
# Advancing Fishery Science around Climate Change and Adaptation in the Humboldt Current Ecosystem

## Workshop Overview, Conclusions, and Collaborative Management Plan

October 2018

Authors

Merrick Burden
Erica Cunningham
Kristin Kleisner

# Executive Summary

Fisheries of the world can continue to be abundant and prosperous in the face of climate change. To do so, we must get management in place that can adapt and be responsive to new conditions thereby mitigating some of the negative effects of climate change (Gaines et al. 2018). With this in mind, Environmental Defense Fund (EDF) has taken an approach driven by innovative scientific collaboration to discuss fisheries of the Humboldt Current and the impact of climate change on these fisheries and the ecosystem that supports them. EDF hopes to foster a path forward for increased collaboration to improve *science and management* in the Humboldt Current region (Chile, Peru and Ecuador). EDF's ultimate goal is to help identify adaptive policies and strategies that ensure high performing fisheries in the face of climate change in the Humboldt Current.[1]

During our recent June 2018 workshop, participants identified a ten-year goal of implementing climate adaptive management across the Humboldt Current ecosystem (in Ecuador, Peru, and Chile). In order to achieve this, stakeholders in the Humboldt Current region will need to better understand and enact management that accounts for changes in the system due to climate change. These will include, but are not limited to (1) measuring and anticipating changes in the frequency and magnitude of environmental fluctuations such as El Niño Southern Oscillation (ENSO), (2) changes in average productivity and yield of key fisheries over time, and (3) changes in the location and distribution of marine resources, including both targeted and incidentally caught species. Appropriately managing for these changes will require supporting science for a three-pronged approach: observation of conditions in the ecosystem, development of early warning indicators, and forecasting for future change:

- Observation refers to the ability to monitor activities in the ocean, including both changes in physical oceanographic features and changes in abundance and availability of harvested species.
- Early warning indicators refers to the development of signals that trigger the need for a management response, and that are based on observations of physical and biological factors in the marine ecosystem.
- Forecasting refers to the ability to project and anticipate future changes so that management can be adaptive and new policies can be issued prior to environmental change occurring.

Workshop participants discussed specific research needs and potential opportunities for collaboration to develop, support and strengthen a shared research agenda capable of achieving the overall goal of having climate-ready fisheries management across the Humboldt Current region within a decade.

[1] High performance is based on three metrics: conservation of habitats and living marine resources, social well-being, and economic prosperity

In order to achieve this ten-year goal for climate adaptive management, workshop participants agreed to several key milestones over the coming years:

1. Creation of two new research volumes that document knowledge to date on the marine ecosystems and fisheries management in the transition zones between Ecuador and Peru, and between Peru and Chile. The group identified these topics as key areas for understanding climate impacts on fisheries, and areas where unique management challenges will reside.
2. Creation of a strategy document that identifies the key scientific capacity gaps, as related to climate science for adaptive fisheries management in each country.
3. Implementation of comprehensive, Humboldt Current-wide observation, early warning and forecasting systems (based on the three-prong approach above).

In relation to this third goal, the group determined specific needs for Chile, Peru, and Ecuador in order to implement climate-relevant ecosystem based management. In Chile, the group identified a need to implement regime shift protocols (e.g., tactical management responses to enact when specific changes occur), while Peru and Ecuador identified a need to better understand upwelling and the role of climate change for more effective fisheries management. Ultimately, the long-term vision for the implementation of Humboldt Current-wide adaptive management is one in which scientists are collaborating across borders with the right capacities, guidelines, and tools in hand to deal with the effects that climate change is having and will have on fisheries. Recognizing that these efforts require multiple stakeholder groups, the scientific institutions in each country plan to further engage policy makers and other scientists through deliberate outreach and communication, and ensure synergy with complimentary programs such as the new phase of the Global Environment Facility (GEF) Humboldt Current Large Marine Ecosystem (LME) Project.

## Background

On June 11 and 12, 2018 Environmental Defense Fund convened fishery science institutes and leaders in the Humboldt Current LME, to discuss the impact of climate change on Humboldt Current fisheries and begin planning the creation of a roadmap to help inform the development of climate adaptive fishery management for this region in South America. This project is part of EDF's larger program goal to secure a future for the oceans where fisheries are sustainable and prosperous, where waters are teeming with life, and where there is a secure future for the millions of people that rely upon seafood for daily sustenance.

To achieve this goal, EDF is working hand in hand with academia, government institutions, NGO, and fishing industry partners around the world to focus our joint efforts on finding innovative solutions to challenges in fishery management. One such challenge concerns the management of small pelagic species, like sardine (*Sardinops sagax*), anchovy (*Engraulis ringens*), and jack mackerel (*Trachurus murphyi*), which not only help sustain marine ecosystems through their role as prey, but also make up over 30% of the world's catch according to the United Nations Food and Agriculture Organization (FAO). These species could play a larger role still with improvements in management. Small pelagic finfish pose a special

challenge to managers because they tend to have populations that fluctuate strongly over time in response to factors other than fishing (including changing environmental conditions); they are often described as "boom and bust" species. This challenge occurs in highly productive upwelling systems around the world. The Humboldt Current, which spans much of the west coast of South America – Chile, Peru and part of Ecuador has the largest fisheries for these species in the world.

As a result, the fishing industry in this region attempts to adjust to these very large swings in abundance, and at times is incentivized to continue fishing stocks even when they are in decline, contributing to conservation problems, and less than ideal economic performance. Fishery managers have been challenged to address the changing patterns of these fluctuations even under current conditions. As climate change continues to unfold, management challenges promise to become more acute and complex. Warming waters promise to alter upwelling and productivity patterns, and drive certain species towards new waters, creating jurisdictional concerns for fishery managers. On a global scale, general poleward shifts in species distribution in both hemispheres have been noted as temperature isotherms or bands have shifted in these directions over time due to overall warming in the oceans. In the Humboldt Current, some southern shifts in species distributions (especially of large pelagic species like tuna and jumbo squid, *Dosidicus* gigas) have already been noted and are influencing and affecting current management policies.

Small pelagic species tend to have critical ecological and economic importance to the regions where they occur and within global markets, and the Humboldt Current is no exception. Because of this critical importance, we are working to understand the nature of boom and bust fisheries and to identify ways to improve their management. In particular, we seek to examine the way these species influence the broader ecosystem such as:

- Their influence on the abundance of populations of larger predators, and their dependence on shifting patterns of primary producers (e.g., phytoplankton) and primary consumers (e.g., zooplankton) in the system, which are strongly influenced by upwelling.
- How fishing affects – and is affected by – these dynamics, and management strategies that can improve the ecological and economic performance of these fisheries.

EDF's goal is thus to work with regional experts to identify management strategies for these boom and bust species that can improve the socio-economic and ecological performance of the fishery in the face of climate change. We view a more sustainable approach as one that leads to more economic stability for fishermen, better social conditions for communities and people who depend on these fisheries, more food on the table for people who rely on these fish for consumption, and fish abundance at levels that enhance ecosystem structure and function and enhance long-term resilience.

To this end, EDF was grateful for the participation of the following institutions for this workshop: Instituto del Mar de Peru (IMARPE), Institute de Fomento Pesquero (IFOP) Chile, SUBPESCA, Subsecretaría de Pesca y Acuicultura de Chile, Instituto Nacional de Pesquerias Ecuador (INP), and Ministerio de Produccion, Peru (PRODUCE). Over the course of two days these institutions worked together to complete workshop objectives and create an open dialogue

around climate impacts on fisheries, and focused on ways to better collaborate to improve the collection of fisheries data and development of science to meet the increasing need for adaptive and ecosystem based management across the Humboldt Current (see Appendix).

## Workshop Objectives

- To discuss the collective understanding and current knowledge of main ecosystem drivers in the Humboldt Current and how they may be affected by climate change
- To identify how these ecosystem dynamics influence pelagic and demersal fish stocks
- To identify the challenges these dynamics pose to the management of fisheries in the region and the key questions related to the management of fisheries in the face of these ecosystem dynamics
- To identify the scientific and bioeconomic approaches that can be taken to investigate these challenges and potential management solutions
- To develop a shared strategy for the scientific evaluation of fisheries impacted by climate change in the HC that incorporates ecosystem level approaches and tools that foster constructive and collaborative solutions to climate-related fisheries impacts for the region

## Desired Workshop Outcomes

- Open and fluid dialogue between science and policy experts overseeing fisheries in the Humboldt Current region, creating lasting connections between individuals and institutions working on climate-related impacts on fisheries in the Humboldt Current
- A shared understanding of the possible challenges climate change will present to the Humboldt Current ecosystem and fisheries, including gaps in the current research and management
- A collective research agenda for addressing key climate change challenges
- A report detailing the discussions and findings of the workshop, which also identifies next steps for advancing collaborative research to address the key questions and challenges discussed

## Workshop Group Discussions

The following sections summarize the conversation and brainstorming activities under the following discussion topics, each addressing environmental and stock variability, changes in average productivity and movement of targeted species.

### 1. What is changing in fisheries? Identifying physical changes in the ecosystem and the effects on fisheries resulting from environmental variability.

## Environmental and Stock Variability

One of the major difficulties in the region is separating inter-annual ENSO effects from longer-term trends. Understanding the persistence of events is critical. On the immediate timescale, ENSO has effects on the availability of stocks like anchovy. On decadal timescales, the Pacific Decadal Oscillation (PDO) is a stronger driver. On longer, centennial to millennial timescales, the patterns of oscillation between sardine and anchovy are not clear, which may suggest that a different regime was operating, or that anchovy and sardines have adapted to the current fluctuations.

In terms of inter-annual timescales, understanding whether there has been an increase in the frequency and/or nature of ENSO events is challenging. Recent studies have noted some evidence of an increase in intensity of ENSO events, but have found no relationship between warming events in the past and current warming. However, the fact that there has not been the appearance of more frequent ENSO events could be attributed to the fact that in the past there were fewer observations due to less developed monitoring systems. This is an area of active research. Conversely, the increased frequency and intensity of extreme events is clearer and their effects on marine species may be easier to visualize and communicate. For example, more frequent floods, which are attributed to more intense ENSO events with heavier rainfall, have had a negative effect on benthic species due to increased sedimentation and release of heavy metals.

It is important to recognize that we cannot discuss climate effects and increased variability in terms of distribution shifts alone. Changes in productivity are important as well. This may be especially true for sessile species that are unable to move and that may be less adaptive to a changing environment. For less adaptive species, there may be larger effects on productivity for which we need to account.

## Changes in average productivity

We are seeing habitat changes across the Humboldt Current region, with interdecadal cooling that is affecting productivity of some species negatively and others positively. During El Niño, which bring warmer waters, primary productivity decreases. In order to better understand changes in average productivity we need to have a complete understanding of the productivity of a species, across both Chile and Peru, including the shared stock of anchovy. Ecuador, meanwhile, has a relative lack of oceanographic information that would be helpful for better understanding productivity changes. This is an area where there is significant room for collaboration and exchange of ideas and expertise between experts in the region that could help species across the Humboldt Current system.

It appears that a paradigm shift may have occurred, starting first in northern Chile, followed by Peru, whereby productivity has increased in the southern Humboldt relative to the north. This shift appears to have led to an increase in the productivity of predator species across the region such as jumbo squid. It may be possible to establish certain indicators of productivity based on species that are easier to monitor, such as the

increase in red squat lobster (*Pleuroncodes monodon*), which is correlated with the increase in anchovy.

### Movement of targeted species

Movement of stocks will occur in several different directions as climate change takes hold, including north-south directional shifts, shallow-deep directional shifts, as well as ontogenetic shifts (movement associated with changes in a species' age and growth). This movement will occur both due to long-term climate change that can alter the average position of a species' distribution, and due to interannual or decadal fluctuation in response to shorter term environmental variability as a result of natural fluctuations of regional and sub-basin effects from ENSO and the PDO. It is important to consider the effects of long-term climate change on the frequency and magnitude of these regional events.

As waters get warmer on average over time, globally, species are expected to follow similar patterns to those observed during historically warmer periods. That is, species will tend to move southward and toward deeper waters. However, in the Humboldt Current, there is the added complexity in understanding long-term climate change effects because this is an upwelling system. In the Humboldt Current, waters may actually cool if upwelling intensity increases and changes in the upwelling patterns may also affect the availability of some species to the fishery through changes to the oxygen minimum zone (OMZ), which is a level in the water column below which oxygen levels decrease. In particular, warmer waters during El Niño events coincides with a deeper OMZ, weaker upwelling, and lower primary and secondary productivity, which is not favorable to anchovy, but which is beneficial for other pelagic species. Compression and expansion of the OMZ can act to compress or expand the vertical distribution of species that cannot tolerate low oxygen conditions. This compression may aid fishermen when species are found at shallower depths, or may serve to spread the species' distribution further from shore and make them more diffuse and difficult to catch.

Changes in the patterns of ontogenetic shifts are also likely to occur in concert with changes in the location of habitat preferred by different life stages. If species are strongly driven by physical conditions like temperature, salinity, and pH, and tied to a particular benthic habitat or depth, then there may be mismatches that occur with changes in physical conditions. There may be a greater effect in this case for demersal species or species that are more sessile. If species can shift to follow optimal physical conditions, they may still be limited by the quality of new habitat, and this may affect their productivity.

Finally, changes in stock structure may occur, driven by changing oceanographic conditions. Long-term warming trends are expected to result in the presence of new species in waters where they have not historically been found and the loss of traditional species in some cases. Subtropical currents are expected to come closer to shore along portions of the coast, driving a wedge between the northern and southern ranges of stocks. This is likely to cause a separation of single stocks into multiple stocks, with the possibility that they may need to be managed as separate units. This, and the changes

noted previously, may also change the mix of species in a given area, creating new species interactions, or breaking previous assemblages. The ecosystem effects of these types of changes need to be considered as well.

## 2. What are the challenges and opportunities in the Humboldt Current, including socioeconomic and management implications?

### Environmental and Stock Variability

When trying to interpret change in stock biomass, it is important to understand the difference between inter-annual variability and long-term trends. These concepts are difficult for fishermen, fisheries managers, and the public to understand, so some work on how to convey these concepts as well as general information about climate and environmental effects will be necessary.

Generally, it was felt that the industrial sector may be more conscience of inter-annual variability, but has less willingness to understand and discuss long-term trends. With respect to inter-annual variability, the industrial sector seems to operate under the assumption that the "good years" will come back, which has been true with ENSO fluctuations, but which may not always be the case if there are more frequent or intense "bad years" for a given stock, or shifts in productivity out of a region. The idea that changes may be longer lasting and directional is generally less palatable because it means more uncertainty. These are also difficult concepts to explain and discuss. For example, uncertainty around the potential need to switch to fishing species that require different gears or fishing strategies was noted as one reason that the industrial sector has been unwilling to engage and learn about the effects of climate change.

### Changes in average productivity

The greatest management challenge may be the uncertainty that shifting ocean conditions will bring in terms of calculating appropriate fishing quotas, wherein a potential management approach is to assign rights to all fisheries and stocks across both industrial and small-scale sectors. There are no standardized procedures for the whole Humboldt Current region, and there is significant uncertainty related to oceanographic data, larval survival and other impacts on the life cycle of species, and impacts derived from changes in trophic structure. Another challenge is how management should respond to predictions of what will happen in the natural system.

Management responses could include a joint Chile-Peru observational system to gather both oceanographic and ecological data on the fisheries in the region, with standardized and synoptic methodologies and timeframes, especially for transboundary stocks such as anchovy in northern Chile and Southern Peru. In addition, regional workshops to standardize methodologies and data use are important, as is coordination in research that prioritizes characterizing and understanding changes in productivity. For improved ecosystem based management, the region needs to coordinate on and develop ecosystem-based models that help to promote multi-species, flexible management that

can respond to changes in the natural system. Supplementing sustainable fishing with sustainable aquaculture could be a way to buffer the negative impacts of climate on fisheries, especially for artisanal fisheries. Lastly, fishery management plans need to include objectives related to food security and productivity over a long period, rather than a short planning horizon, wherein strategies for value-added products can help during lower productivity years.

### Movement of targeted species

Stock movement creates challenges that are linked to accessibility and existing regulations and boundaries that limit adaptability. For instance, in some regions spatial fishery regulations prevent vessels from moving to different areas of the coast. As species move, this limits the ability of the industry to adapt. Being able to anticipate stock movement, and understanding the types of adaptations that will be necessary on the part of regulators and industry, can help to start the process of adapting regulations to future conditions.

Shifting stocks also present management challenges and opportunities in the form of new species. New species occurring in areas where they have not previously been found may create new fishery opportunities. However, to manage these species appropriately, it will be necessary to anticipate their movement and to estimate appropriate levels of sustainable removals. Likewise, the industry will need to anticipate such movement in order to re-tool their capital, and consider harvesting species they have not pursued before.

## 3. What are the tools and approaches that can be used to find solutions? How do they vary by country? What is each country's priority?

### Environmental and Stock Variability

Better understanding of stock variability changes and the ability to more accurately forecast physical and biological changes will help to anticipate and adapt to climate related effects on the ecosystem. This understanding may be assisted by better framing of the issue, including focused studies on pelagic versus benthic species responses, as the response of different species and species groups will vary. There was consensus around the idea that in most cases the artisanal fishers are not aware of either inter-annual or longer-term trends. There is a need to educate artisanal fishers about these concepts and implications for their livelihoods. Dedicated workshops targeted at both industrial and artisanal fishers were proposed as a means of educating both sectors on future impacts of climate change on fisheries in the region. Better dissemination of science to the public, fishermen, and policy-makers on anticipated changes and on the concepts in general is needed urgently. For example, there are several types of El Niño (e.g., Modoki, Costero, Canonical) that can have different effects on fish stocks, fishing communities and fishing enterprises. This is not well-known outside of the scientific community, but will be very important for informing stakeholders.

It was noted that the use of inexpensive technology may be important for gathering more and better fine-scale oceanographic observations. These data could be used to help validate climate models and provide insights on changes in the environment. In particular, it was noted that wave gliders and new, portable remote operated vehicles (ROVs) could be deployed to capture these data. Ideally, these types of fishery independent data collection systems should supplement standard fishery independent surveys, and the spatial and temporal coverage of these existing surveys should be improved so that they are synoptic. Additionally, fishery dependent data collection should be developed, taking advantage of the fishing vessels that are already operating in the region and potentially available to collect valuable data.

### Changes in average productivity

One key approach for improving management performance in the face of changes in average productivity is increasing the number of studies that examine how variable life cycles of species are, given regime changes (e.g., cold vs. warm periods). Understanding the economic dimensions of the impact of changes in average productivity was also highlighted as important for planning and promoting better management. One suggestion was to adapt fisheries management towards a rights-based system, thereby providing rights (i.e., quotas) to fish different species. Limiting open access to fisheries will be important for maintaining sustainable and healthy population and catch levels and should provide higher economic benefits to fishermen as they will be better able to allocated fishing pressure on different species as productivities fluctuate.

### Movement of targeted species

Identifying new and future habitats and ranges of species will require investments in scientific capabilities that estimate where and how the preferred ranges of species will change over time. Investing in this type of science plays the important role of helping managers and industry to anticipate change, and with that anticipation, to begin changing management rules and re-tooling capital to be able to adapt to future conditions.

Management approaches that can be developed and deployed to respond to movement of stocks include reviewing spatial management rules presently in place, and whether those rules make sense given the future locations of species. Ensuring fishery management plans for all fished species as well as scientifically established total allowable catch (TAC) and quotas is another important step in ensuring that the management in place is adequate to meet climate-related challenges. Additionally, when possible, it is ideal to manage the harvesting of species using tested harvest control rules that provide clear guidance on how managers should react when stock biomass (and productivity) change. Other key adaptations include continuing to strengthen international collaboration over stocks that may cross international boundaries and developing these collaborations for stocks that are anticipated to shift.

## Workshop Planning Exercises

The last part of the workshop was dedicated to conducting a regional visioning and planning exercise to determine what types of scientific tools are needed in order to secure a future for climate adaptive fisheries management. The group decided to focus the planning efforts on the two critical zones for climate change in the Humboldt Current: (1) the northern Peru and southern Ecuador region, and (2) the northern Chile and southern Peru region. The workshop participants took the results of the group discussions and brainstorm sessions to first craft a long term vision based on ten and five year timelines, and then participants worked together to create a joint work plan for the following two years (see Gantt Chart below).

### What is the ten-year plan for the Humboldt Current Region?

The overall goal of the ten-year vision for the Humboldt Current is to reach formalized and trans-nationally agreed upon regime shift protocols that are in accordance with the legal frameworks for fishery management in each country. By 2030, we also envision that Chile not only has established guidelines for ecosystem based management and the use of the precautionary principle across all fished species in the fishing law, but that fisheries management interventions are also being implemented through participatory fishery management plans. Over this same timeframe, Peru will have a better understand of the upwelling system in the Humboldt Current and how it is anticipated to be affected by climate change, and will have developed best criteria for adaptive management with an ecosystem focus. Similarly, Ecuador will have increased knowledge of upwelling effects and changes on the system that are likely under climate change, and will incorporate this physical and biological knowledge into fishery management regulations. As a region, all three countries will be collaborating on scientific advances and policy makers in fisheries management will utilize this science in decisions. Lastly, each of the three Humboldt Current countries will have the capacity and tools installed for adaptive management by the fisheries sector to deal with climate change.

### What is the five-year plan for the Humboldt Current Region?

The five-year vision for the Humboldt Current is to first identify priority needs and fill essential gaps to reach the 2030 goals stated above. From there, the scientific collaboration around climate impacts on fisheries will be aligned with the GEF-UNDP Strategic Action Program for key fisheries such as the Chile and Peru transboundary anchoveta stock, as well as other regional programs (e.g. the GEF Peru Ecuador Project on the FAO's Coastal Fisheries Initiative [CFI]) for the two climate-critical zones identified. In addition, over the coming five years participants will identify funding sources for advancing regional observation and information sharing, and will have achieved commitment from each country to create a set of scientific volumes as a compendium of the scientific knowledge and advancement on climate change impact on fisheries in the Humboldt Current. In five years, a scientific capacity building strategy at the regional level will be implemented to achieve the long-term vision. Lastly, in five years' time a Regional Scientific and Governance Framework will be completed that includes:

A. Implementation of technology for real time observational data sharing;
B. Communication with the scientific community, decision makers, and stakeholders regarding regime shifts and climate shocks occurring or about to occur; and
C. Implementation of the components of a comprehensive system to include observations, predictions, and early warning signals.

## Gantt Chart

The following Gantt chart was created as a work plan for the group over the near term (from June 2018 to January 2020).

| Objetivos | Actividades | Fechas | Entregable | Financiamiento | Responsible | Informado |
|---|---|---|---|---|---|---|
| *META: Incrementar el conocimiento compartido y analisis cientifico sobre las zonas criticas de la Corriente de Humboldt en terminos de variabilidad ambiental y cambio climatico (norte Chile/Sur Peru y Norte Peru/Sur Ecuador)* | | | | | | |
| **Crear 2 volumenes de conociemiento cientifico sobre zonas criticas en la corriente de Humboldt (norte Peru/sur Ecuador y norte Chile/sur Peru)** | **Conformar grupo de trabajo (participantes y lider/coordinador del grupo)** | junio-septiembre 2018 | Cada institucion: INP, IMARPE, IFOP define sus participantes | Por institucion | **INP, IMARPE, IFOP** | **Tomadores de decisiones** |
| | **Definir el alcance de los volumenes (geograficos, temporales, disposicion de cada pais)** | Septiembre-Diciembre 2018 | Indices para cada volumen | Compartido mas GEFs | **INP, IMARPE, IFOP** | **Tomadores de decisiones** |
| | **Talleres presenciales con expertos regionales** | Al inicio y fin de trabajar cada volumen | | Compartido mas GEFs | **INP, IMARPE, IFOP** | **Tomadores de decisiones** |
| | **Analisis para informar lo que podria venir en un tercer volumen/capitulo que no viene en los primeros dos volumenes - ciencia no publicada - brechas** | Enero a junio 2019 | Gap analisis de las brechas | Compartido mas GEFs | **INP, IMARPE, IFOP** | **Tomadores de decisiones** |
| | **Creacion de volumes 1 & 2 en espanol** | Diciembre a Junio 2019 | Primer borrador volumenes 1 y 2 | Compartido mas GEFs | **INP, IMARPE, IFOP** | **Tomadores de decisiones** |
| | **Presupuesto para editacion y publicacion** | Diciembre a Junio 2019 | Presupuesto | EDF | | **INP, IMARPE IFOP** |
| | **Edicion y revision y traduccion al ingles** | *Durante 2020* | Producto final de volumen 1 y 2 | Compartido mas GEFs | **INP, IMARPE, IFOP** | **Tomadores de decisiones** |
| | **Lanzamiento volumen 1 y 2 (World Fisheries Congress Australia)** | Diciembre 2020 | Producto final, Evento tres paises | EDF | **INP, IMARPE, IFOP** | **Tomadores de decisiones** |
| *META:Una mejor colaboracion cientifica y de manejo pesquero en base a los avances de los proyectos GEF, capitalizando en los fondos disponibles de organizaciones multilaterales* | | | | | | |
| **Sinergia con proyectos GEFs, multi laterales y planes nacionales de accion** | Entrecruzamiento objetivos y planes de trabajo de los GEFs, planes de accion, etc | diciembre 2018 | actualizacion de plan de trabajo | EDF, GEF | EDF | **INP, IMARPE, IFOP** |
| | Reunion presencial con coordinadores agencias implentadoras tomadores de desiciones | Enero a junio 2019 | minuta | EDF | EDF | **INP, IMARPE, IFOP** |
| | Identificacion de fuentes de fianciamiento de programas regionales (GEF, PNUD, FAO), fundaciones (Walton) y otras instituciones de cada pais para crear un sistema comprensivo para observacion, prediccion, y alerta temprana entre Chile, Peru y Ecuador | Junio a diciembre 2018 | | EDF | **EDF, IFOP, IMARPE, INP** | **Tomadores de decisiones, expertos** |
| *META: Tener un sistema comprensivo a nivel regional para observacion, prediccion y alerta temprana con informacion util para creacion de protocolos formales para el manejo adaptativo en cada pais* | | | | | | |
| **Desarrollo de un plan de investigacion consensuado para ir hacia un sistema comprensivo de observacion, prediccion, y alerta temprana.** | **Discusion sobre cuales tipos de data estan disponibles en cada pais** | Junio a diciembre 2018 | | EDF | **EDF, IFOP, IMARPE, INP** | **Instituciones y expertos regionales** |
| | **Revision de fechas de encuentro y lugares para reuniones en comun entre los tres paises para progresar en el desarrollo del plan.** | Junio a diciembre 2018 | | INP, IMARPE, IFOP | **EDF, IFOP, IMARPE, INP** | |
| | **Mapeo para comparar y mejorar los modelos de cambio climatico de alta resolucion con datos de Chile y Peru para mejorar la capacidad para la prediccion de cambios en surgencia y productividad.** | **Junio 2019** | **Diagnostico de sistema de datos de observacion** | **Compartido** | | |
| | **Taller para discutir como llenar las brechas en capacidad para prediccion basado en los avances en modelos y observaciones** | **Junio a Diciembre 2019** | | **EDF** | | |
| | **Acuerdo en los productos (tipos de modelos) para desarrollo segun este plan en cada pais/ a nivel regional** | **Junio 2019** | | **Compartido** | | |
| | **Compartir avances en bio-economia y aplicacion en cada pais** | **Junio a Diciembre 2019** | | **Compartido** | | |
| | Creacion y comunicacion de plan de investigacion | Diciembre 2019 | | Compartido | | |

## References

Gaines, S.D., Costello, C., Owashi, B., Mangin, T., Bone, J., Molinos, J.G., Burden, M., Dennis, H., Halpern, B.S., Kappel, C.V., Kleisner, K.M., Ovando, D. Improved fisheries management could offset many negative effects of climate change. *Science Advances*. 4: eaao1378. 2018.

# Appendix

## WORKSHOP PARTICIPANTS AND AGENDA

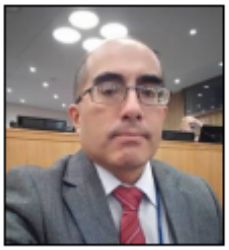
### Participants:

### Participant Biographies

**CAMILO TORRES**
**Instituto de Fomento Pesquero (IFOP), Chile**

Camilo Torres is a researcher in fisheries and aquaculture economics in the Fisheries Research Division of IFOP. His work is oriented to the econometric analysis and bioeconomic modeling of fisheries in the ecosystemic approach, seeking to understand the effects of management measures on the generation of economic returns and the welfare of users involved in fisheries. Work also in the estimation of the direct employment generated in the salmon industry and the indirect employment of the fishing sector at the national level. Camilo previously worked as an analyst in the Fisheries Department of the Undersecretary of Fisheries and Aquaculture of the Government of Chile, performing biogeographical analyzes of fisheries and implementing coastal and marine spatial planning for fisheries management. He has a master's degree in econometrics and a diploma in economics from the Pontifical Catholic University of Chile. He is an academic at the Faculty of Economics at various universities in the Valparaíso region.

**DIMITRI GUTIERREZ**
**Instituto del Mar del Perú (IMARPE), Perú**



Dr. Dimitri Gutiérrez is the Director of Research in Oceanography and Climate Change of the Peruvian Marine Research Institute (IMARPE). He received his Ph. D degree in oceanography at the University of Concepción, Chile, in 2000. As a biological oceanographer, his research has been focused on benthic responses to natural and human-induced hypoxia, effects of climate variability on the marine productivity and subsurface oxygenation in the coastal South Eastern Pacific involving paleoproxies and in situ data analyses, and recent spatial and temporal changes of the Peruvian upwelling as related to global trends. Currently Dr. Gutierrez is also involved in developing adaptation projects for the impact of climate change on Peruvian fisheries and marine coastal ecosystems and participates in the IOC-UNESCO Global Ocean Oxygen Network (GO2NE).

**DOUG RADER**
**Environmental Defense Fund**

Douglas Rader advises EDF leadership on the scientific aspects of policies and programs affecting oceans. He works with international, national and regional teams to leverage cutting-edge science in current Oceans Program projects and emerging ocean issues, including resilience to climate change. His current focus includes building stronger fisheries management policies and programs that help achieve new global upside predictions by aligning conservation with the business of fishing and the needs of coastal communities. He does extensive oceans work in the U.S., Europe and Latin America, and increasingly around the world, most recently in China, Japan and Myanmar. Doug has worked as a senior scientist for EDF since 1988. He previously managed EDF's Oceans Program work in the Mid-Atlantic, Atlantic Southeast and Caribbean regions, and EDF's oceans science team. He formerly worked for the North Carolina Department of Environment and Natural Resources in the Divisions of Coastal Management and Environmental Management, and was the first director of the Albemarle-Pamlico National Estuary Program.

**ERICA CUNNINGHAM**
**Environmental Defense Fund**

Erica Cunningham, is the Director of the Humboldt Current, South America for Environmental Defense Fund, Oceans. Erica has been working in more than 7 countries to find, develop and implement sustainable solutions to improve fisheries management, the lives of fishermen, and the marine ecosystem. Erica has had a passion for nature, as she grew up among the mountains of Colorado and the beaches of Mexico. Erica began at EDF in 2010 as the Outreach Coordinator for EDF Mexico in La Paz, Baja California Sur, from there she went on to manage the Upper Gulf of California fisheries projects. She then spent many years consulting for the Fisheries Solutions Center developing toolkits and leading design efforts around the world. Erica has been living in Santiago and leading the Chile work for just over a year. Erica has a master's degree in international development and environmental public policy from Johns Hopkins University and her BA from Middlebury College in the United States. Erica also has her certification in negotiation of environmental conflicts of the Udall Institution for Environmental Negotiation.

**FERNANDO ESPINDOLA**
**Instituto de Fomento Pesquero (IFOP), Chile**

Fernando Espíndola is a researcher at Department in Resource Assessment in the Fisheries Research Division of IFOP. His is currently working on the stock assessment of anchovy in southern Peru and northern Chile. The stock assessment considers the best biological information available, fishery data, acoustic surveys and length structure as appropriate. This information allows to establish the status of the resource and propose the annual catch to the maximum sustainable yield. Fernando worked previously in advising different projects at IFOP, one of them is the analysis of the spatial and temporal distribution of anchovy's spawning habitat and its relationship with the environmental conditions using the data of the daily egg production method. And finally, he worked on the use of remote sensing in the spatial and temporal pattern of the nominal performances of the swordfish in the southeastern Pacific. He is a fisheries engineer from the School of Marine Science at Pontifical Catholic University of Valparaíso, Chile.

**KRISTIN KLEISNER**
**Environmental Defense Fund**

Kristin Kleisner is a Senior Fisheries Scientist with EDF's Fishery Solutions Center. Her work investigates the utility of applying spatial management in combination with rights-based management measures in fisheries around the world, applying bio-economic models to understand the potential for fisheries management to improve the biomass, harvest, and profits of fisheries, and understanding the implications of climate change on the distribution of fish stocks and the implications for fisheries management. Kristin worked previously as a joint research scientist for NOAA's Northeast Fisheries Science Center in Woods Hole and The Nature Conservancy working on ecosystem based fisheries models and exploring the effect of climate change on fish stock distributions in New England. She also led research on the development of fisheries, food security, and ecosystem status indicators with indiSeas (www.indiseas.org), FAO, UNESCO, and the Sea Around Us project. She holds a PhD in Marine Biology and Fisheries from the Rosenstiel School of Marine and Atmospheric Science at the University of Miami.

**LAYLA OSMAN**
**Environmental Defense Fund**

Layla Osman is EDF Chile's lead consultant for our small scale fisheries projects. She has years of experience providing vision and strategic direction using science and market access solutions to identify, test, and develop new approaches that improve conservation benefits for both nature and people. Layla has worked in the NGO and private sectors managing public-private partnerships, corporate social and environmental responsibility programs and coordinating events, specializing in environmental conservation and natural resource management, as well as sustainable development planning. Prior to joining EDF she worked with the Nature Conservancy and is a published scientist with awards from Austral University of Chile, where she is also a research associate with the Center for Environmental Studies, CEAM. She is a marine biologist and PhD in marine conservation for the Austral University of Chile. She recently also started the NGO Conectar para Conservar and lives in her native city of Valdivia.

**MARIANO GUTIÉRREZ TORERO**
**GEF-UNDP Humboldt Large Marine Ecosystem Project**

Mr. Gutiérrez is Fishery Engineer with a doctorate in aquaculture. He has been Director of Fisheries Research and Director of Detection Technologies at IMARPE, Peru. He has also been Fishery Survey Leader at Tecnológica de Alimentos S.A. and Senior Project Officer in the GEF-UNDP Humboldt Large Marine Ecosystem Project and consultant to NOAA and UNOPS among others. He is currently Scientific Director of the Humboldt Institute of Marine Research and Aquaculture and professor of submarine acoustics at the National University Federico Villarreal. He has been Peruvian delegate to CCAMLR, SCOR, SCAR, ICES, APEC and SPRFMO; and survey leader of two Peruvian surveys to the Antarctic. He has published over 100 articles in scientific and technical journals, and is member of the IRD Research Unit on Marine Exploited Systems, the ICES Fisheries Acoustics, Science and Technology Working Group, the SPRFMO Jack Mackerel Working Group and the IEHMP Commission of Maritime Strategic Studies.

**MAURICIO GALVEZ**
**Instituto de Fomento Pesquero (IFOP), Chile**

Mauricio Galvez is an accomplished fishery and marine conservation advisor with a proven track record achievement in leading fishery policy reforms and marine conservation in Chile. He holds a bachelor degree in fisheries science and postgraduate studies in environmental planning and ocean policy and law. He has extensive experience in dealing with stakeholders to solve fishery management problems and to implement marine conservation agenda. He has practice in policy advocacy at the Chilean Parliament, decision makers and private fishing companies. Mauricio have been active in the area of fisheries science and policy and marine conservation for over 20 years and have experience in strategic planning, budget development, fundraising, reporting and specialized team management with international organizations. Currently, Mauricio is the Chief of the Fishery Research Division at Instituto de Fomento Pesquero (IFOP), the leading fishery research institution in Chile, which provides scientific advice to the government.

**MERRICK BURDEN**
**Environmental Defense Fund**

Merrick serves as a Director and Senior Economist within the Fishery Solutions Center at Environmental Defense Fund where he works to advance fishery management in ways that achieve desired economic, social, and environmental outcomes. His particular focus is on the development and application of bioeconomic tools which measure the potential for sustainable fisheries and help to identify pathways for attaining that sustainability.

**MIGUEL ÑIQUEN**
**Instituto del Mar del Perú (IMARPE), Perú**

Miguel Ñiquen is a Senior Fisheries Scientist with Instituto del Mar del Perú. He is in charge to develop research on pelagic resources aimed at stocks assessment and their spatial fluctuations according to the environment and the fishery. He carries out studies that determine the levels of sustainable extraction to recommend management measures for the sustainability of these resources, and also researches straddling and highly migratory resources and the biology, ecology and population levels of birds, mammals and marine turtles, in accordance with international agreements. He is biologist with mention on fisheries biology from San Marcos University at Lima, Peru. Miguel has worked for IMARPE from the beginning, for more than 30 years. Now he is part of Joint CAgM/JCOMM Task Team on Weather, Climate and Fisheries and is Co-Director of International Joint Laboratory DISCOH with IRD-France. Miguel has great experience in the research of pelagic resources in relation to the environment, with impacts of El Niño – La Niña events and climate change. His main research topics are fisheries biology of small pelagic resources, research of straddling stocks and highly migratory resources and studies of regime shift in small pelagics.

**NINA PARDO**
**Environmental Defense Fund**

Nina Pardo was born and raised in Lima, Peru. She has extensive advocacy, strategic planning, marketing, communications, and public relations experience in the business and environmental sectors. She has worked at Conservation International and Peru's Exports and Tourism Promotion Board (PROMPERÚ). She has also consulted for the World Wildlife Fund, the Shark and Sea Turtle Restoration Program (PRETOMA), the Annual Symposium on Sea Turtle Biology and Conservation, and many other institutions. She also formerly worked as the General Manager of Ecopesca, a Peruvian NGO dedicated to the conservation and sustainable use of aquatic biodiversity. Nina has successfully advocated for the legal protection of dolphins in Peru and the creation of marine protected areas, such as the National Reserve System of Guano Islands and Islets. She currently works as a Consultant for the Environmental Defense Fund in its Oceans Program, as a Liaison Officer for the Andes Amazon Fund, and as Consultant for the International Finance Corporation of the World Bank Group. Nina studied Business Administration at Pacific University in Lima and received an MBA at American University in Washington, DC.

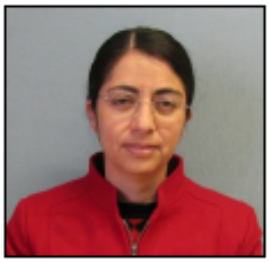
**PILAR SOLIS**
**National Fisheries Institute (INP), Ecuador**

With more than 23 years of professional life in the fishing field, Pilar Solís has developed extensive experience in research, conservation and management of natural resources. She has participated, designed and directed research projects; she also has extensive experience in public management. She has held positions as Coordinator of the Research Area of Bioaquatic Resources, Technical Deputy Director, Director of the National Fishing Institute and Director of Marine Coastal Regulations and Projects of the Undersecretariat of Marine and Coastal Management of the Ministry of Environment. She has given college lectures through distance education. Her experience includes fisheries diagnostics, taxonomic studies of marine fish, fisheries management, research and sustainable development projects, collaborative work, conflict resolution with diverse key players and technical-scientific drafting. She obtained her Biologist degree and Master in Environmental Administration at the University of Guayaquil, Ecuador.

**RENATO GUEVARA**
**Instituto del Mar del Perú (IMARPE), Perú**

Renato Guevara is a fishery biologist, with more than 30 years working for IMARPE in different positions. His work has included the stock assessment of demersal and pelagic fishery resources, the local artisanal fisheries and their relationship between fishery resources and environmental variability, particularly ENSO. In the las decade his work has had more emphasis in the advisory in fisheries management. Currently, he is the Scientific Executive Director at Peru's Institute of the Ocean (IMARPE).

**SILVIA HERNANDEZ**
**Subsecretaría de Pesca y Acuicultura (SUBPESCA), Chile**



Silvia Hernandez is the Head of the Pelagic Resources Unit at the Undersecretariat for Fisheries and Aquaculture. She advises the Undersecretary on technical matters for the decision-making process such as the establishment of management measures, catch quotas, bans, and fishery closures, among others. Her work is related to the definition of the research project portfolio on pelagic issues and monitoring of pelagic Fisheries and their interaction with public and private users. She has recently cooperated with the implementation of the new fisheries institutionality in the constitution and with the participation of the Technical Scientific Committees and Management Committees as well as with the development of their products: Management Plans, Discard Reduction Plan, among others. Silvia has worked with subjects related to the Regional Study of El Niño Phenomenon (ERFEN) in the South-Eastern Pacific of the Permanent Commission of the South Pacific (CPPS) and in the Scientific Committee of the South Pacific Regional Fisheries Management Organization (SPFRMO).

**TELMO DE LA CUADRA**
**National Fisheries Institute (INP), Ecuador**

Telmo De la Cuadra has 25 years of professional life in Marine Sciences. He has been a researcher at the National Fisheries Institute (INP) and the Polytechnic School of the Litoral (ESPOL), and professor at the Pontifical Catholic University of Ecuador (PUCE) - Bahía de Caráquez Campus. The research projects in which he has participated include related to Environmental Sciences, Fisheries Oceanography, Adaptation to Climate Change, Disaster Risk Management, and Impacts of the El Niño and Southern Oscillation Event in Latin America. He obtained his Oceanographic degree and Master of Environmental Sciences in ESPOL. Telmo has been directly linked with the Joint Regional Oceanographic Research Cruises Program in the Southeast Pacific, has been a member of the Scientific Committee for the Regional Study of the El Niño Phenomenon (ERFEN) of the Permanent Commission of the South Pacific (CPPS), Coordinator Institutional of the National Program on Climate, and Institutional Delegate to the Scientific Advisory Group of the Ecuadorian Antarctic Institute (IAE).

**Monday June 11th, 2018**
**Day 1: Identifying Key Challenges**

Climate change is a present and growing challenge, affecting the physical environment in complex ways, and creating significant shifts in the range, distribution, and productivity of key commercial species. The Humboldt Current region is an area defined by significant levels of inter-annual variability, and some of the largest and most important fisheries in the world. The oceanography of the region varies from Ecuador to Chile. While some species are unique to different regions within the Humboldt Current, many species are currently distributed across the region. These distributions are likely to change with climate variability creating challenges for fisheries managers, fishers, and fishing communities. The goal of the first day of this workshop is to understand the drivers of change in this system, understand the current knowledge on the physical and biological status of the system, and discuss likely future changes in the system. This discussion will help to set the stage for understanding the needs for science to inform management and to begin to develop a research agenda for the Humboldt Current.

8:30 AM Arrive at EDF Office
8:30 AM – 9:00 AM Breakfast (in pre-function area outside meeting room)
9:00 AM – 9:20 AM Welcome & workshop overview
9:20 AM – 10:30 AM Introductions: Presentations from each participating institution on existing research programs, key research questions, program goals and key challenges identified to date (10 minute presentations)

10:30 AM – 10:45 AM Break
10:45 AM – 12:30 PM What is changing in environment: Identify the likely physical effects of climate change on the Humboldt Current ecosystem (e.g., changes in upwelling intensity and location (driven by winds, temperature, etc.), and questions that remain unanswered 8

Summarize and discuss collective understanding of main ecosystem drivers in the Humboldt Current and how they may be affected by climate change
Identify key questions regarding how climate change will impact these dynamics

Identify areas we feel we have more certainty/less certainty about; research gaps on physical/environmental side of things

1:45 PM – 3:00 PM What is changing in fisheries: Identifying changes to fisheries resulting from environmental variability
Environmental and stock variability (inter-annual and decadal variability)
Changes in average productivity
Movement of targeted species (introduction, loss, straddling stocks)

3:00 PM – 3:15 PM Break
3:15 PM – 4:30 PM In-depth small group discussions regarding the implications of impacts to fisheries – challenges and opportunities in the Humboldt Current, including socioeconomic implications
Why are these issues a challenge for management?
What are some ways these challenges could be overcome?

Group A: Environmental and stock variability
Group B: Changes in average productivity
Group C: Movement of targeted species
4:30 PM – 5:30 PM Small groups report out
What fishery effect did each group discuss?
What are the scientific and management responses that need to be overcome to address this challenge?

**Day 2: Building a Plan for Success**
Science informing decision-making is not just about addressing the right research questions. It is about aligning the capabilities of science with the mounting challenges fishery managers will face under a changing climate. This requires that we think anew about ways to foster more durable relationships between scientists and decision-makers to identify and address priority knowledge gaps. We will build on yesterday's sessions to have a vibrant discussion around ways to bring these worlds closer together.

9:00 AM – 9:45 AM Review & refine lessons from Day 1
How will the Humboldt Current ecosystem be affected by climate change?
What scientific questions do we still have about these effects?
What management challenges are created by these effects?

9:45 AM – 11:00 AM Identifying tools and approaches that are appropriate for addressing management challenges, including:
Bioeconomic modelling illustrating insights to management interventions
EBFM
Adaptive management
Scenario planning
Management strategy evaluation

Prioritizing tools and approaches, including identifying those that currently exist, and what new research initiatives are needed to create new approaches

11:00 AM – 11:15 AM Break
11:15 AM – 12:00 PM Envisioning success for Humboldt Current fisheries: developing a collaborative research agenda for a shared 10 year vision
What are the key attributes of a successful ecosystem wide research agenda for the Humboldt Current?
What are the big open scientific questions that need to be addressed? What does success look like?

12:00 PM – 1:00 PM Lunch
1:15 PM – 2:15 PM Envisioning success for Humboldt Current fisheries: developing a collaborative research agenda for a shared 5 year vision
What are the key attributes of a successful ecosystem wide research agenda for the Humboldt Current?
What are the big open scientific questions that need to be addressed?
What does success look like at a 5 year timeframe?
What are the institutional needs and collaboration required to achieve our research agenda?

2:15 PM – 3:30 PM Developing a collective work plan
3:30 PM – 3:45 PM Conclusions and next steps