
10	1	0	0	0	0	1	0	0	0		0	0	0	0	2
11	0	0	0	1	0	0	0	0	0	1		0	0	0	2
12	0	0	0	0	0	0	0	0	0	0	0		0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0		0	0
14	0	0	1	1	0	0	1	0	0	1	1	0	0		5
Dependence Σ X	3	0	2	3	0	3	1	1	1	4	1	1	1	0	

c Central government

Issues	1	2	3	4	5	6	7	8	9	10	11	12	Driver Σ Y
1		0	0	0	0	0	0	0	0	0	0	0	0
2	0		0	0	0	0	0	0	0	0	0	0	0
3	0	0		0	0	0	0	0	0	0	0	0	0
4	0	0	0		1	0	0	1	0	0	0	0	2
5	0	0	0	0		0	0	0	0	0	0	0	0
6	0	0	0	1	1		0	1	0	1	0	0	4
7	0	0	0	0	0	0		0	0	0	0	0	0
8	0	0	0	0	0	0	0		0	0	0	0	0
9	0	0	0	0	0	0	0	0		0	0	0	0
10	0	1	0	1	1	0	0	1	0		0	0	4
11	0	0	0	1	1	1	0	0	1			0	4
12	0	0	0	0	0	0	0	0	0	0	0		0
Dependence Σ X	0	1	0	3	4	1	0	3	0	2	0	0	

d Expert scientist

Issues	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Driver Σ Y
1		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
2	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0			0	0	0	0	1	0	0	0	1	0	0	0	1	3
5	0	0	0	0		0	0	0	0	0	1	0	0	0	0	0	0	0	1
6	0	1	0	0	0		0	0	0	1	0	1	0	1	0	0	0	0	4
7	0	0	0	0	1	1		0	1	1	0	1	0	1	0	0	1	0	7
8	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0
9	1	0	0	0	0	0	0	0		1	0	1	0	1	0	0	0	0	4
10	0	0	1	0	0	0	0	0	0		0	0	0	0	0	0	0	0	1
11	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0
12	0	0	1	0	0	0	0	0	0	1	0		0	0	0	0	0	0	2
13	0	0	1	0	0	0	0	0	0	0	0	0		0	0	0	0	0	1
14	0	0	1	0	0	0	0	0	0	1	0	1	0		0	0	0	1	4
15	1	0	0	0	1	1	0	1	0	1	0	1	0	1		0	0	1	8
16	0	0	0	1	0	0	0	1	0	0	0	0	0	1	0		0	0	3
17	0	0	1	0	1	0	0	0	1	1	0	0	0	1	0	0		0	5
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0
Dependence Σ X	2	1	5	1	3	2	0	2	2	8	1	5	0	7	0	0	1	4	

Figure 3. Structural Analysis Matrix made by stakeholders.

DISCUSSION

The results of this study give an initial situational explanation (Matus, 2000) of the key issues in the fisheries sector on Easter Island, taking into account the stakeholders involved (fishers, local and central government and expert scientists). This situational explanation is a simplified reconstruction of the processes that generate the issues highlighted by the stakeholders, such that the elements comprising these processes appear systematically interconnected in the generation of the issues and of their particular characteristics. The situational explanation aims to systematize how we think about the causes of a problem, forcing us to think before proposing solutions and to recognize that the problem may be explained from the different perspectives of the stakeholders who are in direct or indirect contact with it. This is presented and summarized in Table 2, which indicates "what is to be done" to begin to overcome the limitations on the growth of fisheries activities on Easter Island.

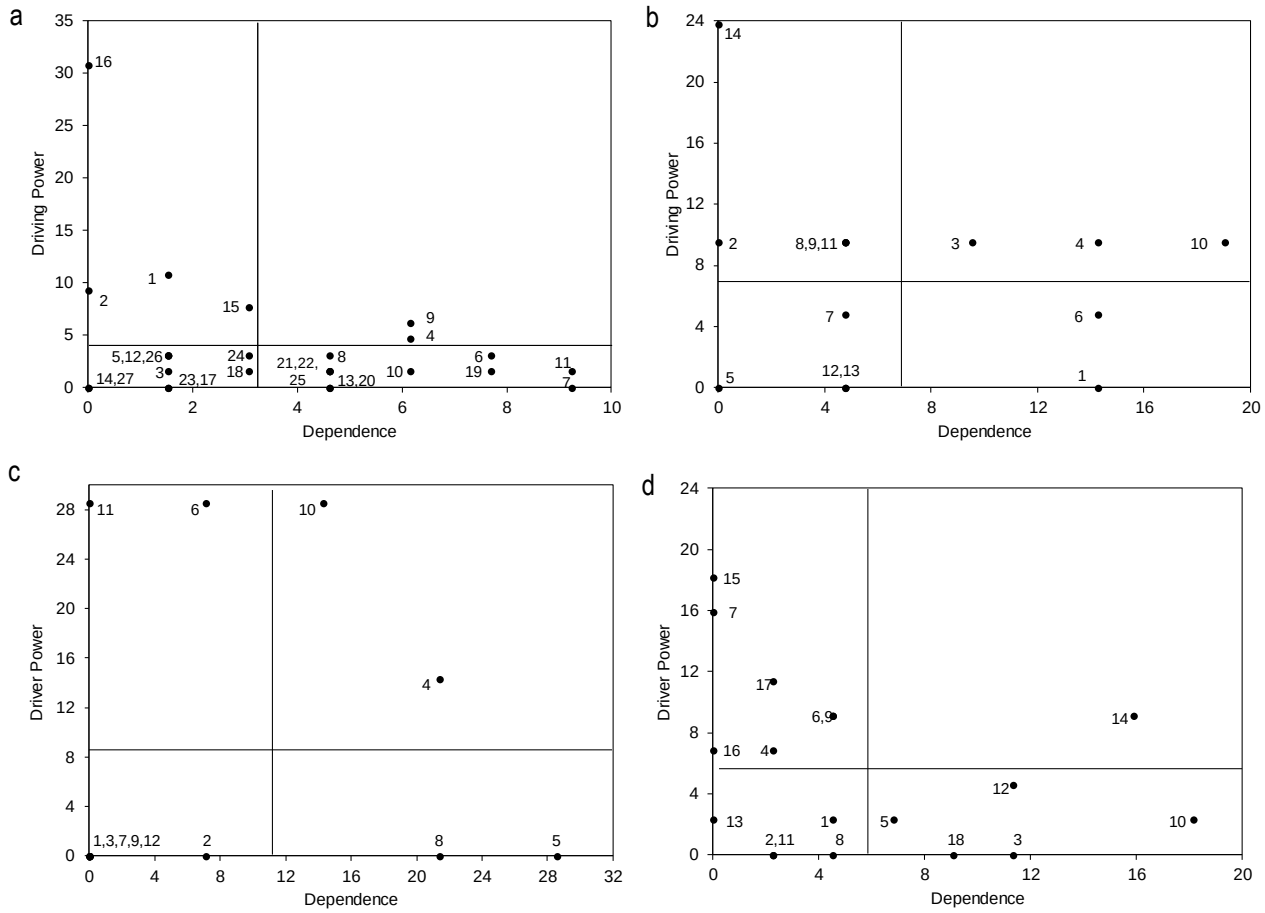


Figure 4. Graph of structural analysis by the a) fishers, b) local government, c) central government, and d) scientists. Numbers indicate the issues identified by stakeholders shown in Table 1.

With respect to the key issues by stakeholder and by category, it can be seen that in the technological area, the key issues mainly relate to incorrect types of boats, while in infrastructure, issues of immediate resolution (accumulation of sediments) and medium-long term resolution (alterative infrastructure: dock/harbor) can be seen. With regard to cultural issues, the issues are seen from the continent and not from the island, implying the need to generate actions that educate and change the arrogant behavior of the continental population towards the islanders. The island expression, "but we understand the Chileans, they do not understand us," reflects the culture clash between its Polynesian origin and the Latino Chilean culture. This cultural issue affects the human relations between the authorities of local and central government institutions. With regard to organization, the fishers themselves highlight the most notable key issue: a lack of collaboration or associativity among them. This together with the legal and bureaucratic prejudices of the central government makes it more difficult for fishers to approach institutions when formulating fisheries projects. This is also seen in the key issues associated with Governance and Legality, which is what gives life to the actions of any group, particularly one which comes together for production purposes. The accumulation of broken promises from the central government throughout its one hundred years of dealings with Easter Island has fueled the fire of distrust felt by the fishers and the general population of Rapa Nui towards the continentals (they come, they eat, they go). This is a deep rooted feeling in the island population that has led to a new leadership, more proactive, enterprising and demanding for the rights of Rapa Nui, represented by the young and the elderly, and which has already begun to take over some old spaces. Regarding the economy, one key issue that affects the life and economic wellbeing of the island is the supply of fish to the local population and tourists through hotels, restaurants and residents. In terms of the ecosystem, two issues related to fisheries strategies are recognized: the variability of currents and the expansion of fishing zones.

Table 2. Key issues detected by stakeholders.

	Fishers	Local government	Central government	Expert researchers
Legal	Difficult access to credit		No adherence to fishing law	Absence of a legal framework of incentives for the development of fisheries in this isolated place
Cultural			Cultural barrier	Rapa Nui people and culture
Organizational	Poor associativity of fishers	Lack of fisheries projects by organizations currently constituted	Fishers and boats are unregistered in the AFR (Chilean Artisanal Fishing Register)	Lack island skilled manpower
Economy		Increasing tourists and there are no fish to offer. Landing tends to decrea-sed. High prices of fish on local markets		Idiosyncrasies of the islanders, who have other means of subsistence or more profitable jobs than what they would obtain from fishing
Technology	Lack of training in the use of new technologies (GPS, Sounder)	No boats with sufficient autonomy and equipped with advanced technology		Lack in adaptation of suitable fishing technologies
		Lack of technological up-grading of the existing fishing fleet		
Infrastructure	Accumulation of sediment in harbor basin			Lack of dock infrastructure Lack of facilities for the maritime berthing, loading and protecting boats
Governance	Lack of credibility in the central government	The unwillingness of fishers to formalize his professional activity	Rapa Nui people do not recognize the Fisheries authority and the General Law on Fisheries and Aquaculture of Chile	
		Poor relationship of Rapa Nui Fishers with Chilean Under-secretary of Fisheries and Aquaculture, no statistical information		
Ecosystem	High variability of marine currents	Expand the fishing area		

With respect to the fishery resources of the island, it is clear that relevant species, such as cowry (*Monetaria caputdraconis*) and Easter Island lobster (*Panulirus pascuensis*), should be recovered from their current deteriorated situation through aquaculture and repopulation of natural banks. The species most intensely exploited by these fishers is the cowry, which has led to a significant decrease in its abundance (Rivera, 2003). Furthermore, in the tuna fishery, it should be considered that the issues are associated with changes in resource availability due to environmental changes. There have been recent declines in landings of yellowfin tuna, which could be caused by depletion by foreign fleets in neighbouring waters, among others factors (Castilla *et al.*, 2013). Therefore, concern should be focused on the exploitation of fisheries resources for bait and human consumption, such as nanue (*Kyphosus sandwicensis*) generally intended for

subsistence consumption and recreational activity (AMBAR, 2001; Yáñez *et al.*, 2007). Besides the above, how environmental changes affect these fisheries should be considered. To that end, a research and development program to analyze the environmental and ecological conditions around Easter Island is proposed to improve the knowledge about the true environmental and ecological variability of southeastern Pacific.

The results reaffirm the idea that in order to achieve the endogenous development (Dalton *et al.*, 2005) of the island in the long-term, the only option that makes sense is to reach complete sustainability of the socio-ecological system (SES). The reason for taking into account the system as a whole is the existence of important links between nature and society on Rapa Nui. Therefore, it is necessary to seek inherent sustainability in the SES, which will bring balance to the following three factors: 1) the economic development of fisheries, 2) the development of the island community, and 3) ecological sustainability. Thus, the functioning and permanence of the SES over time as well as the quality of life on Easter Island will become viable.

Research and development programs

The fisheries research and development programs for Easter Island are proposals, made by the authors of this study, of how to deal with the most important issues or drivers and also a call to action to establish a commitment from the management or with the organization that plans to manage the system to the society it aims to represent. The following research and development programs propose a series of changes to the current fisheries situation on the island:

a) Technical economic feasibility of fisheries for tuna and similar fish using artisanal boats: selection of boats, equipment and training; exploratory fisheries within 200 nm; conservation and manipulation of catches; and sale to locals, tourists and off Easter Island.

b) Infrastructure maintenance and development: control and maintenance of the levels of sediments in fisheries harbor basins; improved facilities such as boxes, bathrooms, meeting rooms and access to harbors; and alternatives for harbor development.

c) Organizational, legal and governance program: create an Easter Island Fishers Organization and a Fisheries and Aquaculture Development Center to support the development of short, medium and long-term projects.

d) Monitoring management and conservation of the ecosystem: in the area of oceanography, the following is recommended: analysis data collected on Easter Island, installation of current meter, fisheries campaigns with oceanographic sampling, and coastal oceanographic monitoring. Regarding marine resources: marine protected areas and management areas, construction of an aquarium, development of aquaculture, particularly native species and over-fished species such as the Easter Island lobster (*Panulirus pascuensis*) and the cowry (*Monetaria caputdraconis*).

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