Sociedad Chilena de Ciencias del Mar

IFOP
GENERANDO CONOCIMIENTO Y SUSTENTABILIDAD
INSTITUTO DE FOMENTO PESQUERO ★ CHILE

INTERNATIONAL WORKSHOP REPORT

ECOSYSTEM APPROACH TO MANAGEMENT OF AQUATIC RESOURCES: PROGRESS, GAPS AND PERSPECTIVES

(1 - 3 December, 2020)

Valparaíso, 2022

Chilean Society of Marine Sciences / Sociedad Chilena de Ciencias del Mar
Fisheries Development Institute / Instituto de Fomento Pesquero

International Workshop Report 2020

ECOSYSTEM APPROACH TO MANAGEMENT OF AQUATIC RESOURCES: PROGRESS, GAPS AND PERSPECTIVES

RESPONSIBLE AGENCIES:
Sociedad Chilena de Ciencias del Mar (SCHCM)
Instituto de Fomento Pesquero (IFOP)

Organizing Committee
Eleuterio Yáñez Rodríguez (SCHCM)
Claudia Andrade Díaz (SCHCM)
Carlos Montenegro Silva (IFOP)
Carolina Lang Abarzúa (IFOP)

Communications
Gabriela Gutiérrez Vivar (IFOP)
Mario Loyola Bermúdez (IFOP)
Natalia Golsman Guzmán (IFOP)

Translation
Mariluz Cartagena Gómez
Sebastián Velásquez Moneny

Collaborators
Ximena Puentes Bozzo (IFOP)
Ximena Arenas González (IFOP)

Recommended Reference:
Yáñez, E., Lang, C., Barbieri, M. A., Montenegro, C & Andrade, C. 2022. Report of International Workshop on Ecosystem Approach to Management of Aquatic Resources: progress, gaps and perspectives. Organized by Sociedad Chilena de Ciencias del Mar and Instituto de Fomento Pesquero, Chile. Instituto de Fomento Pesquero, Valparaíso, Chile, Editions 54 pages.

https://www.ifop.cl/enfoque-ecosistemico/

Eleuterio Yáñez R.[1, 3], Carolina Lang A.[2], María Ángela Barbieri B.[3], Carlos Montenegro S.[2] & Claudia Andrade D.[1, 4]

[1] Sociedad Chilena de Ciencias del Mar (SCHCM), Chile
[2] Instituto de Fomento Pesquero (IFOP), Chile
[3] Prof. Titular Pontificia Universidad Católica de Valparaíso (PUCV), Chile
[4] Universidad de Magallanes (UMAG), Chile

Index

1. ACKOWLEDGEMENTS

The International Workshop entitled: “Ecosystem Approach to Management of Aquatic Resources: progress, gaps and perspectives” was made possible thanks to the initiative of the Chilean Society of Ocean Sciences (SCHCM) and the Fisheries Development Institute (IFOP). The support and funding provided by the representatives from both agencies is appreciated, since the meeting allowed national and international scientists to share their knowledge and experiences related to the implementation of an ecosystem approach to fishery and aquaculture management. The Organizing Committee would also like to thank all national and international participants that contributed to the meeting with a comprehensive view on the various componentes, impacts and applications of this approach, turning this event into a space to effectively promote the interest in ecosystem based management, but also, to ensure resource sustainability and conservation and aquatic ecosystem biodiversity. We would also like to thank all those who played an important role in internal and external communications. All of these efforts led to the success of this international workshop, which we expect will translate into a long term collaboration experience among agencies and a path toward achieving sustainable and healthy ecosystems.

Research in Management Areas

Fish and seafood market

2. INTRODUCTION

The continuous reduction in catches since the end of the nineties suggests that degradation of fisheries is a global problem (Pauly, & Zeller, 2017), evidencing that fisheries resource management has not proved to be entirely successful. Scientists have gained an understanding of the dynamics of exploited populations and their management, and also witnessed failures in the capacity of prediction models (Melvin et al., 2016). This has led to concerns over aspects that may impact the conservation, biodiversity and degradation of ecosystems, and therefore, management strategies to ensure the sustainable development of fisheries. The vast impact of fisheries activities causes visible changes in resource abundance, with implications in stock parameters, such as mortality and growth rates beyond the population of interest by impacting other organisms that form part of the trophic network in a waterfall effect (Walters, & Martell, 2004).

Trophic interactions play an important role in regulating stock dynamics and may alter the composition of communities in ecosystems (Bax, 1998). To this regard, it is noted that trophic interactions improve the assessment and comprehension of ecosystem dynamics, measuring the net effects of relationships between groups of species (Chávez et al., 2003; Cury et al., 2005). Thus, the identification of the structure and functioning of the ecosystem can help improve the inference about the possible impacts on other species. Other stress factors, such as climate variability and climate change play a role in controlling stock size, their shifts (Chávez et al., 2003; Cury et al., 2005, Yáñez et al., 2018) and available habitat (Silva et al., 2016; Swartzman et al., 2008).

Among the explanations related to the limitation of prediction models is the fact that stocks are considered isolated from their surroundings and fishing as the main driving force2. Ecosystem based fisheries management suggests researching stock dynamics bearing in mind environmental, ecological and socio-economic factors, including interactions.

In Chile, the General Law on Fisheries and Aquaculture created in 2013 sets forth the “ecosystem and precautionary approach to resource management”. This approach considers a more integrative approach to aquatic resource assessments, which involves renewing the way research is conducted in order to be transdisciplinary. The idea is to encourage work to be developed toward this direction, which implies establishing medium and long term research programs. At present, a wide array of fisheries and harvesting systems are developed (mainly salmon and shellfish). Resources are permanently assessed from the sustainable management point of view, although this is rarely achieved, despite the high economic profits, which do not consider ecosystem service costs. Thus, research is aimed at estimating how much resources are available and certain biological characteristics in order to adopt management measures. The approaches are monospecific, considering that the stocks are mainly affected by anthropogenic actions, without taking into account how these actions impact the ecosystem or how the ecosystem impacts exploitation. Climate events known as El Niño and La Niña, for example, influence resource distribution and abundance, but only represent a scale of enironmental variability. Inter-decadal changes and climate change would have more significant effects on marine ecosystems; in addition to the effects caused by pollution, loss of diversity, increase of demand and changes in price markets, among others. As a result, the need to estimate the load capacity of ecosystems in which present and future harvest systems are developed, is imperative; as well escapements of harvested species on ecological communities, which also bear the cost of such impact.

Using an ecosystem approach to aquatic resources research and management is therefore highly relevant, even if it has not received the attenton it deserves. The promotion of inderdisciplinary research and extending the scope of models, (bioeconomic, multispecific and ecosystem) considering environmental interactions, among species and technological, in addition to socioeconomic and institutional aspects, among others, is required. Managers of aquatic resources recognize these needs, but there is still great uncertainty as to how to put in practice an efficient ecosystem based management method. In order to face this challenge we must think about a systemic approximation, or rather about ecosystem modeling and simulation. We need to focus on the medium term and, particularly, in functional data collection protocols to achieve a better and more appropriate approximation to our ecosystems. This involves making changes to existing assessment approaches.

It is worth noting that, in many cases, monospecific models continue to be used as the basis for fisheries management. Nevertheless, fisheries research cannot continue to be simply limited to monospecific management, separately from environmental variability, other species and the actions of humans. Thus, systemic research becomes inevitable, and to this end, it is necessary to: a) describe the habitat and spatio-temporal variability of biotic and abiotic aspects; b) study the interactions between the various biotic components (species, predators, prey, competitors); c) understand the response of resources before environmental variability, natural and anthropic pressures; and d) take into account socioeconomic constraints.

Multispecific spatial modeling requires a coupling between environmental variability, populations spatial dynamics (latitude, longitude, depth) and the exploitation in all its dimensions (from fishing to the consumer). The latter illustrates the path to follow before truly understand the functioning and evolution of stocks and their ecosystems. Nevertheless, this comprehension is indispensable to foresee the consequences of environmental phenomena and the anthropic impacts on stocks and their ecosystems. These are dynamic units and to understand them well it is necessary to observe them in the three mentioned dimensions, also including the time factor. In order to progress in the understanding of natural systems, direct observations of organisms-environment, prey-predator-competitors relationships, among others, are needed. Equipments improve, methods evolve, and the simultaneous research of the various components is an important step toward achieving a better understanding of marine ecosystems.

In this context, it is suggested to integrate the various components of the system, but there is no clarity as to how to go about this, what to measure, what geographic limits, and which trophic levels should be considered, among others. This is the reason why cooperation is key and it is believed that two approaches prevail in this regard. The first seeks the involvement of all actors in a space that allows them to share their knowledge and bring together different interests, hold practical discussions that are useful for management purposes and directed towards achieving a common goal. The second highlights training and especially, previous experience in ecosystem modeling. In this context, international cooperation would allow for the exchage of knowledge, sharing skils and procedures, facilitating the acquisition of new knowledge related to systems in which this approach has already been applied. A path to apply successful efforts in similar systems shall need to be defined (or transfer), involving better management to ensure resource sustainability, as well as the capacity to adapt to extreme scenarios, such as climate change.

The aim of the international workshop was to gather national and international scientists to share experiences and knowledge about the ecosystem approach to fisheries and aquaculture systems, and by this, take a closer look at this integrating approach, understand its components and identify gaps and progress through applications that are presently operational. The workshop took place remotely from 1-3 December, with the participation of national and international scientists and authorities in charge of research and management of aquatic resources. In that opportunity, five modules were developed, each comprised by four or five presentations, followed by a questions and answers session. It is noted that the last two days (4 and 5), international guests of recognized trajectories and an expert from FAO (Module 1) held discussions related to the main subject of the workshop. The presentations provided different perspectives on the regulatory framework, the present status of the ecosystem approach, the progress made in aquaculture, approximations to resource-habitat and applications in fisheries. The agenda and summaries of each presentation and each module, and final observations are presented below.

References

Bax, N. (1998). The Significance and Prediction of Predation in Marine Fisheries. *ICES Journal of Marine Science*, 55(6), 997-1030. https://doi.org/10.1006/jmsc.1998.0350

Chávez, F., Ryan, J., Lluch-Cota, S., & Ñiquen, M. (2003). Climate: from anchovies to sardines and back: Multidecadal change in the Pacific Ocean. *Science,* 299(5604), 217–21. https://doi.org/10.1126/science.1075880

Cury, P.M., Shannon, L.J., Roux, J-P., Daskalov, G.M., Jarre, A., Moloney, C.L., & Pauly, D. (2005). Trophodynamic indicators for an ecosystem approach to fisheries. *ICES Journal of Marine Science*, 62(3), 430-442. https://doi.org/10.1016/j.icesjms.2004.12.006

Melvin, G., Gerlotto, F., Lang, C., & Trillo, P. (2016). Fishing vessels as scientific platforms: an introduction. *Fisheries Res*, 178, 1-3. https://doi.org/10.1016/j.fishres.2016.02.022

Pauly, D., & Zeller, D. (2017). Comments on FAOs State of World Fisheries and Aquaculture (SOFIA 2016). *Marine Policy*, 77, 176-81. https://doi.org/10.1016/j.marpol.2017.01.006.

Silva, C., Andrade, I., Yáñez, E., Hormazabal, S., Barbieri, M.A., Aranis, A., & Böhm, G. (2016). Predicting habitat suitability and geographic distribution of anchovy (Engraulis ringens) due to climate change in the coastal areas off Chile. *Progress in Oceanography*, 146,159-174. https://doi.org/10.1016/j.pocean.2016.06.006

Swartzman, G., Bertrand, A., Gutiérrez, M., Bertrand, S., & Vasquez, L. (2008). The relationship of anchovy and sardine to water masses in the Peruvian Humboldt Current System from 1983 to 2005. *Progress in Oceanography*, 79(2): 228-237. https://doi.org/10.1016/j.pocean.2008.10.021

Walters, C., & Martell, J.D. (Eds.) (2004). *Fisheries Ecology and Management*. Princeton University Press. https://doi.org/10.1007/s11160-005-0057-1

Yáñez, E., Hormazabal, S., Silva, C., Montecinos, A., Barbieri, M.Á., Valdenegro, A., Órdenes, A., & Gómez, F. (2008). Coupling between the environment and the pelagic resources exploited off northern Chile: Ecosystem indicators and a conceptual model. *Latin American Journal of Aquatic Research*, 36(2), 159-181. https://doi.org/10.3856/vol36-issue 2-fulltext-3

Demersal crustacean fishery

3. PRESENTATION SUMMARIES

Landings in Caleta Tubul

A perspective of the challenges of an ecosystem approach to fisheries management

Luis Parot / IFOP Director

Including an Ecosystem Approach to Management (EAM) of fisheries and aquaculture represents a huge challenge for Chile, both for the scientific community and public institutions. Stepping from individual species monitoring oriented research toward comprehensive research —surrounding the array of related species in an ecosystem— is, undoubtebly, a challenge of epic proportions. Nevertheless, the fact that it is a difficult challenge must not cause us to abandon the decision to move forward taking steps that, be they small, take us closer and clear the way toward reaching the goal.

In order to make EAM possible and ensuring useful results, strong collaboration efforts between scientists, fishers, environmentalists and authorities is required, as in the case of all public policies in these times. This strategy will not simply be sustained by the sanctionary principle enforced by the authority, but rather by the collaboration of all stakeholders. Hence the importance of defining EAM as a tool, determining its scope, making it operational and implementing it —even if at a small scale— in order to display the outcomes that capture the support of scientists, NGOs, small-scale and industrial fishers and farming communities.

For now, it seems to be mostly part of an academic effort, although our researchers at IFOP are already working on specific intiatives, the results of which we expect will lead the way toward a change of paradigm: from the protection of a species-resource to the protection of the ecosystem.

As an applied Research Institute in the area of Fisheries and Aquaculture, responsible of providing recommendations to the Government of Chile, IFOP is in the process of modifying its internal structure and developing a culture that encourages collaboration among its researchers, facilitating the exchange of experiences and different perspectives related to resources that share a specific ecosystem.

Even with this collaborative attitude and a clear vision of the road ahead, EAM will continue to be a challenge, although the anthropogenic environmental phenomenam changes and impacts that we witness almost daily could anticipate the need to obtain answers in the short term. Things are happening faster than expected, and the community will demand consistent and efficient answers from the scientific world. IFOP will be at the forefront, exploring alternatives and seeking answers, in addition to actively joining efforts of dialogue and exchange of experiences such as this meeting.

Perspectives on ecosystem-based approaches to fisheries and aquaculture management in Chile

Mauro Urbina / SUBPESCA

Since 2013, the legal framework for fisheries and aquaculture provides for the conservation objective, which involves the sustainable use of aquatic resources and protecting the ecosystem by implementing an ecosystem approach; along with a transparent, responsible and inclusive management. The ecosystem approach promotes sustainable development, human and ecological wellbeing, by means of appropriate governability and governance. At the end of the first decade of the year 2000, a research program was launched together with the Fisheries Development Institute (Instituto de Fomento Pesquero, IFOP), related to gathering scientific knowledge that will allow a shift toward an ecosystem approach to management. Standing legislation includes advising agencies, such as Technical Scientific Committees that state their position in scientific matters, and Management Committees that recommend management plans and address biological, ecological, economic and social aspects, as well as a recovery program aimed at over-exploited and depleted fisheries.

The implementation of an ecosystem approach to fisheries management has progressed in five lines:

1) Biological, establishing long term objectives in fisheries conservation and management, and in the protection of ecosystems. Thus, biological reference points were determined, to take fisheries toward maximum sustained yield (MSY), creating recovery plans for over-exploited or collapsed fisheries.

2) Ecological, implementing the Discard Law, a reduction program and quantifying discarding levels. As a result, since 2020, cameras were installed on board the industrial fishing fleet, and the program shall be exted to the small-scale fleet in 2024. In this context, a By-Catch Release Plan was implemented through IFOP (sharks, chimeras, chondrichtyans, birds, turtles, others). In addition, marine protected areas were declared jointly with the Ministry for the Environment, to ensure the conservation or preservation of specific and delimited areas.

3) Socioeconomic, supporting the productive diversification of small-scale fisheries, promoting human consumption, Marine Coastal Spaces for Native Peoples (ECMPO, its abbreviation in Spanish) and creating the National Institute for the Development of Sustainable Small-Scale Fisheries and Aquaculture (INDESPA, its abbreviation in Spanish).

4) Governability, transparency and participation, by creating 36 Management Committees and developing 18 management plans. As to the legislative agenda, laws such as the Fishing Bays Law, the Algae Harvesting and Repopulation Law were enacted, INDESPA was created, as well as legal regulations on Small-scale Aquaculture in Benthic Resources Management Areas (AMERB) and benthic activities.

5) Research, developing lines such as trophic levels, the role of ecosystems, total removal estimations, determining biological reference points (BRPs) in various fisheries and the use of ecosystem models, a pilot study to implement an ecosystem approach to the southern sardine fishery, among others.

In particular, several aspects related to the implementation of an ecosystem approach to management have been developed, incorporating participation and transparency mechanisms, establishing rules to promote product diversification, increasing scientific knowledge used as a basis to develop management actions and rules to enforce compliance. Nevertheless, socio-economic aspects must be strengthened and specifically included in related domestic legislation.

Interdisciplinary research as a key element of the ecosystem approach to aquaculture

Renato Quiñones / INCAR Director

Domestic aquaculture development faces many gaps and challenges at the production, environmental, economic and social levels. Meeting these challenges requires scientific knowledge generation from a multidimensional approach to reality, incoporating formal, natural and social sciences, in an interdisciplinary manner. Such challenges derive from the basic fact that aquaculture is an activity that is part of highly complex socio-ecological systems. As expressed by FAO, an ecosystem approach to aquaculture (EAA) is a strategy that enables the optimal integration of aquaculture activities, contributing to the sustainable development and resilience of socio-ecological systems. Thus, there is an inseperable link between EAA and inter-disciplinary research. But, what is inter-disciplinary research? Following the definition proposed by the Science Academy of the United States, it is a way of conducting research by a research team or individuals that integrates information, data, techniques, tolos, perspectives, concepts and/or theories of two or more disciplines or bodies of expert knowledge, to move forward toward a basic understanding or resolve problems, the solution of which is beyond the scope of a single discipline or research area. It is clear that sustainability issues related to domestic aquaculture activities are far too complex to be dealt with appropriately by a single scientific discipline, and therefore requires an inter-disciplinary approach to produce the required knowledge. That said, undertaking inter-disciplinary research is no small challenge for any research team, since it is necessary to develop a common language and approach, which requires each member to open their minds to new forms of perceiving and tackling the matter under review.

At the international level, the following gaps in developing inter-disciplinary research have been identified: 1) university structure mainly based on unidisciplinary departments; 2) difficulties related to job placements for inter-disciplinary researchers; 3) limited inter-disciplinary training at undergraduate, postgraduate and posdoctoral levels; 4) communication and epistemological problems between many disciplines; 5) increased effort on behalf of researchers to understand the fundamental views and concepts of other disciplines; 6) difficulty to obtain funding in traditional funding agencies, with a predominating unidisciplinary culture; 7) less availability of high impact scientific journals to publish inter-disciplinary results compared with unidisciplinary journals; 8) difficulty to find researchers who can lead inter-disciplinary efforts; and 9) the need to generate clear and efficient criteria to assess inter-disciplinary research on behalf of government agencies. These internationally recognized gaps certainly apply to our domestic reality.

Finally, it is also crucial that decision makers in processes of governance include an inderdisciplinary perspective in order to implement EAA. To this end, sectoral agencies must diversify their work and assessment teams with professionals with different backgrounds in order to acheive a comprehensive approximation of the natural, social and economic reality. Institutional progress has been made in Chile, both at the sectoral and university levels to strengthen inderdisciplinary approaches, but there is still a long way to go in terms of promoting interdisciplinary research and implementing EAA in the country.

Ecosystem approach to aquaculture management: a global vision.

José Aguilar-Manjarrez / FAO Aquaculture Officer

Over a decade ago, the ecosystem approach to aquaculture (EAA) arose from discussions between the Food and Agriculture Organization of the United Nations (FAO) and international experts in this discipline to progress toward a more sustainable development of this activity. An ecosystem approach to aquaculture consists in “strategy to integrate the activity in the larger ecosystem, such that it promotes sustainable development, equity and the resilience of interlinked socio-ecological systems” (Food and Agriculture Organization of the United Nations [FAO], 2011, p. iv).

The presentation builds on a critical review of the use and integration of the EAA at the global level and its possible evolution in the next decade. It also highlights lessons learned from EAA experiences, opportunities and relationships between EAA and the Sustainable Development Goals in the 2030 Agenda.

The results indicate that there is no standard understanding of what EAA is, what it involves and what it can be used for, and this is mainly because there is a gap between those who use EAA to conceptualize sector development and those who embrace the concept. The lack of consensus on a commonly agreed definition may be due to its name and the different perspectives in which the term “ecosystem” is interpreted.

The following main obstacles for the implementation of an EEA have been identified: 1) difficulty to define administrative limits and those of the ecosystem; 2) lack of autonomy of the countries involved in the adoption of an EAA; and 3) changes in organizational culture. On the other hand, the most relevant limitations faced by governments in the implementation of an EAA are: 1) poor or limited governance and regulations; 2) lack of inter-agency involvement and coordination; 3) lack or limited technical capacity; 4) financial restructions, and 5) the ambiguity of the benefits received by managers and producers. Nevertheless, despite the indicated limitations, EAA has promoted a radical change in the way aquaculture development is understood and planned; increased awareness about the usefulness of comprehensive and participative approaches involved, and has been key to create awareness about the importance of FAO principles of the code of conduct for responsible fishing to guide the sector toward increased sustainability and to strengthen the spatial planning of aquaculture in many government and local institutions.

The emphasis on spatial planning that has been developed as part of the EEA implementation efforts and the close links between EEA and initiatives such as “Blue Growth”, provides significant opportunities for the future of the approach, although its ability to address increasingly complex governance issues may be limited. It is therefore considered timely to reconsider the rationale for the EAA, taking into account ongoing developments within and outside the aquaculture sector.

What is needed in the future is an approach that makes use of the available experience, in addition to existing technical knowledge, to draft and improve guidelines, and create appropriate frameworks for increased development. The EAA must evolve to encompass better and new developments that have an impact on the sector.

References

United Nations Food and Agriculture Organization. (2011). Development of Aquaculture. 4. Ecosystem approach to aquaculture. Series: FAO Technical Guidelines for Responsible Fishing. Edited by the author. https://www.fao.org/documents/card/es/c/62908212-fe4a-5021-96e3-7d156815682d

Macrocystis pyrifera

Progress made in the practical implementation of an ecosystem approach to aquaculture in Chile

Doris Soto / INCAR

An ecosystem approach to aquaculture (EAA) is a strategy to integrate the activity in the larger ecosystem, such that it promotes sustainable development, equity and the resilience of interlinked socio-ecological systems" (FAO, 2010).

The EAA is aimed at three general principles: 1) aquaculture must be developed in the context of ecosystem services and functions (including biodiversity), without degrading them beyond its capacity for resilience; 2) aquaculture should improve human wellbeing and equity for all relevant stakeholders; and 3) aquaculture should be developed appropriately in the context of other sectors, policies and goals.

Some questions that EAA tries de answer include: How much matter/energy enters and exits ecosystems by action of aquaculture? ¿Are the socio-economic benefits greater than the externalities? Are they distributed equally?

The EAA is implemented better at the local level through the development of management plans by areas or geographic zones or specific territories. Nevertheless, this is not possible in Chile. Some key elements, gaps and progress in the practical implementation of EAA in Chile include: 1) a territorial scope in accordance with the ecosystem (beyond the individual farm); 2) load capacity of ecosystems (productive, ecological and social) should determine production by area and volume. Nevertheless, there are clear examples, both in salmon and shellfish farming that indicates that this would not be fulfilled; 3) ecosystem based management plans could facilitate the multitrophic integration of aquaculture (IMTA). Nevertheless, the integration of aquaculture with other uses and users of coastal areas and the marine environment is not possible since present rules "treat" each type of aquaculture and fishing activity as "closed boxes" and does not facilitate multitrophic integration or integration with other uses, for example.

In the case of salmon farming, the impact on the marine environment in the surroundings of farms has been researched and regulated (SEIA, RAMA). Nevertheless, the existence of concessions granted to create management areas is a limitation to tackle most environmental and social issues.

A scientific report containing a set of environmental indicators to estimate, regulate and control negative impacts at the ecosystem level in salmon farming in Chile was delivered in January of 2020. The initiative came from a collaboration between the Interdisciplinary Center for Aquaculture Research (INCAR) and WWF Chile, with contributions from various scientistis and agencies. The aim of this initiative is to ensure that floating salmon farms carry out their activities by respecting the balance as far as nutrient contributions and circulation and other elements, without deteriorating biodiversity, and with regard to the load capacity of ecosystems.

Existing regulations that are focused on what occurs below or around floating pins, only provide part of the information. We need persistent data related to what occurs at the ecosystem level or relevant bodies of water. For example, the above mentioned report offers a preliminary eutriphication risk analysis in various bodies of water, highlighting that in the estuary of Reloncaví Sound and Comau Fiord in the Los Lagos Region, fiords Puyuhuapi, Cupquelan and Quitralco in Aysén show comparatively higher levels and require urgent attention in terms of monitoring, prevention and mitigation. For example, salmon production could be reduced in those environments, and maintained with caution in other bodies of water with better circulation and higher load capacity. While always taking into account the permanent assessment of ecosystem health indicators, which currently does not occur.

When the salmon farming sector is accused of causing a significant impact on the ecosystem, the truth is that sufficient information is not available to enable us to accept or reject this claim. We clearly need persistent, transparent and open monitoring activities that would allow us to perform ongoing status assessments of these ecosystems, in which other activities that may have impacts also coexist. Salmon escapements, to mention one of such activities, require this systemic vision.

The creation of conservation areas is suggested in the Los Lagos Region, particularly in Comau fiord, in order to compare areas with and free from salmon farming, and small-scale fishing activities. Under the present scenario of climate change, there is a need for spaces free from direct human impacts in northern Patagonia in order to separate the effects of climate change and develop better adaptation measures.

In terms of the actual application of an ecosystem approach in salmon farming, we are discussing a strategy that is expected to adequately balance the goals of environmental conservation, equitable economic and social development, with proper governance. This is a tremendous challenge for a more sustainable future of the planet, and aquaculture certainly has a role to play.

Sustainable development in aquaculture: current trends and challenges

Alejandro Buschmann / ULAGOS

Global aquaculture production shows a sustained upward trend; similarly in Chile, there has been an increase in salmon farming production (Atlantic salmon, pacific salmon and trout) and shellfish (mussels, abalone and scallops) and, at a lower rate, macroalgae and microalgae. One of the challenges for sustainable development in salmon farming are the environmental and ecological effects these activities have in the soutermost part of Chile. Research conducted in salmon farms show an important load of inorganic nutrients and organic enrichment below the cages and up to depths of 100 m. Benthic effects predominate in the surrounding areas, as a result of organic growth, sedimentation, oxygen reduction and the contribution of inorganic nutrients. Subsequently, a change in the composition of phytoplankton occurs, with possible algae blooms and a reduction in biological diversity, leading to the spread of diseases and pathogens to farms and the wild population. Another threat is the introduction of new pathogens and invasive species, which alter the trophic chain. Research indicates that a production of 800.000 tons of salmon in Chile produces 22.400 tons of NH4.

A significant impact of the high load of inorganic nutrients is the eutrophication in coastal waters. To mitigate the effect, experimental harvests of Gracilaria have taken place in farms at diferrent production levels. Results indicate that the macroalgae capture nitrogen and reduce the production of toxic microalgae. Subsequently, in order to move forward toward the adoption of an ecosystem approach to management promoting sustainable aquaculture, it is suggested to transition toward a multitrophic integrated aquaculture, leading the way toward bioremediation, where a combination of trophic levels that share an environment and the various organisms (for example, macroalgae, shelfish and crustaceans) can make use of organic and inorganic nutrients. To this end, the regulation system must be modified to increase knowledge regarding the scale of environmental impacts, develop an environmental monitoring program with open access and validated data, design more sustainable and resilient aquaculture production strategies, considering climate/oceanographic uncertainties.

Environmental modeling in Patagonian ecosystems: coastal management tools, with emphasis in aquaculture

Elías Pinilla / IFOP

Environmental management of aquaculture in Patagonian ecosystems, based on determination of risks such as: euthrophicatin, benthic enrichment, chemical demand of oxygen or bacterian changes, continues to be an important challenge for the Government of Chile, bearing in mind that it is necessary to combine, both local environmental effects, as well as those across a wider geographic scale.

Based on an ongoing research program financed by the Government of Chile, the Fisheries Development Institute has developed important capacities in environmental modelling as a way to describe local and large scale proceses in marine ecosystems, specifically physical, chemical and biological componentes. On the other hand, monitoring and forecasting capacities, biotic indexes validation such as AMBI or ITI, together with water column parameters such as: water renovation or disolved oxygen variability, has made it possible to account for various degrees of fragility of the ecosystems of the Patagonia, and are considered essential tools for appropriate aquaculture management.

A significant portion of the information produced in the above mentiond areas is available in the environmental information system CHONOS (chonos.ifop.cl). This is a web platform comprised by a wide array of products based on oceanographic numeric modeling in the fiords of the Chilean Patagonia. The platform offers several applications developed in a flexible environment. CHONOS is an effort to generate free access information of public interest for decision makers and the general public.

In recent years there have been important advances in the production of information and knowledge in the integration of the environment and aquaculture. However, there are still important challenges pending that should be prioritized in the short and medium term, for example: 1) creation of ocean observation systems (physical, chemical and biological) with wide coverage and free access to information; 2) make progress in interdisciplinary research that will contribute to linking environmental aspects to economic and social areas; and 3) advance in environmental regulation with an adaptive approach and precise, updated and operational definitions of carrying capacity in marine ecosystems.

Hydrodynamic modeling and biophysical coupling in fiord systems

Andrés Sepúlveda / UDEC

Fiord systems are complex zones as far as their hydrodynamic and biochemical characteristics. In particular, the fiord system of the northern Chilean Patagonia has been the subject of several numerical modelling studies that may contribute to aquatic resource management using an ecosystem approach. These are complementary with other observational studies regularly performed in this area and efforts to establish long term time series in sampling sites, allowing researchers to assess the contribution of various forcing factors in the observed results.

This numeric contribution shows significant progress, but also important gaps. For example, the use of a last generation numeric model has enabled the hydrodynamic representations of fiords with a grid size of hundreds of meters. This level of detail is necessary to correctly represent the complex geometry and topographic variations of fiords. Nevertheless, the importance of a detailed numerical study of wind forcing has been discussed (Olivares et al., 2015), considering that the rugged topography surrounding the fiords must be correctly represented to understand the surface layer flow that influences the spread of aquatic pathogens such as ISAv.

Traditional regional ocean modelling tools enable the representation of a fiord system at a scale of hundreds of meters. Nevertheless, these tools are not appropriate to represent the effect of artificial structures, such as aquaculture farm cages, that measure around 30 m width and depth, and 300 m length. To assess its influence in the retention time in a fiord, CFD models can be used and included explicitly in the mesh of the model, and also to describe the buffering effect they have in local and nearby circulation (Herrera et al. 2018). This combination of regional models and CFD is a valuable step to understand the influence of artificial structures in fiords and other narrow channels. Recent progress in the implementation of a numeric representation of the ocean has allowed public agencies in Chile to provide daily forecasts of the oceanographic conditions in the fiord areas of northern Patagonia. The CHONOS system developed by the Fisheries Development Institute (IFOP), provides a daily forecast (across three to ten days) to support the understanding of the environment of aquacuture activities. Such system enables the use of such forecasts to estimate the spread of a virus, and, foremost, it is a huge step toward facilitating public access to numeric models, approaching this information source to local decision makers and stakeholders who are concerned about local oceanographic conditions.

Other numerical model applications in fiord systems are underway, such as the estimation of tidal energy variability (Artal et al., 2019), the effect of climate change in fresh water inflow (Aguayo et al., 2019) and the inflow glacial sediments (Marín et al., 2013), and the general vulnerability of the biophysical and socio-economic system to climate change (Soto et al., 2019). IFOP is also using numerical models to understand the biochemical variability in the fiord system through coupling of regional oceanic models (for example, CROCO) and biogeochemical models (such as PISCES), but these are recent and ongoing developments. The main concern with this progress is that the results end up buried in the form of technical reports or scientific publications unless access to their use, handling and interpretation is facilitated. Finding a way to ensure an interaction between the community, decision-makers and scientists with the results of the numerical modelling community is critical. It is also key for this community to grow, in terms of the number of members, and to establish mechanisms to facilitate cooperation and comparison of results.

Harvests of crustaceans and hard bottom biodiversity in fiords of the Patagonia

Giovanni Danneri / CIEP Director

The aim of the Project developed by CIEP and financed by CORFO was to collect fisheries and biological data for rock crab (*Metacarcinus edwards*) during fishing operations in the Region of Aysen. Rock crab is a species of commercial interest with potential to promote a sustainable activity. Nevertheless, until this project there was no clarity about the status of exploitation, nor the reproduction cycle of the species. The initiative, supported by the Under-Secretariat for Fisheries and Aquaculture (Subpesca), suggested a methodology directed toward developing indicators to complement the the Fisheries Development Fund's existing monitoring program.

The Project envisaged direct work with fishers operating on crab in the southern zone of Puerto Aguirre. In this context, four field seasonal campaigns, and four planning and reviews took place. The campaigns covered the fishing zones in Traiguén Island (Las Mentas), Costa Island, Meninea Island, Playas Largas, Vergara Island and Vidal Bay. The main results associated to fishing yields showed that the zones located in the southernmost part (Traiguén Island) of the study area reported a lower fishing yield compared to the fishing areas in the central-northern sector (Vidal Bay, Costa Island sector). Nonetheless, the size structure indicated that the population is in a healthy state across the areas studied. Most traps have escape windows (opening of 8 cm) that allow undersized crabs to escape without causing a negative imipact on commercial catches. The time the traps remain in the water (resting time) from one to more days, did not reduce commercial catches, unless the trap mesh was damaged.

Reproductive indicators, both in males and females, showed values similar to those found in fisheries with low explotation levels. The reproductive cycle in the Aysen Region shows that the copulation takes place in spring, followed by gonadal development of females, which ends at the end of automn and beginning of winter with fertilization and egg laying. This cycle is similar to the findings in Valdivia and Chiloe, demonstrating a lack of latitudinal differences. The morphometric maturity estimated for males was 116 mm and 104 mm in females, showing that the minimum harvesting size (120 mm) corresponded with the size of maturity in the Aysen Region. From this first initiative, the importance of reproductive indicators is highlighted as a proxy of the exploitation state, which should be monitored annually and complemented with environmental, social, economic and ecological data (inter-specific relationships) and thus achieve an ecosystem approach to management.

Tools for an ecosystem approach to management in fisheries and aquaculture: practical cases in Chile

Claudio Silva / Centro IOS

There is a need to connect with the "Blue Growth" strategy to ensure sustainabe oceans, by implementing an ecosystem approach to fisheries and aquaculture, including adaptation to climate change (CC) in national policies, strategies and plans. Among other factors, small-scale aquaculture needs increased visibility (SMA) and marine spatial planning (MSP) needs to be included in operational management schemes. In this context, habitat suitability and spatial modelling of important fishing resources and the impact that CC would have under the different scenarios suggested by the Intergovernmental Panel on Climate Change (IPCC). The results of the model are inputs for the Action Plan and the Adaptation Plan to CC in fisheries and aquaculture. The use of satellite data is shown to create maps of probable fishing zones for pelagic resources, which helps fishers reduce operation times, use of fuel and costs.

On the other hand, an atlas on the effects of CC on small-scale fishing and aquaculture is shown, which is participative in the spatial distribution of productive hierarchies. It is also demonstrated how PEM allows the systematization of decision making in a synoptical way and the spatial suitability modelling work and load capacity for small-scale aquaculture, with the involvement of the communities in the collection of socioecologic variables, considering the available spaces and restrictions. In the case of salmon ocean farming, the way the habitat and operation zone is established is presented, as well as the subsequent selection of the sites to install the pins. Finally, the Environmental Information and Red Ride Service is explained, which envisages the spatial distribution of data bases through a multi-agency and integrated platform.

Perceptions, progress and gaps in the implementation of an ecosystem approach to fisheries management

Stefan Gelcich / PUC - sgelcich@bio.puc.cl

International agreements and guidelines play an important role in reaching the sustainable development goal. They have encouraged countries to move forward toward the implementation of an ecosystem approach (EA) to oceans, which involves the integrated mangement of species, natural services and multiple uses of the coastal zone. But there are many different views: for some, it is a hard to reach utopia, while others consider that progress has been made in the implementation of an EA in domestic fisheries policies, including gap analysis and identification.

In order to continue with the implementation of the EA, multiple challenges must be addressed, such as the institutional framework, the reasons behind the existing situation, the inertia of the application of the monospecific approach in management, capacities, data and integration. Improving EE-based management efforts requires a better understanding of how they are included within marine resource management policies at the national level. A baseline is built to assess the degree of implementation of EA principles nation wide. Actions are analyzed in documents that set the agenda, policy formulation, implementation and evaluation of policies and programs. To this end, government programs, presidential speeches, the state of the environment and international agreements are examined. As to policy responses (laws, decrees, documents and action plan) 1.384 were reviewed and classified on the basis of 12 EA principles of the Biological Diversity Agreement (BDA), considering socioeconomic, sociocultural and biological-ecological aspects. It is separated by pereiods, one from period 1990-2003, in which international agreements played a key role; from then were are gradually included in the national legislation; whereas since 2006, the EA became part of fisheries regulations.

Additionally, fisheries management plans were examined and thus the minutes of the common hake and southern hake Management Committees were reviewed. The results point to key gaps that need to be resolved to ensure effective management, such as creating confidence, especially with regards to decision making, providing human resources, funding and capacities. In order to impement an EA, the representation and involvement of all stakeholders is crucial, as well as co-production and integration of various types of knowledge, from bureaucratic procedures to local and academic. It must be noted that Technical Scientific Committees only deal with the biologial dimension.

The results show that policies at the national level increasingly share common ground with the principles of ecosystem-based management. International agreements are incorporated in regulations, decrees and action plans. Some EA principles, such as impacts on adjacent ecosystems, have been specifically included in regulations. Although significant progress has been made in terms of adopting basic EA principles, a holistic vision integrating all such principles in the creation of public policies is still lacking.

Ecosystem approach in fisheries research and management: Considerations

Eleuterio Yáñez / Professor PUCV

The General Law on Fisheries and Aquaculture sets forth an “ecosystem and precautionary approach to management”. This approach involves transdisciplinary work and envisages medium and long term research programs. Until now, fisheries resources are assessed with a view to manage them on the basis of sustainable activities, which is not immediately evident. The approach used is based on an analysis of monospecific fisheries that considers the assumption that stocks are mainly impacted by fishing activities, but does not explicitly include other variables, such as ENSO events, interdecadal changes and climate change, which will also have impacts on marine ecosystems; this in addition to the consequences of increased demand and prices.

It is therefore necessary to promote extending the scope of the models, taking into account environmental, interspecific and technological interactions, without setting aside socioeconomic and governance interactions. To take up this challenge, we must think about ecosystem modeling and simulation, which is obviously complex. It is necessary to improve the knowledge of ecosystems and for this purpose we must: 1) research resource habitats and the spatio-temporal variability of biotic and abiotic aspects; 2) study the interactions between the different biotic components (species, predators, prey, competitors, etc.); 3) understand the functioning of resources in the face of environmental variability and anthropogenic constraints; 4) take into account socioeconomic constraints; and 5) establish forecasting and projection models, assuming different climate change scenarios.

The above illustrates the path that needs to be followed before actually gaining a good understanding of the functioning and evolution of stocks and ecosystems. However, this understanding is fundamental in order to predict the consequences of environmental phenomena and anthropogenic impacts on a population. Several research groups are currently in the process of building ecosystem models. It should be noted that these models do not yet integrate all the main components, characteristics and interrelationships of exploited ecosystems.

Progress toward an ecosystem approach to highly migratory fisheries resources: perspectives and future directions

Patricia Zarate / IFOP

Highly migratory fisheries resources have an extensive spatial distribution in Chile and harvest activities mainly take place from Arica to Lebú. The target species are: swordfish (*Xiphias gladius*), pelagic sharks such as the blue shark (*Prionace glauca*), mako shark (*Isurus oxyrinchus*), porbeagle shark (*Lamna nasus*) and dolphinfish (*Coryphaena hippurus*). Small-scale fishing operations are seasonal and use purseine and harpoon fishing methods, and the longline industrial fleet operated in the area up to the year 2018. To progress toward an ecosystem approach, biological, fishery and ecological data is collected by scientific observers on board and at landing sites of target species, associated fauna and bycatch species (reptiles, birds and marine mammals).

At the beginning, the fishery was monospecific and targetted swordfish and pelagic sharks in the northern area. Since the eighties, with the opening of new markets, harpoon fishing methods were replaced with purseine and longline fishing, and the fishing grounds were extended with the use of satellite information. A continuous effort to record by-catch began in 2001, in addition to research related to the trophic level of the ecosystem; whereas satellite monitoring, genetic and habitat studies of target species began in 2010.

In recent years, progress has been made in the application of ecosystem models, integrating biological, satellite, environmental and fisheries information. An analysis of trophic and trophodynamic levels has also been carried out, revealing the health of the ecosystem, which is highly relevant since if the abundance of key species decreases, this may trigger a cascade effect on top predators, such as swordfish.

Progress in terms of gaining knowledge using an ecosystemic approach can contribute to adopting management actions, such as protection zones or periods for pregnant female sharks. Chilean legislation prohibits the capture of reptiles, birds and marine mammals; they must be returned to the sea and the law mandates mitigation measures in the event that they are caught incidentally. Thus, the results and knowledge achieved are allowing us to move towards using an ecosystemic approach to management and the establishment of management measures that will allow a sustainable fishery over time, safeguarding ecosystem health.

Ecosystem modeling of anchovy fishery between Atacama Coquimbo

Carlos Montenegro / IFOP

With respect to the results of ecosystem modeling of the ecological system associated to the anchovy fishery between the Regions of Atacama and Coquimbo, there is a need to make paradigm changes, involving ontological change, where the object of study is no longer the fisheries, but rather every component, both ecological and sociological. This new paradigm implies an epistemological change, which is developed through transdisciplinary research on the basis of a set of social, political, economic and environmental disciplines. Two approaches were used in the case study that is presented: qualitative modelling of socioecological systems through loop analysis and quantitative modelling using Ecopath with Ecosim (EwE).

The first approach considered 26 components, both from the ecological dimension (wind conditions, primary producers, herbivores, primary consumers, secondary consumers, top predators and detritivores), and from the socioeconomic dimension (internal and external demand, sales prices, jobs, profits, among others). It is evident that the system is marginally stable, which is due to the complexity emerging from the structure of interactions, mainly because of the high presence of omnivores in the system. The EwE modeling considered 16 components of the ecological dimension. The model made it possible to make projections for different exploitation strategies and determine the impacts on the different functional groups included in the model.

Ecosystem approach to the southern sardine fishery in inland waters of the Los Lagos Region

Sergio Neira / UDEC

Sprattus fuegensis is a fish that sustains the small pelagics fishery in the inland sea in southern Chile and plays a key ecological role as prey for hoki (*Macruronus magellanicus*), southern hake (*Merluccius australis*), kinglcip (*Genypterus blacodes*), marine birds and mammals. In this presentation we show the results of alternative exploitation results of S. fuegensis in a monospecific and multispecific context, as part of FIPA 2017-64 Project "Implementation of the ecosystem approach to the southern sardine fishery in inland Waters of the Los Lagos Region", funded by the Fisheries and Aquaculture Fund of Chile.

First, we reproduced the official stock asessment of *S. fuegensis*, using an estimation model and developed a operating model to assess the monospecific management procedure. The operating model showed a good adjustment to CPUE, the acoustic biomass and size composition. The variables also showed the same trends as the estimation model and both models showed the same population status.

The present management strategy (F60 % with a 20 % risk) gave way to a sustainable exploitation of *S. fuegensis* (probability of collapse=0; probability of recovery=0.4) and the biomass of kingclip and southern hake did not show a decrease below the limit set at 20 %. Nevertheless, poor recruitment scenarios increased the probability of collapse and the response to declining predators reached close to 20 %.

Subsequently, we built a food web model representing the study area using Ecopath software with Ecosim. The model encompassed 16 functional groups, from primary producers to top predators and fisheries, and was fitted to a time series of relative abundance of major groups using fishing mortality, vulnerability to predation, and environmental forcing factors. We projected the model forward in time to assess the impacts of various management strategies (e.g., F60 %) on the dynamics of *S. fuegensis*, its predators, and the broader ecosystem. Results indicated that the current management strategy allowed sustainable exploitation of *S. fuegensis* without compromising predators and the broader ecosystem.

These results indicate that the fisheries and ecological data related to *S. fuegensis* and its ecosystem enables the development of a modeling framework that combines monospecific and multispecific models to assess sustainable exploitation strategies in the context of the ecosystem. This framework can be easily adapted and applied to other pelagic and demersal fisheries in Chile, and represents an important step in the effort to comply with the ecosystem approach to fisheries, as mandated by the Chilean Law on Fisheries and Aquaculture.

Modeling tools applied to the understanding of jack mackerel (*Trachurus murphyi*) spatial structure in the southeastern Pacific

Sebastián Vásquez / INPESCA

Jack Mackerel (*Trachurus murphyi*, Nichols) is a pelagic species distributed in the South Pacific from the costas of Ecuador, Peru and Chile, reaching up to New Zealand and Tasmania. The vast distribution of this species in the region and its highly migratory behaviour hinders the collection of tests that support specific hypothesis about its spatial dynamics and stock structure. Also, due to its straddling nature, Jack mackerel is harvested by various fletes that operate in different areas across its global distribution, which constitutes a huge challenge to monitor its spatial structure. Modeling tools that incorporate the structure and functioning of the marine ecosystem, together with data from the various stages of its life cycle are useful tools to examine the spatial distribution with relation to habitat changes to understand the population structure in the Southern Pacific. This presentation shows modeling studies aimed at 1) describing the extension of the spawning habitat of Jack mackerel in the southeast Pacific; 2) understand the early life cycle of jack mackerel, with emphasis on transportation of eggs and larvae, and 3) predict the presence of adult juveniles from the fishing data of every fleet operating on the species.

Habitat-based models were used to determine that spawning is a key process for Jack mackarel population mixing. The potential spawning area is extensive and associated with the subtropical front, with a higher density off central-southern Chile and lower densities in the coastal sector of northern Chile and Peru. The occupation of the potential spawning area would be related to the size of the population, and becomes increasingly irregular during periods of low biomass. Regional research undertaken in the southeastern Pacific are suggested as an alternative to validate these results. This is a key aspect of understanding population structure, as a large and connected spawning area promotes genetic mixing and movement of individuals between different regions of their global distribution area.

To examine larvae dispersion and connectivity through transportation of the first development stages, biophysical coupling models that include the development of regional ocean circulation models were used (ROMS) coupled with marine species early vital history simulation tools (Ichthyop).

This modeling approach has shown that dispersal of jack mackerel eggs and larvae can promote transport from oceanic waters to the coastal region, where most spawning occurs. The latter could explain the differences in spatial age distribution observed for jack mackerel larvae in the oceanic area versus the central-southern zone of Chile. On the other hand, our results suggest that all potential jack mackerel spawning areas are connected to the main nursery area, located in the coast of northern Chile and southern Peru, through larval transport. Therefore, the transport of early life stages suggests an important stock mixing mechanism that should be considered in the definitions of the spatial population structure of jack mackerel in the southeastern Pacific

Finally, the implementation of species distribution models is presented (SDM), applied to Jack mackerel to identify its essential habitat in the southeastern pacific and predict the response of the species to environmental variability. En general, the information to build marine SDMs can be obtained from two main sources: independent data from catches and dependent data from catches. In this case, the implementation of a baysian hierarchical model is presented (using R-INLA package), with information from all fleets involved in the Jack mackerel harvests: Peru, northern Chile, central-southern Chile and the distant internacional fleet. SDMS indicated that temperature and biomass of phytoplankton (that is, chlorophyll) are critical factors that modulate the extension of Jack mackerel habitat. High temperatures and low biomass of phytoplankton limits its presence. The species is mainly distributed in oxygenated water, although it has the potential to enter regions with shallow minimum oxygen zones.

The greatest proportion of jack mackerel habitat occurs off central-southern Chile, extending towards the oceanic zone. A certain degree of spatial segregation in jack mackerel habitat is observed during the summer, with a certain discontinuity between ~18°S and 22°S. In spring there is a spatial continuity of habitat between Ecuador and the oceanic zone off south-central Chile. Finally, El Niño events promote important changes in jack mackerel habitat, affecting its spatial structure. There is a decrease in favorable habitats on the northern edge of distribution (coast of Ecuador and Peru) that promotes southward movements. In addition, there is a decrease in northward oceanic circulation, which impacts connectivity mediated by the transport of eggs and larvae.

Indicators and models in fisheries resource using an ecosystem approach to management in the northern ecosystem of the Humboldt Current

Jorge Tam / IMARPE, Perú

The ecosystem approach to fisheries (EAF) avoids the limitations of the monospecific approach to fisheries by including multispecific relationships, environmental impacts and the human dimension, elements that are needed to deal with the complexity of any socioecological system. At the global scale, there are few cases in which an EAF has been included successfully in management regulations. The EAF is a ongoing process in the northern ecosystem of the Humboldt current (ECNH). Once the goals and operational objectives are set, an important step in the implementation of an EAF is to develop appropriate indicators and reference points. The long term data base and high frequency comprehensive monitoring implemented by the Oceans Institute of Peru (IMARPE) provide the opportunity to develop a holistic system of indicators that includes processes such as: upwelling of forcings, El Niño conditions, inter-seasonal scenarios, habitat, fertility, phytopankton and zooplankton communities, nekton, population dynamics of the main fisheries resources, fleet performance and predators. With the increasing impacts of climate change, it is also necessary to include extreme climate phenomena (that is, marine heat waves, anoxic/hypoxia phenomena and toxic algal blooms).

The complexity of multispecific relationships requires the use of ecosystem models to assess the status, trends and scenarios of the ecosystem at different spatio-temporal scales (intra-seasonal, interanual and interdecadal). Several physical, biochemical and ecosystem models are under implementation in the ECHN (for example, WRF, ROMS-PISCES, CROCO, Ecopath with Ecosim, OSMOSE) to address the impact of different processes (such as winds, oxygen minimum zone, Kelvin waves, El Niño and Southern Oscillation, regime shifts and climate change) and anthropogenic activities (e.g., fishing strategies and aquaculture) facing Peru. Climate change could exacerbate these processes and activities, thus a participatory ecosystem modeling is required to co-design simulations, forcings and scenarios with local actors in the socio-ecological system to assess future turning points and optimal adaptation measures. Strong intra and inter-institutional collaboration will be a key requirement for the implementation of a transdisciplinary EAF in the NHCE.

MODULE 5

The ecosystem approach from various perspectives: lessons learned and factors that contribute to success

Making ecosystem based management operational: EwE's contribution?

Villy Christensen / UBC, Canada

Ecosystem based management (EBM) is goal for many countries around the world, progress has been made and it is clear that ecosystem modeling is an important component as we move towards EBM. The path leading to EBM has a number of steps, from ecosystem-based approaches to fisheries management (EBFM) to ecosystem-based fisheries management (EBFM). Ecosystem modeling can and is contributing at all these levels. This presentation reviewed how the most widely used ecosystem modeling approach, Ecopath with Ecosim (EwE), is being used at the various levels towards ecosystem-based management. EwE includes ecosystem (especially depredation) and environmental factors (such as temperature and red tide) in stock assessments. Many Fisheries Management Councils in the United States are now using EwE to assess and establish reference points for management. The interactions between menhaden and striped bass in the Gulf of Mexico.

At the EBFM level, the United States has taken active measures to implement fisheries resource management through the National Marine Fisheries Service, including the definition of a framework for implementation and integration of ecosystem models. In the European Union, the Common Fisheries Policy has implemented multispecies MSY and landing obligations. The consequences of such policies have been extensively evaluated with EwE ecosystem modeling. An example of landing obligations is that the policy results in higher biomasses when a quota system is implemented, but lower profitability for the industry due to "choke species" which result in fishing vessels having to cease operations. Therefore, landing obligations requires the development of a more selective fishing operations in order to be successful.

EBM involves various sectors that use marine ecosystems, which include not only fisheries, but to name a few, mineral and renewable energies, oil platforms and shipping. Therefore, a fundamental question for EBM is how to assess trade-offs between different sectors, and this is an area where EwE is increasingly being applied. An interesting example is related to marine zoning, where marine spatial planning (mspchallenge.info) provides a learn-and-play approach, involving stakeholders, integrating geographic, marine and marine data with EwE modeling, shipping and energy production.

An important aspect of EBM is to monitor the status of the ecosystem at a high multisectoral level. The EU has solved this through the Marine Strategy Framework Directive that mandates all country members the task to develop, maintain and report on the "good environmental status" of the region's marine waters. The EU addresses this through reports, where EwE is an essential part used to quantify the majority of the descriptors used (6 to 11), a method that is used for all of the oceans in the EU.

In general, where there is a general commitment to develop EAFM, EBFM and EBM, the progress has been slow, but there are clear and continuos improvements.

Ecosystem models, a blurry future versus a precise failure?. An example case for a Vulnerable Marine Ecosystem.

Javier Porobic / CSIRO, Australia

As in many other countries, Chile uses a monospecific approach as a basis for management and assessment of its marine resources. Although this involves the use of sophisticated models to support fisheries management, it does not consider other crucial elements of the ecosystem and the fisheries themselves, such as competition, prey-predator relationships and technical interactions between fishing fleets. Therefore, management decisions are based on a limited understanding of the ecosystem dynamics and the real impact (or commutative effect) of various human activities.

Currently, many ecosystem models are available that help understand the different components of the ecosystem and its dynamics. These models can be powerful tools to work in synergy with other monospecific models, as strategic support tools during the decision making process or for the purposes of logistics planning. To illustrate the power of using an ecosystem model, we used the Atlantis model (end-to-end) to understand the effects of fishing in the vulnerable marine ecosystem (VME) of the Juan Fernández ridge.

This VME, situated off the coast of central Chile, has unique biological and oceanographic features, characterized by small and discrete geographic units, a high degree of endemism and connectivity. Two fleets have historically operated in the region: a long-established coastal and small-scale fishery associated with the islands, targeting mainly lobster; and a demersal finfish fishery operating in the seamounts (currently considered overexploited). Recently, there has been growing interest in increasing the exploitation of fisheries, and to upgrade the fishing fleet operating in the JFRE. Under this scenario, the increased levels of fishing exploitation and the high level of interspecific interactions, it would be necessary to understand the impact of these fisheries.

The Atlantis model has a high degree of capability to represent the trends and fluctuations observed in the JFRE. The model shows that industrial fishing operations have a localized impact, while small-scale fishing has a relatively low impact on the ecosystem, mainly through the lobster fishery. It also indicates that the depletion of larger-sized lobsters has caused an increase of sea urchins. Although this increase is not sufficient to cause significant impacts on other groups for now, precaution is recommended in case the additional pressure takes the ecosystem toward a regime shift.

This ecosystem model developed for the JFRE provides valuable information on the effects of different fisheries and how this activity impacts ecosystem dynamics. The results provide data on the state of the ecosystem that other monospecific models did not provide. They highlight differential footprints, which act as an early warning of potential system change, and provide evidence-based support for those actively concerned with system management.

These models are powerful instruments to support strategic evidence-based decisions, since they provide useful information when a high quality monospecific model continues to be the dominant tactical tool (anual cycle) for decision making. In order to move forward toward an ecosystem based management, Chile will undoubtebly need to diversity its tool box to include those that are able to assess ecosystems and its dynamics, and not only the status of a single species. Focusing on a single component of the ecosystem can provide an incomplete, and sometimes misleading view of its health.

Advancing ecosystem based management in small-scale fisheries through a multi-species approach, case studies from Latin America.

Kendra Karr / EDF, USA

Many global fisheries harvest multiple species or stocks as targetted or untargetted catch. The use of fishing gear to capture multiple species with different productivity creates the risk of serial depletion of stocks with less productivity, altering the interactions between entire species and ecosystems. Although many monospecific fisheries are becoming more sustainable due to science- and rights-based management strategies, multispecies fisheries often face greater sustainability challenges, which will increase with climate change. Multispecies fisheries can involve commercial, small-scale and recreational sectors; large, medium and small, and can include subsistence fisheries that extend to multiple landing points. This complexity hinders monitoring and assessment to establish science-based adaptive management for resilient multispecies fisheries, putting at risk the food security and nutrition, jobs, benefits, livelihoods and culture of coastal communities.

There is great interest in the world to develop fisheries management options that balance social, economic and ecological objectives of multispecific fisheries. This presentation shows a science based strategy that intends to balance the needs of these types of fisheries with limited data, that are being developed to be resilient to climate change and to reach both social-ecological and fisheries management objectives. In Chile, as in all marine systems in the world, people who live and fish on the Juan Fernández and Desventuradas Islands will feel the impacts of climate change. This is why the community is being proactive and starting to plan around known impacts and those potentionally unknown in our changing world. This collaboration work has already led to the creation of the first multispecific management plan adapted to Chile´s climate, motivated by the community aimed at the many other fisheries on which these islands depend on for their livelihood and tourism, as well as for bait for the lobster fishery, famous both at national and international levels.

Initial work for the climate-adaptive multispecies fisheries management plan has begun, including identification of all species that need to be managed, in particular, finfish that are important for maintaining the community's economy, as bait for the lobster trap fishery and the resilience of this unique and biodiverse ecosystem. Stakeholders are fully commited to the use of the Framework Integrated Stock and Habitat Evaluation, FISHE (fishe.edf.org) to guide the collaboration process in the development of a fisheries management plan based on the ecosystem. The FISHE is a step-by-step designed based framework incorporating expert knowledge from the community, government scientists and other related stakeholders that allow to move forward across each of the eleven steps of the FISHE process, that envisages establishing objectives, ecosystem assessment, development of a fisheries management plan based on science, and the implementation and adaptation of the fisheries management plan. The climate-resilient multi-species fisheries management plan for the Juan Fernández and Desventuradas islands has complex ecological, economic and social management objectives, all of which are part of the pathway to enabling resilience of people, ecosystems and fisheries.

In order to create local resilient management systems that through collaboration can ensure the health of fish populations, the prosperity of fishing communities and the reislience of ecosystems, Chile is on its way toward a more sustainable future. The pathways toward preparing for climate in multi-species fisheries (resilientseas.org) in the archipelago will be adapted to meet the recommendations of fisheries science and management tools appropriate for the area. The community's goal is to develop sustainable fisheries and a healthy ecosystem, as the lives of islanders are defined by the health of the marine ecosystem that supports local fisheries, which are critical to livelihoods, cultural identity and food supply. The ecosystem-based fisheries management objectives of the Juan Fernandez and Desventuradas community can also serve to inform other fishing communities around the globe about sustainability and ecosystem-based management, especially in light of climate change.

Ecosystem modeling to improve fisheries management in the Gulf of Mexico.

David Chagaris / UF, USA

In the Gulf of Mexico, fisheries management measures have been traditonally based on stock assessment results. While the single species approach has worked well to rebuild over-exploited populations, it has fallen short of considerations on the ecosystem. Ecosystem models are another tool that can be used to integrate data from multiple species, improve monospecific stock assessments and directly advise management measures. Recommendations provided by ecosystem models can be qualitative and strategic, for example, when to increase precautions or whether to adjust stock assessment parameters, or help identify key drivers of population change. They can also provide tactical and quantitative advice, examining recommended harvest policies in the context of environmental change, analyzing policy options in terms of their impact on other species, or developing multi-specific reference points.

This presentation describes how ecosystem models are used to approach two important issued in the Gulf of Mexico, red tides and forage fish management. This work was supported by the NOAA Restore Science program and its aim is to integrate information related to predator-prey interactions and ecosystem stress factors in fisheries assessment and management. To obtain inputs from managers and scientists in charge of stock assessments, an analysis workshop was held at the beginning of the Project to identify and prioritize the matters that would benefit from an ecosystem modeling approach. Based on the information, we adapted and updated two existing ecosystem models in the Gulf of Mexico. The first, a model of the entire gulf used to identify the tradeoffs in foraging fish management reveals how the ecosystem (defined by a set of ecological indicatos) can respond to changes in menhaden fisheries mortality and establish new reference points for species management. The second is a platform west of Florida used to quantify the impacts of red tides in valuable fish reefs that are subsequently used as feedback for the stock assessment, providing contemporary and timely assessments of ongoing upwelling mortality.

We recognize that ecosystem based fisheries management (EBFM) is probably decades away. Nevertheless, the adoption of EBFM strategies is not a pre-requisite for useful and informative ecosystem models. One approach in the Gulf of Mexico has been the use of ecosystem models to approach discrete questions surrounding the ecology and management of important species. With this approach, ecosystem models can be applied considering standing single species management and assessment frameworks. Prioritization of the question(s) and definition of the ecosystem performance criteria on which management decisions are based should be done with input from scientists, managers and fisheries stakeholders.

Benthic resources fishing operation

4. FINAL COMMENTS

In Chile, since 2013, the legal fisheries and aquaculture framework has provided for conservation goals, involving the sustainable use of hydrobiological resources and the care of the ecosystem, together with the implementation of the ecosystem and precautionary appraoches; in addition to transparent, responsible and inclusive management. The ecosystem approach promotes sustainable development, human and ecological wellbeing, through adequate governance and governance. At the end of the first decade of 2000, the Undersecretariat of Fisheries and Aquaculture and the Fisheries Development Fund jointly initiated research programs on the scientific knowledge needed to move towards management with an ecosystem approach. In parallel, important Chilean research centers and universities have made important contributions to advance research aimed at understanding the integral dynamics of the social-ecological systems associated with fisheries and aquaculture activities.

The ecosystem approach requires enormous effort and cooperation among scientists, fishers, environmentalists and authorities, and shall not be simply sustained on the santionary principal of the authority, but rather on the collaboration of all stakeholders. On its part, IFOP, responsible for providing advise to the Government of Chile, is in the process of modifying its internal structure to develope a culture inclined to encourage the collaboration among its researchers, facilitating the integration of experiences and different perspectives on the resources that share a specific ecosystem.

The implementation of an ecosystem approach to management in the country has progressed in various lines; for example, by implementing the Law on Discards, its quantification and reduction. As a result, since 2020, cameras were fitted on board the industrial fleet and the same is expected for the small-scale fleet in 2024. A by-catch release plan was also developed (sharks, chimeras, chondrichthyans, birds, turtles, others); marine protected areas were declared to ensure the conservation of specific and delimited areas; productive diversification of small-scale fisheries was supported; human consumption was promoted; Marine Coastal Spaces for Native People were proclaimed; the National Institute for the Sustainable Development of Small-Scale Fisheries and Aquaculture was created; among others.

In practice, various actions oriented towards the implementation of an ecosystem approach to management have been developed, including participation and transparent mechanisms, establishing rules that favor productive diversification, extending scientific knowledge used as a basis for management measures and setting rules to enforce its compliance. However, the incorporation of aspects of the associated human dimension, such as social and economic variables, must be strengthened. Although there are several initiatives on the integrative approach, including research groups that have developed studies on interspecific relations and the effect of environmental variability, there is still a long way to go to achieve management based on ecosystemic considerations. For this reason, it is important to consider more advanced programs in this area, such as NOAAs Restore Science Program with applications in Mexico (Dr. Chagaris in this report), and various Ecopath with Ecosim applications (EwE) (Prof. Christensen in this report), of which the most notable are ecosystem monitoring at a multisectoral level, and the use of environmental status indicators in the European Union. Also worth mentioning are the advances in ecosystem-based management in small-scale fisheries through a multi-species approach (Dr. Karr in this report) and the implementation of indicators and models in the management of fishery resources with an ecosystem approach in the northern Humboldt Current ecosystem (Dr. Karr in this report) and the implementation of indicators and models in ecosystem approach to fisheries resource management in the northern ecosystem of the Humboldt Current (Dr. Tam in this report).

Other initiatives in Chile are related to the creation of participation efforts that favor governance, such as Technical-Scientific Committees, Management Committees, Zonal Councils and the Fisheries and Aquaculture Councils. Currently, projects related to the “Implementation of the Ecosystem Approach in the Southern Sardine Fishery” (Dr.

Neira in this report), the Ecosystem Modeling of the Anchovy Fishery between Atacama and Coquimbo (Dr. Montenegro in this report) and the implementation of the Atlantis model in the Juan Fernández Ecosystem (Dr. Porobic in this report) are underway. In addition, the second stage of the GEF-UNDP Humboldt project “Towards an Ecosystem-Based Management of the Large Marine Ecosystem of the Humboldt Current” was launched in collaboration with Peru. Progress has also been made in analyzing the impacts and projections of fisheries and aquaculture in relation to climate change.

Presently, projects related to the “Implementation of the Ecosystem Approach in the Southern Sardine Fishery” (Dr. Neira in this report), Ecosystem Modeling the Anchovy Fishery between Atacama and Coquimbo (Dr. Montenegro in this report) and the implementation of the Atlantis model in the Juan Fernández Ecosystem (Dr. Porobic in this report). Also, in collaboration with Peru, the second stage of the GEF-PNUD Humboldt Project “Toward an Ecosystem Approach to Management of the Humboldt Current Great Marine Ecosystem” was launched. Progress has also been made in the analysis of the impacts and projections of fisheries and aquaculture with relation to climate change (Yáñez et al., 2018).

However, it is clear that these initiatives require the formation of an interdisciplinary group to analyze the situation and suggest a way to move forward quickly on this issue. Meanwhile, the academic community needs to establish a medium and long-term scientific strategy to improve its capacity to provide the appropriate skills to implement ecosystem-based management of aquatic resources. For its part, the institutional framework should specify the definition of an ecosystem approach to management in the General Law on Fisheries and Aquaculture, and how to promote it, as well as define a fisheries policy that pursues clear objectives.

In particular, the Fisheries and Aquaculture Research Fund (FIPA) must be managed by duly selected experts and move on to funding medium to long term research,

considering all exploited species and not only a few target species. With respect to the basic research program for a comprehensive advice in fisheries and aquaculture (ASIPA), that envisages the ongoing execution of projects through IFOP, should define a strategy and structure that enables reviewing available scientific information, generating information as inputs for ecosystem models, proposing potential indicators of ecosystem status and a consolidated database that accounts for changes in regime, biomass and distribution of species that are expected to have an impact on ecosystem structure. Finally, actively contribute to the scientific community by updating information on national and international public websites and databases on species related biological and ecological aspects.

Aquaculture in Chile faces gaps and challenges at the productive, environmental, economic and social levels. Bridging these gaps and challenges also requires the generation of scientific knowledge with a multidimensional perspective of reality. These challenges lie in the fact that

Yáñez, E., Lagos, N., Norambuena, R., Silva, C., Letelier, J., Muck, K.-P., San Martin, G., Benítez, S., Broitman, B., Contreras, H., Duarte, C., Gelcich, S., Labra, F., Lardies, M., Manríquez, P., Quijón, P., Ramajo, L., González, E., Molina, R., Gómez, A. … & Böhm G. (2018). Impacts of climate change on marine fisheries and aquaculture in Chile. En B. Phillips & M. Pérez (Eds.). Impacts of Climate Change on Fisheries and Aquaculture. Volume 1 (pp. 239-332). Wiley.

aquaculture is part of highly complex socio-ecological systems, as in the case of fisheries. As stated by FAO, the ecosystem approach to aquaculture (EAA) is the strategy that allows optimal integration of aquaculture activities into the ecosystem, favoring the sustainable development and resilience of social-ecological systems; thus, there is an indissoluble link between EAA and interdisciplinary research.

Aquacuture is not a separate matter, and therefore, shares strong similarity with fisheries when it comes to an ecosystem approach. Inderdisciplinary research is key to move forward in the comprehension of these systems and solve issues that go beyond a sigle discipline or research area. To implement the EAA it is essential to ensure that decision-makers in governance processes have an interdisciplinary perspective of aquaculture and its challenges. This requires that sectoral institutions diversify their work and analysis teams with professionals from different areas in order to achieve a comprehensive approach to the natural, social and economic reality.

The most relevant limitations faced by governments in the implementations of the EAA are: 1) bad or limited governance and regulation, and the lack of integration and inter-agency coordination; 2) the lack or limited technical capacity, in addition to financial restrictions; and c) the ambiguity of the benefits received by managers and producers.

The emphasis on spatial planning that has been developed as part of the EAA implementation efforts and the close links with initiatives such as "Blue Growth" provide significant opportunities for the future, although its ability to address increasingly complex governance issues may be limited. It is therefore considered timely to reconsider the rationale for the EAA, taking into account ongoing developments within and outside the aquaculture sector.

Environmental management of aquaculture in fiord ecosystems is currently based on risk identification. Fiords are complex areas, with high environmental variability, that posess various hydrodynamic and biogeochemical characteristics. In the last decade, several lines of research have been developed in northern Patagonia, such as environmental modeling, the description of local and larger scale processes considering physical, chemical and biological components in the marine ecosystem. Models

have allowed the numerical representation of fiords, with details of the complex topographic geometry. This research is complementary to observational research that develops time series at various sites and sampling points. Studies of ecological dynamics and processes in Chile are scarce and partial.

To shift toward an ecosystem approach to management in aquaculture correctly, there is a need to move forward in researchm technological, productive and institutional innovation, in an independent but complementary mananer. It is necessary to determine how much matter and energy enters and exits the ecosystem on account of aquaculture. It is necessary to find a way to take advantage of the elements that remain in the ecosystem, recover nutrients and move towards integrated multi-trophic harvests to make use of nutrients from various origins. For example, salmon harvests, macroalgae and invertebrates could be integrated. The main idea, which will probably define more than one future action in this area, is to find balances, avoid loosing carbon in bacterial respiration, recover these nutrients and to explore the possibility of developing integrated cultures.

Off-shore salmon harvests and closed harvesting on land require environment impact assessments. Production costs will be higher than the present harvesting method and in both cases, the amount of organic matter generated is going to be the same, with a greater dissemination in the off-shore harvesting environment. Closed harvesting is more efficient in the use of water, but in both methods the various elements will remain in some part of the ecosystem, and scale and scaling problems also occur. Therefore, these problems reinforce the idea of integrated harvests, which are more efficient from an environmental point of view.

In Chile, unlike what occurs at the global level, fisheries continue to be higher in volume than aquaculture, this proves that there is a gap at the country level; an example is the fact that wild capture fishing reached its limit in the eighties, stabilising since then. On the other hand, freshwater aquaculture showed the highest growth on the planet. Nevetheless, while aquaculture of salmonids continues to rise, this activity has also diversified toward the production of mytilidae and algae.

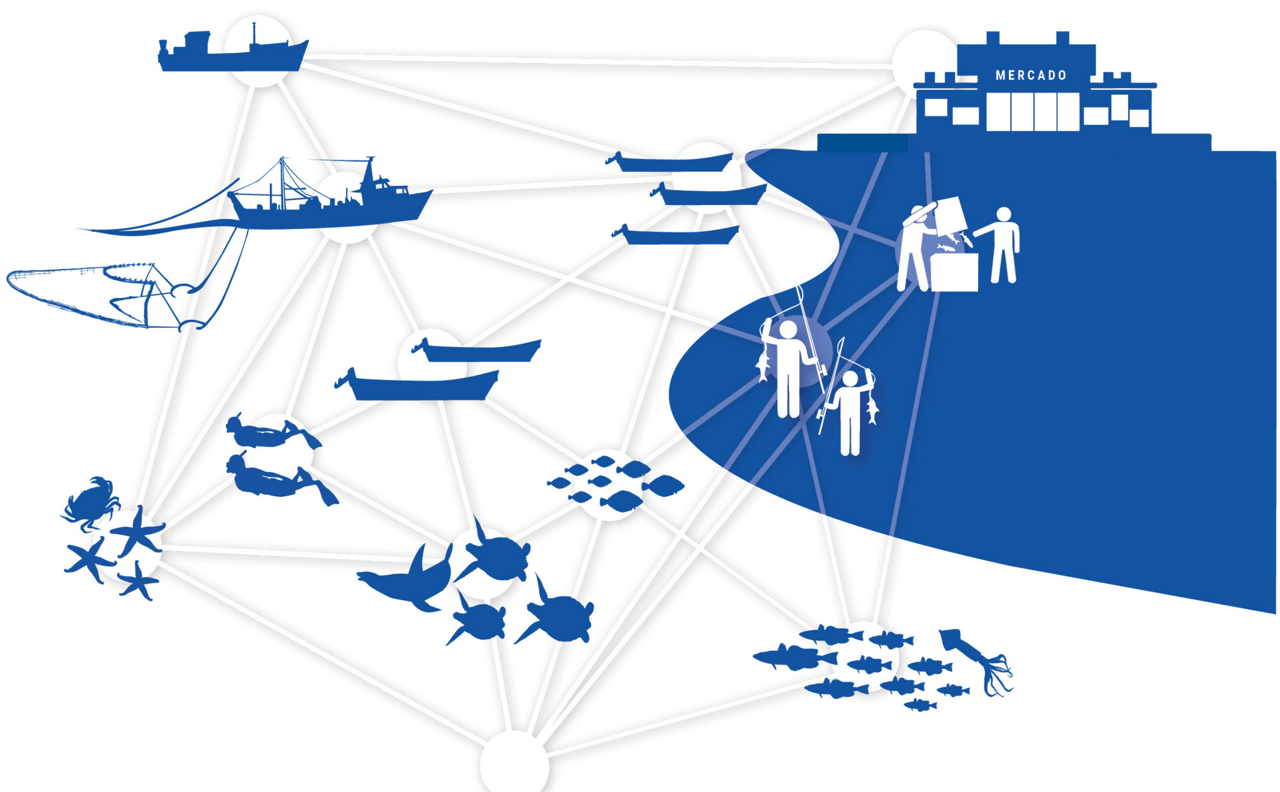
The impact of aquaculutre on fish stocks such as southern hake, sarine or other aquatic species of the channels and fiords ecosystem of southern Chile is unknown. There is a low level of knowledge about the impact of species responses to changes in the ecosystem. One of the fundamental challenges is to effectively recover ecosystems impacted by aquaculture. It is true that research has increased in recent years, new teams, institutes and centers of excellence have been created. However, although research has been strengthened, in order to obtain scientific progress it is very important to have the freedom to choose research topics. It is also necessary to strengthen multi- and transdisciplinary research work. Questions always arise in science, but decisions must be made with the best available information. It is therefore necessary to separate decision making and science, because they do not always go hand in hand.

In order to implement ecosystem based management other anthropogenic activities must also be considered, such as agriculture, mining, water discharges, as well as environmental variability and climate change scenarios that could impact the resilience of ecosystems. Also bearing in mind the coastal zone and the marine environmental, integrating the various users and many impacts that go beyond the limits of aquaculture farms. The way spaces, aquatic species and the environment are used must also be modified. It was also stressed that the dichotomy between the social and ecological realms is not aceptable, since we are all part of the same ecosystem. As a result, we need to apply an approach that will allow us to asume the costs of occupying nature's resources, pinpoint the externalities of aquaculture and not wipe out aquatic species populations. This is in addition to building a different relationship between the environment and society, and consider that a new constitution could offer an opportunity for change.

Finally, institutional frameworks play an important role in articulating the actors and components of the system. Different positions have been expressed regarding the type of framework required. During a first stage, at least one secondary legislation for inland ocean waters is suggested to be created in coordination between the Ministry for the Environment, the Under-secretariat for Fisheries and Aquaculture and the Coastline Commission; at present they seem to be independent units.

The existence of elements to move forward towards an ecosystem approach to aquaculture management has been shown, as the existence of significant progress in collecting knowledge during the last decades and that science must be considered in aquaculture and fisheries management. The ecological, social, productive and regulatory gaps need to be determined in order to progress in decision making and achieving sustainable fisheries and aquaculture across time.

Likewise, the existence of human interventions that cause impacts in different levels of the ecosystem has been recognized. Therefore, information and research is required to determine the negative effects of such interventions, establish and implement public policies that will sustain aquaculture production and reduce the impacts by dealing with the environmental issues and developing the technology that can assist in their mitigation.



ANNEX: SUMMARY OF MODULES

Summary Module 1
Dr. Carlos Montenegro

The legal framework for fisheries and aquaculture in Chile provides for conservation goals since 2013, which involves the sustainable use of aquatic resources and the protection of the ecosystem using an ecosystem approach; in addition to transparent, responsible and incluse management. Thus the importance of the ecosystem approach (EA) that promotes sustainable development, human and ecological wellbeing, through appropriate governability and governance.

At the end of the first decade of the year 2000, as a result of joint actions between the Undersecretariat for Fisheries and Aquaculture (SSPA) and Instituto de Fomento Pesquero (IFOP), research programs related to scientific knowledge were launched in Chile to move forward towards an ecosystem approach to management. Important research centers, including research teams from the main Chilean Universities, have made important contributions to advance towards research aimed at understanding the dynamics of the social-ecological systems associated with fishing and aquaculture activities.

In order to make EAM possible and ensuring useful results, strong collaboration efforts between scientists, fishers, environmentalists and authorities is required, as in the case of all public policies in these times. This strategy will not simply be sustained by the sanctionary principle enforced by the authority, but rather by the collaboration of all stakeholders. As an applied Research Institute in the area of Fisheries and Aquaculture, responsible of providing recommendations to the Government of Chile, IFOP is in the process of modifying its internal structure and developing a culture that encourages collaboration among its researchers, facilitating the exchange of experiences and different perspectives related to resources that share a specific ecosystem.

In this context, the implementation of an ecosystem approach to management in the country has progressed in various lines; for example, by implementing the Law on Discards, its quantification and reduction. As a result, since 2020, cameras were fitted on board the industrial fleet and the same is expected for the small-scale fleet in 2024. A by-catch release plan was also developed (sharks, chimeras, chondrichthyans, birds, turtles, others); marine protected areas were declared to ensure the conservation of specific and delimited areas; productive diversification of small-scale fisheries was supported; human consumption was promoted; Marine Coastal Spaces for Native People (ECMPO) and the National Institute for the Sustainable Development of Small-Scale Fisheries and Aquaculture were created (INDESPA).

In practice, various actions have been taken to implement an ecosystem approach to management, including mechanisms to enhance participation and transparency, setting rules that benefit productive diversification, expanding the scientific knowledge on which management measures are based and establishing standards for monitoring compliance. However, the incorporation of aspects of the human dimension of the social-ecological systems associated with fishing and aquaculture activities, such as social and economic variables, must be strengthened.

With respect to aquaculture in Chile, the sector faces gaps and challenges at the productive, environmental, economic and social levels. Bridging these gaps and challenges also requires building scientific knowledge with a multidimensional perspective of reality. The challenges faced in aquaculture lies in the fact that the activity is part of highly complex socio-ecological systems, as in the case of fisheries. As stated by FAO, the ecosystem approach to aquaculture (EAA) is the strategy that allows optimal integration of aquaculture activities into the ecosystem, favoring the sustainable development and resilience of social-ecological systems; thus, there is an indissoluble link between EAA and interdisciplinary research, which is a way of conducting research by a team of researchers or individuals, that integrates information, data, techniques, tools, approaches, concepts and/or theories from two or more disciplinkes or bodies of expert knowledge to progress in basic understand or solve problems, the solution of which goes beyond the reach of a single discipline or research area.

At the international level, the following gaps in developing inter-disciplinary research have been identified: 1) university structure mainly based on unidisciplinary departments; 2) difficulties related to job placements for inter-disciplinary researchers; 3) limited inter-disciplinary training at undergraduate, postgraduate and posdoctoral levels; 4) communication and epistemological problems between many disciplines; 5) increased effort on behalf of the researcher to understand the fundamental views and concepts of other disciplines; 6) difficulty to obtain funding in traditional funding agencies, whith a predominating unidisciplinary culture; 7) less availability of high impact scientific journals to publish inter-disciplinary results compared with unidisciplinary journals; 8) difficulty to find researchers who can lead inter-disciplinary efforts; and 9) the need to generate clear and efficient criteria to assess inter-disciplinary research on behalf of government agencies. These internationally recognized gaps certainly apply to our domestic reality.

Finally, it is also crucial that decision makers in processes of governance include an inderdisciplinary perspective in order to implement EAA. To this end, sectoral agencies must diversify their work and assessment teams with professionals with different backgrounds in order to acheive a comprehensive approximation of the natural, social and economic reality.

On the other hand, a critical examination of the use and integration of EAA at the global level and its eventual evolution during the following decade reveal the lack of a standard understanding of the definition of EAA, what it involves and what it can be used for, mainly as a result of a detachment between those who use EAA to conceptualize sector development and those who adopt the concept. The absence of a common definition of EAA may be due to its name and the different perspectives in which the term ecosystem is interpreted. The main limitations in the implementation of EAA are identified as the difficulty to establish administrative and ecosystem limits; the lack of autonomy of the countries invoved in the adoption of EAA, and changes in organizational culture.

Also, the most relevant limitations faced by governments in the implementation of EAA are: poor or limited governance and regulation; lack of inter-agency integration and coordination; lack of or limited technical capacity; financial constraints; and ambiguity of the benefits obtained by managers and producers.

The emphasis on spatial planning that has been developed as part of the EEA implementation efforts and the close links between EEA and initiatives such as “Blue Growth”, provides significant opportunities for the future of the approach, although its ability to address increasingly complex governance issues may be limited. It is therefore considered timely to reconsider the rationale for the EEA, taking into account ongoing developments within and outside the aquaculture sector.

Summary Module 2
Dr. María Ángela Barbieri

Aquaculture of salmon and mytilidae species has grown steadily in the southernmost region of Chile. Farming intervenes the ecosystem by incorporating organic matter that may cause impacts on the water quality, habitat modification, organic enrichment, eutrofication, among others. In order to preserve and protect the functions and services of ecosystems, including its biodiversity and resilience, the country is moving towards sustainable farming using an ecosystem approach to management, ensuring the ecological and human wellbeing and equity among stakeholders.

Presently, environmental management of aquaculture in fiord ecosystems are based on risk identification. Fiords are complex areas, with high environmental variability, that posess various hydrodynamic and biogeochemical characteristics. In the last decade, several lines of research have been developed in northern Patagonia, such as environmental modeling, the description of local and larger scale processes considering physical, chemical and biological components in the marine ecosystem. Models have allowed the numerical representation of fiords detailing the complex topographic geometry. This research is complementary to observational research that develops time series at various sites and sampling points.

The need to move forward towards addressing ecosystems in a holistic manner, conducting research on its dynamics and ecological processes; these are currently scarce and partial. In order to take specific steps towards implementing an ecosystem approach to management in aquaculture, progress should be made in research, technological innovation, production and institutions, independently but complementarily. The idea is to determine how much matter and energy enters the ecosystem and how much energy is lost due to the action of aquaculture, in order to find a way to take advantage of what remains in the ecosystem, recover nutrients and move towards integrated multi-trophic harvests to make use of nutrients from different origins. For example, farming of salmon, macroalgae and invertebrates could be integrated.

Nutrients are energy and it is necessary to find a way to take advantage of them, so that they are not lost, but rather used to produce more energy. In the future, we must find the balances and avoid loosing carbon in bacterial respiration, recover those nutrients and explore the possibility of developing integrated harvests.

An environment impact assessment is required in the case of off-shore salmon harvesting and closed harvesting on land. Production costs will be higher than the present harvesting method and in both cases, the amount of organic matter generated is going to be the same, with a greater dissemination in the off-shore harvesting environment. Closed harvesting is more efficient in the use of water, but in both methods the various elements will remain in some part of the ecosystem, and scale and scaling problems also occur. Therefore, these problems reinforce the idea of integrated harvests, which are more efficient from an environmental point of view.

The impact of aquaculture on fisheries resources such as southern hake, sardine and other aquatic species of the ecosystem is unknown. There is scarce knowledge on the ipact of species response to changes in the ecosystem.

As to the anthropogenic perspective in aquatic resource management, the need to change the approach is raised, as the manner in which spaces, aquatic species and the environment are used. It was also stressed that the dichotomy between the social and ecological realms is not aceptable, since we are all part of the same ecosystem. As a result, we need to apply an approach that will allow us to asume the costs of occupying nature's resources, pinpoint the externalities of aquaculture and not wipe out aquatic species populations. This is in addition to building a different relationship between the environment and society, and consider that a new Constitution could offer an opportunity for change.

One of the fundamental challenges is to effectively recover ecosystems impacted by aquaculture. Recently, research has increased, new teams, institutes and centers of excellence have been created, but in order to advance in science it is very important to have the freedom to choose research topics. It is also necessary to strengthen multi- and transdisciplinary research work. Questions always arise in science, but decisions must be made with the best available information. Therefore, decision-making and science must be separated, because they do not always go hand in hand.

To implement an ecosystem approach to management, an institutional frameworks that deals with the impacts on the coastal and oceanographic ecosystem is required. It is important to consider that we are not only dealing with aquaculture and fisheries, but also with other anthropogenic activities, such as agricultura, mining, water discharges, as well as integrating environmental variability and climate change. In addition to a perspective of the coastline and the marine environment, integrating the various and impacts that go beyond the limits of aquaculture sites. In this regard, different positions on the type of institutional framework are proposed. For the time being, it is proposed that in a first stage at least a secondary legislation on inland waters should be created in a coordinated manner by the Ministry for the Environment, Undersecretariat for Fisheries and the Coastal Border Commission, which currently appear to be independent units.

Human interventions that cause impacts in different levels of the ecosystem have been recognized. Therefore, information and research is crucial to determine the negative effects of such interventions, establish and implement public policies that will sustain aquaculture production and reduce the impacts by dealing with the environmental issues and developing the technology that can assist in their mitigation.

The existence of elements that contribute to move forward towards an ecosystem approach to aquaculture management has been shown, as the significant progress made in collecting knowledge during the last decades. The fact that science must be considered in aquaculture and fisheries management was also stressed. Finally, the ecological, social, productive and regulatory gaps need to be determined in order to progress in decision making and achieving sustainable fisheries and aquaculture across time.

Summary Module 2 b

M. Sc. Mauricio Gálvez & Dr. Claudia Andrade

There are pesently certain gaps between the development of science and public policies. From the perspective of impementing an ecosystem approach to aquaculture (EAA), it is possible to extrapolate the following questions: How much organic matter enters and exits the ecosystems? Are socioeconomic benefits higher than externalities? Are they being distributed fairly? In this regard, an EAA is locally implemented in a more efficient manner thorugh management plans. Thus, three main pillars need to be examined: 1) a territorial scope that is in line with the ecosystems is needed. It still has not been implemented from regulatory or research perspectives; 2) the load capacity of ecosystems is the aspecto that must determine the guidelines for production by area and volume; and 3) management plans base don EAA must be capable of encouraging integrated multitrophic aquaculture (IMTA), to combine inputs of feed with extraction, an aspect that is unlikely to take place in Chile.

In general, concessions as management areas do not allow most environmental and social problemas related to the activity to be dealt with since the effects of salmon farming on the marine environment have been studied in the farm environment and therefore relevant scientific questions remain unsolved, such as the destination of nutrients. In this context, fiords accumulate organic matters and nutrients on the bottom floor and not on the margins. Nevertheless, they do not disappear and could accumulate, posing challenges and problems that need to be researched. Therefore, it is necessary to define the limits of the water bodies, address the carrying capacity of the ecosystems, and solve the problems associated with the fact that the aquatic ecosystem does not have an infinite capacity to process inputs.

The proposal of a research collaboration with WWF, entitled “Proposal of ecosystem indicators for the environmental performance of chilean salmon farming during its grow-out phase”, raises three perspectives that must be considered: identification of relevant water bodies; the use of indiators at the ecosystem level; and a risk appromation to estimate if the load capacity of ecosystems is being exceded. The conclusion here, from the pressure analysis —focusing the Los Lagos and Aysen regions as salmon farming study cases—, based on the calculation of indexes to identify relevant water bodies, is that management plans are required, beyond the health status, but the response is negative when considering if they are possible under the current Chilean legislation.

The same applies to mytilidae farming, the use of an ecosystem approach is absent, seeds are increasingly collected, and over 60 % originate from the Reloncaví estuary and the Hualaihue area alone. Therefore, a management plan is needed for the seed collection areas, beyond individuals sites, in addition to assessing the status of Banks, identify external forcings and climate variability (CV) and climate change (CC), to improve the seed collection eficiency and consider their demand and price.

The above leads to the question: is the implementation of fisheries-aquaculture management areas to streamline the collection of seeds, minimizing environmental impacts, increasing resilience and social benefits in line with the current regulations? This aspect is still in doubt. Thus, it is concluded that out-grow and trade of mussels urgently requires an ecosystem management, since the expected growth is much less than the observed growth, and it is therefore necessary to exmine the shared use of food, at the phytoplankton and seston levels, regulating the productive load by area on this basis.

Considering the above questions, the empirical results of scientific research and the challenges posed, EAA management areas should facilitate the implementation of an IMTA, increasing productivity and minimizing environmental impact, as it is possible that there are subsidies between mytilidae and salmonid farming, since mussels are able to reduce the level of nutrients in a bay, suggesting a potential for an integrated management plan. However, the main challenge to implement a management plan with EAA lies in meeting the following objectives: optimizing mussel and salmon production (this means zero use of chemicals in salmonids) to implement an IMTA; along with achieving economic improvement and growth based on equity, also considering the territorial and social dimensions.

From the perspective of an IMTA, an ecosystem approach is an aspect that has faded away in Chile, following an opposite course in our development. It is thus recognized that the most relevant aspecto that needs to be identified in a farming system is the mass balance. In each harvest, generally no more than 20-25 % of N (nitrogen), P (phosphorus) and C (carbon) are removed. About 75 % of the feed input persists in some form in the marine environment, and although phosphorus reaches the bottom, nitrogen as excretion passes into the water column as inorganic nitrogen, also considering the effects of biological pollution, fish escapements, antibiotics and other compound inputs, as well as pathogenic organisms.

In view of the above, Weiztman classification and other collaborators was discussed to determine environmental effects, which can be described as near-field (within the first 10 m) and far-field (> 100 m). Near-field effects include benthic effects; water quality and habitat modification, while far-field effects include the dissemination of pathogens and diseases; introduction of invasive species; alteration of trophic levels and inclusión of solid waste. Nonetheless, contrary to this classification, the effects of inorganic nitrogen production are rather far from the farm, if the mass conservation law is included. Thus, not all residues from fish production would be constituted by feaces and solid organic matter, but would also include breathing and CO2, as well as excretion.

Thus, a mass balance that considers a production of 800.000 tons of salmonids in Chile would mean inputs into the ecosystem where fish are produced with this level of biomass and the corresponding levels of organic carbon, ammonium, phosphate, total nitrogen loads, etc. In other words, this would account for 22,400 tons from 800,000 tons of salmonids and 1,700 tons of ammonium from 5,000 tons of salmonids. These 800,000 tons are equivalent to a production 10 times greater than what the dumping of salmon in Chiloé would have meant, which is of particular relevance.

Algae of the gracilaria genus that are harvested close to floating pins are one example, with a production of 400 tons of salmon in more remote sites. In those areas this algae shows a significant decrease in growth rates, the closest algae grow faster and have more inorganic nitrogen in their tissue. Disolved nitrogen measurements alone cannot be used to state that salmonids would be incorporating it, but the algae capture it and represent a continuous sensor of nitrogen that enters the system. After 15 years, these experiments have been repeated, but on an adjacent site in a shopping center, where the increases in productivity of algae were reiterated near the pins, even at a distance of 1 km from the farm, with increase of nitrogen in tissue.

These nitrogen enrichments can also be associated to coastal eutrophication processes by means of SIA (Stable Isotope Analysis) in spring, when there is higher growth, and elevated nitrogen isotopic values, revealing the relationship with the presence of mytilidae and salmon harvests. IMTA was suggested to bioremediate this situation, where in addition to the removal of 25% of nutrients by salmon production, the extraction by filtering and sedimentivorous bivalve organisms is also involved. However, a persistent problem is related to sizing to determine whether these extractive organisms are significantly decreasing nutrient loads, thus evidence from experiments conducted in countries with high production levels should be considered.

According to a study presented in this module that details the types of farming impacts at the spatial level, there is evidence indicating the such impacts reach beyond the farming site, that is, they exceed the local level reaching regional scales. Therefore, it concludes that it is crucial to modify the regulation system to increase the scales that represent environmental impacts; develop en environmental monitoring program beyondd the free access site with validated data; and improve research capacities to produce models that will help manage these sites, including possible modifications associated to climate change or other future environmental influences.

The Fisheries Development Institute presented a conceptual framework of a research related to environmental modeling of patagonic ecosystems. In general, aquaculture is interacting in an environment with special characteristics in the southern part of Chile, essentially due to its currents, oxygen levels and the load of nutrients that enter the system. This causes near-field and far-field effects beyond the farm, leading to research opportunities at different scales.

The regional scale (northern Patagonia) is implemented for the purposes of this study, and although aquaculture is the focus, large part of the research is related to the natural system in the aquaculture environment. There is also an interaction at different scales, where the ocean modualtes these proceses, which is why the bathimetric structure is important in fiords. To understand this, numerical modelin is needed coupled with monitoring networks from various programs, such as Aquaculture Environmental Monitoring, Red Tides and oceanographic studies. Various models are available: hydrodynamic, atmospheric, hydrological, and those than can couple biology and chemistry taking into account water and sediments.

The research conducted by IFOP has mainy focused on transport and circulation of particles associated to pathogens in aquaculture. Nevertheless, the idea that circulation and patterns of water movement structures is relevant for a wide array of contexts within and outside aquaculture has extended. Thus, this modeling is important for several aspects related to aquaculture. Dynamic models could therefore allow for future scenarios, and coupling chemistry and biology to understand the behavior of the marine system at the larger scale. The concept of water retention that has been applied indicates how slow the circulation is in a location, in ecological terms it can indicate the fragility of a site. For example, in Aysen, the fiords have slower movements than in the Los Lagos Region.

The need to integrate biogeochemical processes (e.g., the interaction of nutrients with phytoplankton and dissolved oxygen in the ecosystem) is satisfied from a broader spatial analysis using ROMS-Hydrodynamic. The more simple model NPZD to the more complex which is PISCES, with an intermediate model called FENNEL. Using these models allows us to understand what is happening from the ocean to the outer part of the fiords. At the same time, there are simpler models such as the ones related to dissolved oxygen.

The model that incorporates hypoxia indexes compared to climatology is quite consistent: it manages to detect sites with lower oxygen concentrations. Puyuhuapi fiord is almost permanently hypoxic, while Quitralco fiord has shown severe hypoxia levels (low oxygen), in an anomalous manner in the deepest zone, very close to 0. Oxygen has dropped gradually since 2016.

At the local scale or near-field, biochemical models are implemented based on organic enrichment that reveal how aquaculture can disturb marine sediments by means of organic matter discharge. The processes that intervene to increase carbon are also examined (food and feaces), and this research approach makes it possible to relate the measured parameters in monitoring or biotic indexes such as AMBI or ITI, with a depositing rate from the model. The experience in Compu fiord to test the model showed very energetic sites and other slower sites, with a higher accumulation toward the head of the fiord, which indicates a coincidence with reality.

In general, near-field modeling is very expensive, since it requires a large amount of input to increase resolution. Nevertheless, this framework is very useful to perform specific experiments. Likewise, it was possible to estimate the dispersion zone of organic matter, and in this manner in Compu fiord, the dispersion distance or area of influence of deposited organic matter was determined. The differences between farms have been explained on the basis of depth, which results in deposits in near-field zones and a greater associated fragility. These models have been validated in INFA reports related to aerobic and anaerobic zones.

Inputs, approaches and advances that can be implemented in ecosystem-based management policies are presented. With this in mind, a key study was conducted with relation to the ISA crisis, on the ways to understand dispersion, showing that numerical models can be the answer.

High resolution modeling in Aysen sound is presented, where the wind dispersion obtained was very different, and what it impacted depended on the type of wind and the time of year measurements were taken. Management areas must be based on this understanding of hydrodynamics. Another work by Pablo Cornejo highlights another progress recognized in aquatic systems modeling, where regional models that approach the coast with more detail were coupled, implementing models used in engineering (aeronautics) that are not availabe in oceanography, adopting an interdisciplinary approach. Using CFD model it is possible to identify circulation and ocean residence lengths with or without pins, even outside the fiord.

On the other hand, the work developed by IFOP through the CHONOS platform (chonos.ifop.cl/) facilitates public access to information, and having these models available makes it possible to develop, for example, studies on renewable energies, as well as to identify where and when dispersion velocities that may affect farms may be greater.

Where are the gaps? The effect of climate change is one of the weak points of the models, it is therefore necessary to understand and correctly represent river input variations through discharge. On the other hand, glacier input should also be studied, especially with relation to sediment coverage. It is also important to monitor, river nutrient inputs from a biogeochemical perspective to take better advantage of using the PISCES model, as well as glacier input and its relationship with sediment coverage, and the creation of vulnerability indicators.

Finally, it is necessary to enhance the understanding of physical and biological interactions to transform the Chonos-PartiMOSA model (particle release to study residence time) into a model based on individuals, in such a way that particles act as a larva of a certain species, for which the larval life cycle of a target species must also be known.

In summary, imprtant progress has been made in modeling, but challenges remain, such as the scarce use of wide array of models, which should be publicly available to the scientific community and other users, such we do today with CHONOS. The number of modelers must also increase, in order to compare, strengthen and integrate the models that are developed, where the most likely shortcoming will be to incorporate the contribution of floating pins as specific sources of nutrients to the environment.

The significance of fiord and channel ecosystems in the southernmost part of Chile is highlighted, harbouring biodiversity, endemism, nursery habitats and large productivity at the water column level. That said, there are many threats to these ecosystems, particularly at the CC level, and anthropogenic activities. With respect to fisheries, eleven benthic species are the most relevant, especially shellfish and crustaceans. Thus, the idea to grasp an understanding of what occurs in the benthos when two of the eleven species are captured in this region, kingcrab and rock crab, noting that there is a weakness in the country in terms of the number of experts in benthic biodiversity, with the exception of the work conducted by Vreni Haüssermann and Eduardo Quiroga.

The threats in this zone are particularly represented by CC; reduction of freshwater contribution; modification of the water columna structure; acidification and its effect on calcifying benthic organisms during their early stages; intensive aquaculture in terms of the organic matter released on the bottom; discharges of compounds, and even transit of vessels and its influence on large cetaceans. Similarly, fisheries also constitute an important threat, from the lack of monitoring and researchers in the field present in the region, as well as the net effects of the fishery, direct (catches and discards) and indirect (on the structure of the biological community). Fishers also use other species as bait in their pins (for example, bivalves as bait in the kingcrab fishery). Another related issue is related to abandoned fishing gear that increase ghost fishing with accumulative effects, and habitat degradation as a result of the use of fixed gear. Finally, there is an impact on the scenic value of the environment.

Two types of bottom-up and top-down impacts are described on target species and benthic communities, since these species are both prey and predators. Evolutionary impacts are also trigerred since the strongest individuals are removed and changes in sizes and periods of sexual maturity are produced; a disturbance both in prey and predator populations, and finally, cascade effects in more than one trophic level. In this context, the ecosystem approach to fisheries (EAF) has emphasis not only on exploited resources, but at the ecosystem level, incorporating ecological interdependencies between species and their relationship with the environment and socioeconomic aspects.

The EAF is difficult to apply, since all existing trophic relationships are unknown. This management should go beyond the traditional measures associated with the estimation of maximum sustainable catches, based on catches and fishing effort. In this way, it becomes evident that a greater effort should be made to consider more elements based on the scarce measures applied to harvesting activities of both species.

The information related to what would occur if crabs and kingcrabs were removed from the ecosystem is still scarce and poorly understood, but the work by Boudreau sheds light on what could happen, and the path to take depends on addressing the approach of this work for the lines of research. In this regard, the existence of reproductive indicators in male crabs can be used to determine how healthy a fishery is, such as the number of viable sperm in the vas deferens, as welll as gonadal-morphometric maturity. It is necessary for the authority to consider these tools for management purposes. Likewise, management measures are recommended for crab management in the Aysen Region; and to prohibit ovigerous female catches and individuals below 120 mm (AC). Fisheries management measures must also address these reproductive indicators, consideering an annual monitoring or assess the status of the population every two years.

In conclusion, small-scale fisheries are socioecological systems than must include co-management (management areas, marine protected areas, etc.) bearing in mind gender equality and the generational renewal of the small-scale fishery. It is necessary to make progress in the implementation of ecosystem approaches to benthic fisheries resources in the fiord and channel zones of southern Chile; establish programs to monitor the broader effect that fisheries have on the resilience of benthic food webs; develop tools for realistic ecosystem management, because it is difficult to describe all interactions and allocate greater resources and critical masses of researchers, considering these costs in the economy associated with the extraction of benthic species.

Summary Module 3

Dr. María Ángela Barbieri

With regard to management tools to move towards and ecosystem approach to fisheries and aquaculture, progress has been made in marine spatial planning in operational management, in spatial modeling of habitat suitability, in the impacts of climate on the distribution and abundance of various species, and a fisheries and environmental information service has been set up to support extractive and aquaculture activities; an atlas has also been prepared on the effects of climate change (CC) on small-scale fisheries and small-scale aquaculture (SSA).

The panel discussed the accessibility of the final users of these services and it was stated that companies generally have their own platforms. Coastal communities can be accessed through the map viewer of the Undersecretariat for Fisheries and Aquaculture (Subpesca), which currently shows the position of the AMERB, ECMPO, AMP and coves, among others. It is proposed that different layers of information (satellite, fishing, aquaculture, productive, environmental) be incorporated and integrated through local models. To this end, conceptual, suitability and forecast models should be developed; the use of integrated models should have a positive impact and could be used in decision-making. It is recognized that several R&D projects have been carried out that generate products such as those mentioned above, but that there are limitations in the transfer of their results to users: a gap that must be overcome. On the other hand, it is shown that this type of research has been scarce in demersal resources, despite the fact that most of them have a pelagic phase in their life history.

The implementation of an open service requires a synergy between the agencies that collect data, those that produce information, those that conduct research and those who take decisions. Progress should be made towards integrated platforms and work in a collaborative and transdisciplinary manner. Funding should come from the fisheries and aquaculture sector, in exchange for the use of ecosystem services. Making ecosystem models operational in fisheries and aquaculture management, incorporating the environment, resources and operations, is a major challenge in Chile today. Fisheries management is of a monospecific type; a fishing quota is set with the aim of taking the resources to maximum sustainable yield, but it is argued that it is more precautionary to take fisheries towards maximum economic yield, with less catch and pressure on the resource, with which even greater socioeconomic profitability can be achieved.

In the swordfish fishery, the biotic, abiotic and recently, socioeconomic component has been included; market pressure was a forcing element to include the latter. In relation to the biotic component, data and information are collected on board fishing vessels and at the ports of landing of the target species, associated species and bycatch (reptiles, birds and mammals). As of 2018, the longline fleet stopped operating in the nursery area; as a result, information is not available to establish the conservation status of the turtle and other species. The shark fishery is associated to the swordfish fishery, but a shark fishery operates in the northern zone; the available information indicates that juvenile specimens and gravid females are harvested. The level of onboard sampling is low; therefore, it is hoped that the use of onboard electronic monitoring cameras will allow more information to be collected. The proposal is to advance in the application of artificial intelligence in analysis and modeling. The Fisheries Management Committee is expected to be created soon and that the importance of good governance will be appreciated.

Funding is a significant limitation; progress has been made in research through networks and collaboration, with the participation of students and thesis students, to conduct specific research, resorting to external funds such as NGOs. Thus, the big challenges to move towards an ecosystem approach to management (EAM) has three specific components: the first are the models, as analyzed above; the second is how a governance process is structured and constituted; and the third is the implementation of how incentives are generated for regulation compliance, understanding legality and illegality. In addition to ensuring collaboration and understanding among the varioius actors. These components have different dimensions and should be solved to transition toward EAM. Currently, progress is being made in understanding the legality and the factors that influence this framework, as well as the complexities and challenges that must be resolved. In order to implement an ecosystem approach to management it is necessary to move from a participatory process to a deliberative process, and in terms of transdiscipline, the different types of knowledge (scientific, local, cultural, bureaucratic) must be incorporated.

In Chile, Scientific Technical Committees (STC) and Management Committees (MC) are advisory organs to the Undersecretariat for Fisheries and Aquaculture that are not mandated to interact with each other. It is expressed that the global trend is to move towards a reduction in the number of committees until only one type of committee is formed. In this regard, it is noted that the National Fisheries Council used to set the global catch quota until 2013, the council has high representation from the industrial and small-scale productive sectors, which exercises strong pressure on the resource. In this context, an environment of distrust was created; then, as of 2013, the MC and SCT were established; the latter is mandated to determine the range of global fishing quotas. In order to shift towards an ecosystem approach to fisheries and aquaculture, we need to overcome the cuture of mistrust between the various actors of the ecosystem and begin to share the different types of knowledge. In any case, some committees have progressed, but it is important to integrate the different types of knowledge in them, encouraging a deliberate participation among actors.

As to including the ecosystem approach in the new Constitution, it is indicated that the subject has not been placed on the political agenda. In this regard, it is important to point out that the underlying issue is “environmental justice”, which has three components: the first is “distributive justice”, for example, fishing quotas, which is a service provided by the ecosystem and is closely related to governance; the second is “justice of representation” of interest groups; and the third is “procedural justice”, which must be conceived as fair and transparent.

It is suggested to move forward toward a socioecological approach, where que ecosystem approach is only one component. With regards to the institutional framework to effectively implement an ecosystem approach to fisheries and aquaculture, a group of experts to put forward a medium and long term proposal is recommended.

Summary Module 4:
Dr. Eleuterio Yáñez

The development framework of the study is identified as the Lenfest International Project and subsequently the conceptual framework, a qualitative and quantitative modeling. The case study considera the anchovy fishery in the central-northern zone (Caldera-Coquimbo), that dispays egg concentrations in bays. The industrial fleet operated in this area until the year 2000 and subsequently the small-scale fleet began to operate up to date.

The change in the object of study leads to the analysis of a socioecological system that requires the joint work among different disciplines (social, political, economic and environmental). Work begins with a few variables, in this case 26 of the social-ecological system, considering qualitative and quantitative models.

The lessons are that a change of paradigm is needed, because the system is complex; a greater amount of data is required; a qualitative model can be considered, even when quantitative data are available; the participation of the different actors of the social-ecological system is required; and the work must be collaborative.

The ecosystem approach seeks a balance between human and ecosystem wellbeing (species and the species with which they interact). How can we achieve this?, considering the ecosystem as a unit that we are exploiting and that we are a part of.

The wide array of species must be taken into account, where forage species are special because of their contribution as controllers, following the ecological concept of the wasp's waist. These species channel energy to higher levels and are susceptible to environmental changes.

The southern sardine fishery that mainly operates in the inland ocean of the Los Lagos Region, the study was based on complementing approaches: monospecific fisheries management; ecosystem approach to fisheries management; ecosystem-based fisheries management approach; and ecosystem-based management. The objective determined following the management plan workshop: achieve a sustainable southern sardine fishery in the biological, economic, social and ecological dimensions.

Transzonal fisheries are varied and the levels of connection that occur between different waters of marine organisms. In the nineties, Jack mackerel mortalities reached their highest levels, which led to work aimed at their recovery. To this end, assessments were made of the potential extension of Jack mackerel spawning area; the larval connectivity of transzonal and migratory population; the habitat-dependent habitat distribution of adult Jack mackerel with the use of fishing sets data; larval dispersion, by means of otolith readings. It is noted that Jack mackerel is distributed across the coast and transitional coastal waters, in minimum oxygen waters, where there is continuity in the probability of finding Jack mackerel.

Final observations: establish indicators and models in fisheries resources management using an ecosystem approach north of the Humboldt current ecosystem.

Indicators: variable that describes the status of a phenomena, with a significance that goes beyond what is directly associated to such value.

Models: the most recommended models by FAO (WRF-ROMS, ROMS-PISCES, EwE, IBM, OSMOSE and DEB).

Progress: indicators of ecosystem status and trends; identification of trends, cycles and regime shifts in all components; indicators of regime shifts (landings 1950-2018); participatory modeling of climate change impacts.

Outlook: collaboration at different scales (intra- and inter-agency); analyze ecological vulnerability and socioeconomic vulnerability.

FAO recommends the following steps to implement the ecosystem approach to fisheries.

The ecosystem approach to fisheries (EAF) avoids the limitations of the monospecific approach to fisheries by including multispecific relationships, environmental impacts and the human dimension, elements that are needed to deal with the complexity of any socioecologica system. Once the goals and operational objectives are set, an important step in the implementation of an EAF is to develop appropriate indicators and reference points. It is necessary to develop indicators on processes such as: upwelling, ENSO, inter-seasonal scenarios, habitat, fertility, phytopankton and zooplankton communities, nekton, population dynamics of the main fisheries resources, fleet performance and predators. With the increasing impacts of climate change, it is also necessary to include extreme climate phenomena (that is, marine heat waves, anoxic/hypoxia phenomena and toxic algal blooms).

The complexity of multispecific relationships requires the use of ecosystem models to assess the status, trends and scenarios of the ecosystem at different spatio-temporal scales (intra-seasonal, interanual and interdecadal). Several physical, biochemical and ecosystem models are under implementation in the ECHN (for example, WRF, ROMS-PISCES, CROCO, Ecopath with Ecosim, OSMOSE) to address the impact of different processes (such as winds, oxygen minimum zone, Kelvin waves, El Niño and Southern Oscillation, regime shifts and climate change) and anthropogenic activities (e.g., fishing strategies and aquaculture). Climate change could exacerbate these processes and activities, thus a participatory ecosystem modeling is required to design simulations, forcings and scenarios and future turning points and optimal adaptation measures. Strong intra and inter-institutional collaboration will be a key requirement for the implementation of a transdisciplinary EAF.

Summary Module 5:
Dr. (c) Carolina Lang

As we approach ecosystem management, ecological modeling becomes esencial. Ecosystem modeling using Ecopath with Ecosim (EwE) is widely used, contributing to the different stages of ecosystem based fisheries management (EBFM), an approach that integrates ecological and environmental variables. Several examples can be mentioned on the use of this tool that vary from assessing and determining reference points for management based on EwE analysis, an example of which is developed in the United States by NOAA in association with the academic world. It has also been used in the European Union (EU) to assess the implications of regulation related to landings and MSY, biomasses have been improved, while the profitability of the sector decreased, which requires more selective fishing. Another example, also in the EU, is the agreement between member states to carry out multisectoral monitoring on the state of ecosystems, therefore, all parties must report and manage EU maritime waters under this approach. Other examples are found in areas related to minerals, renewable energy, dismantling oil platforms and maritime transport. Intra-agency collaboration is a major part of EBM. Globally, several EAFM commitments have resulted in gradual but steady growth.

As many other countries, Chile uses a monospecific management and assessment strategy. Lack of knowledge related to ecosystem dynamics and true impacts (or commutative effect) of different human activities leads to poor management decisions. The various ecosystem models that exist help to understand the components and processes, which can be used in parallel with monospecific models, as a tool to support decision making or logistical planning. The Atlantis model, was specifically used to understand the consequences of fishing in Juan Fernández. Recently, there has been growing interest in increasing the exploitation of fisheries, and to upgrade the fishing fleet operating in the JFRE. Under this scenario, the increased levels of fishing exploitation and the high level of interspecific interactions, it would be necessary to understand the ecological impact of these fisheries. It was found that the Atlantis model has a high degree of capability to represent the trends and fluctuations observed in the JFRE. Another finding was that industrial fishing operations have a localized impact, while small-scale fishing has a relatively low impact on the ecosystem, mainly through the lobster fishery. It also predicted an increase of sea urchins due to the decline of large lobsters. Although this increase is not sufficient to cause significant impacts on other groups for now, precaution is recommended in case the additional pressure takes the ecosystem toward a regime shift.

The use of a type of fishing gear can harvest several species or stocks with different productivity levels, thereby increasing the risk of depletion, this could affect the relationships between species and ecosystems. Contrary to monospecific fisheries, multispecific ones have bigger sustainability issues due to climate change. Thus, the Juan Fernández and Desventuradas Island community is being proactive and planning actions to face climate change scenarios. Food security, nutrition, job placements, income, life and culture of coastal communities are being threatened by this complex scenario. Multispecies fisheries management solutions are linked to balancing social, economic and ecological objectives. The initial work of the climate-adaptive multispecies fishery management plan is to identify all species to be monitored, especially finfish that are essential for community income and ecosystem resilience. This initiative envisions developing an ecosystem-based fishery management plan, stakeholders are actively engaged using the Framework for Integrated Stock and Habitat Assessment, called FISHE (fishe.edf.org/). Each phase of the process builds on the knowledge of practitioners, residents, scientists, government and other stakeholders. A changing climate and the goals of ecosystem-based fisheries management in the community of Juan Fernández and Desventuradas can help other coastal communities learn about sustainability and ecosystem-based management.

Stock assessments have guided fisheries management in the Gulf of Mexico for a long time. The integration of multispecific data, improving stock assessments and management decisions can be achieved using ecosystem models. This approach can provide qualitative and strategic recommendations, such as when to increase precaution or change stock assessment criterio, or identify the main factors of change in a population. It can also help determine multispecific reference points or assess catch plans recommended under changing environmental conditions. In the case of research conducted in the Gulf of Mexico, practitioners and stock assessment experts identified and prioritzed the main issues that could be addressed using ecosystem modeling. Ecosystem models have been used to respond to specific concerns about species ecology and management. One of them was used to establish trade-offs in forraging fish management and new reference points based on ecology and a second model was used to assess the impacts of the red tide in key species such as corral reefs.


Lobster fishery in the Juan Fernández Archipelago

Chilean Society of Marine Sciences
(Sociedad Chilena de Ciencias del Mar)

The Chilean Society of Marine Sciences (SCHCM) is a private law Corporation created in 1960 as the Oceans Science Committee. Its mission is to encocurage and disseminate scientific and technological research in Oceans Sciences, provide advice to public and private agencies, both national and international, publish and disseminate the work developed by the Society, and in genera any action aimed at a better understanding of the significance of Ocean Sciences for scientific, economic, social and cultural development in Chile.

The SCHCM annually holds the “Ocean Sciences Congress”, to summon its members and the national and international community. The aim of this Congress is to present the scientific progress made, but especially to build and maintain collaboration networks at the national and international levels. The SCHCM also promotes working groups in various subjects of interest, seeking to represent ocean sciences at local, regional and national forums in the private and public sectors.

Fisheries Development Institute
(Instituto de Fomento Pesquero)

Instituto de Fomento Pesquero (IFOP) is a non-profit private law corporation created in 1964 by the Production Development Corporation. In its early stages, IFOP was dedicated to further actions to develop fisheries and aquaculture activities, and later specialized in the field of scientific research to provide recommendations to the Government on an ongoing basis, in order to contribute to developing sustainable fisheries and aquaculature activities in tyhe country and ensuring the conservation of marine ecosystems.

IFOP has three large areas of specialization, the first is oriented at fisheries research situated in the city of Valparaíso, the second area focuses on aquaculture research in Puerto Montt, and the third is related to the environment. The Institution also has 9 offices across the country from Arica to Puerto Williams and 41 sampling centers across the coast of Chile, allowing for direct contact with the many users and collecting fisheries, biological and economic data from the varios fishing feets, as well as undertaking aquaculture research.

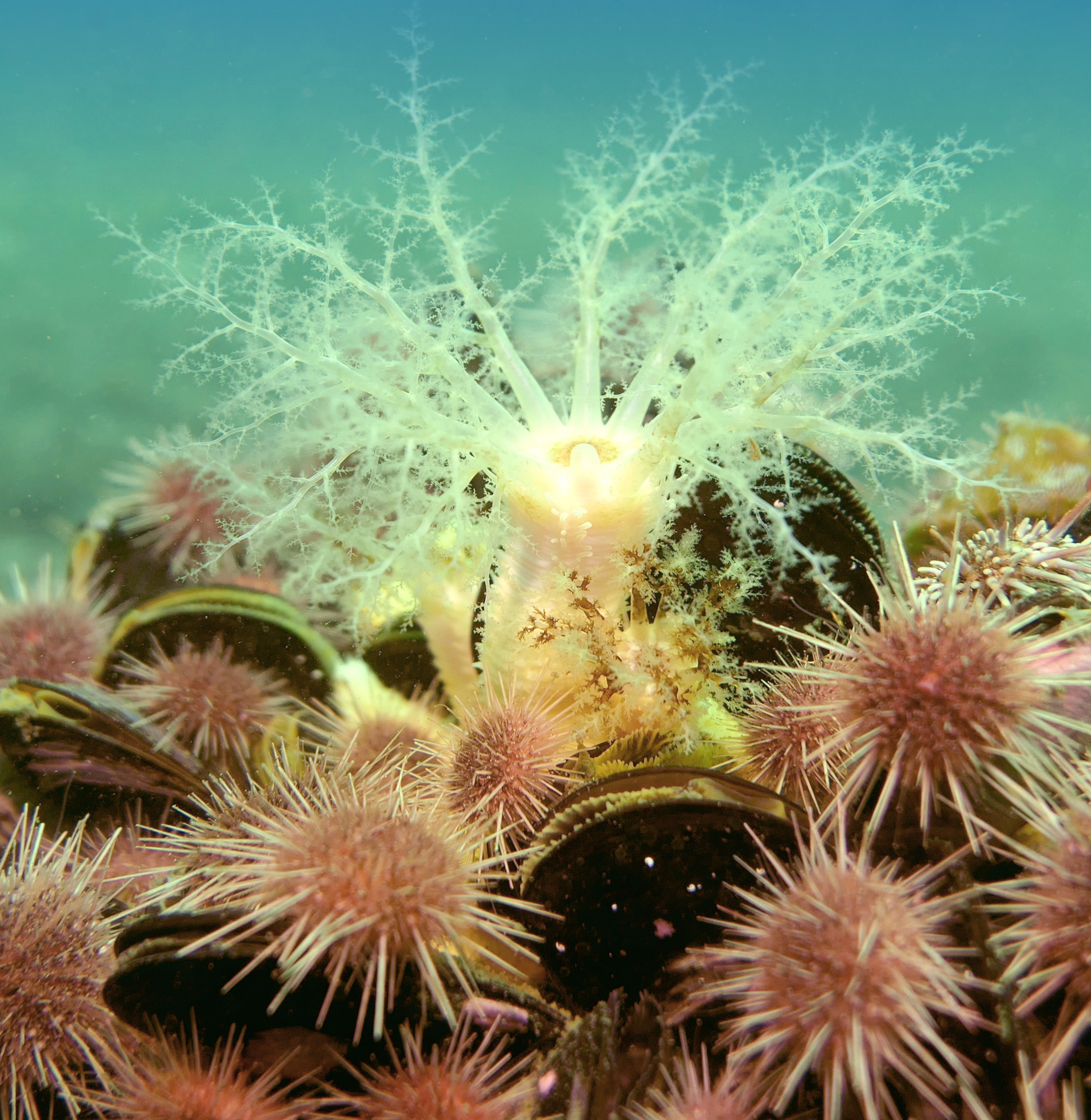
The mission of our Institute is fulfilled thanks to ongoing work performed by many of our working groups and the invaluable collaboration of the actors of the fisheries and aquaculture sectors in our country.

IFOP

GENERANDO CONOCIMIENTO Y SUSTENTABILIDAD

INSTITUTO DE FOMENTO PESQUERO ★ CHILE

Sociedad Chilena de Ciencias del Mar



www.ifop.cl