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Preface

Overview of recent advances in oceanographic, ecological and fisheries research on oceanic islands in the southeastern Pacific Ocean

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The Chilean oceanic islands have been received little attention, both scientifically and in terms of conservation. In fact, the first marine protected areas around these islands were created in the last two years, 10 years behind those established in continental Chile. This occurred in spite of the high concentration of endemic species (Fernández *et al.*, 2014; Pérez-Matus *et al.*, 2014; Rodríguez-Ruiz *et al.*, 2014) and growing fishing pressure around Chile's oceanic islands (Castilla *et al.*, 2014; Zylich *et al.*, 2014). Nonetheless, a few sporadic studies, associated with both national (*e.g.*, CIMAR, Yáñez *et al.*, 2008) and international initiatives (*e.g.*, Friedlander *et al.*, 2013), have contributed to our knowledge of the ecosystems associated with seamounts and oceanic islands in Chile. This special volume presents a review and analysis of the current information available on marine ecosystems associated with the oceanic islands in the Juan Fernández Archipelago and Easter Island Province (Easter and Salas y Gómez islands).

Oceanic islands are characterized by their isolation, small size and volcanic origins. At distances of 3700 and 3400 km respectively, Easter and Salas y Gómez islands are more isolated than other oceanic islands of Chile. Meanwhile, the Juan Fernández Archipelago (made up of the Robinson Crusoe, Alejandro Selkirk and Santa Clara islands) are 600 km from continental Chile. Chile's oceanic islands are substantially smaller than other Pacific islands (Hawaii: 28,310 km^2, Galápagos: 45,000 km^2). Easter Island is 164 km^2; Robinson Crusoe Island is 47.94 km^2; Alejandro Selkirk Island is 49.5 km^2; Salas y Gómez Island is 2.5 km^2; and Santa Clara Island is 2.21 km^2 (Newman & Foster, 1983; Rodrigo & Lara, 2014). These islands are the visible peaks of a chain of seamounts and volcanoes known as the Easter-Salas y Gómez Seamount Chain (*e.g.*, Kingsley & Schilling, 1998; Simons *et al*., 2002) and Juan Fernández Ridge (Rodrigo *et al*., 2014).

Rodrigo & Lara (2014) and Rodrigo *et al.* (2014) conducted a qualitative and quantitative morphological analysis of the seamount chains and oceanic islands. They used recent bathymetric compilations that include combined satellite derived and shipboard data ("Global Topography"), multibeam bathymetric data (from NGDC-NOAA), and a magnetic data set, to establish clues about the origin of both seamount chains and their relationships with regional tectonics. Rodrigo *et al.* (2014) identified 514 seamounts along 2900 km of the Easter Submarine Alignment. In general, the largest seamounts (>1000 m in height) are aligned and have a larger volume, with an elongation of their bases along the seamount chain. On the other hand, smaller seamounts tend to be distributed more randomly with circular bases. The best possible mechanism to explain the origin of the seamount chains that emerged from the morphological analysis is the existence of a localized hotspot west of Salas y Gomez Island. The Easter Fracture Zone, which produced crustal weakening, may also have contributed in the Easter Island region (Rodrigo *et al*., 2014). These hotspots could explain the substantial portion of the Easter Submarine Alignment sea floor occupied by seamounts (27%; Rapopport *et al*., 1997) in comparison with the Eastern Pacific (6%; Rapopport *et al.*, 1997).

Rodrigo & Lara (2014) characterized the bathymetry along the 800 km alignment of the Juan Fernández Ridge, which ranges from the Friday and Domingo seamounts in the west to the O'Higgins seamount in the east. The results show a continuous west-east corridor with a base at ~3900 m depth formed by four groups of seamounts/islands with a total of 22 summits. From east to west the four seamount/islands clusters are a) Gamma and Beta seamounts, b) Alfa Seamounts and Robinson Crusoe Island, c) Duke, Cinque Ports and Dresden seamounts along with Alejandro Selkirk Island, and d) Friday and Domingo seamounts. The superposition of the magnetic pattern of the western and eastern Juan Fernández Ridge segments, which showed no correlation with bathymetry, suggests that the faults/fractures of the Nazca Plate played a role in the ridge's formation. Although geological evidence supports the hypothesis of a fixed mantle plume for the origin of Juan Fernández Ridge. Rodrigo & Lara (2014) suggest that tectonic processes play a role, fueling the global controversy about these competing processes.

Islands and seamounts have an important influence on oceanographic patterns. The interaction between the physical forcings (*e.g.*, wind and currents) and the seamount/island topography fosters the formation of meso and submesoescale eddies, which promotes the injection of macro and micronutrients into the euphotic zone stimulating biological productivity (Sangrà *et al.*, 2007; Hasegawa *et al.*, 2009; Andrade *et al.*, 2014a, 2014b, 2014c). In the chain of seamounts and islands associated with the Easter Submarine Alignment and the Juan Fernández Ridge, significant increases in Chl-*a* have been observed, the variability of which is strongly influenced by the presence of meso and submesoscale eddies (Andrade *et al.*, 2014a, 2014c). Surface and subsurface mesoscale eddies formed along the continental coast travel west at speeds on the order of 2 km d^{-1} (Hormazábal *et al.*, 2013; Andrade *et al.*, 2014a). Depending on the disapation methods, some of these eddies may reach Easter Island after ~5 years while others may reach Robinson Crusoe Island after ~8 months (Andrade *et al.*, 2014a, 2014b). The surface and subsurface anticyclonic eddies that interact with the Juan Fernández Archipelago are formed primarily within the coastal transition zone between 33° and 39°S (Andrade *et al.*, 2014a). The transport associated with these eddies could have deep implications for the connectivity of biological communities between islands and between island and mainland areas.

On a smaller scale, Andrade *et al.*, (2014b, 2014c) show that the observed formation of submesoscale eddies around Eastern Island and the Juan Fernández Archipelago could be associated with a strong incident flow produced in the contact area between mesoscale eddies and islands. The submesoscale structures have similar sizes to the islands and the Chl-*a* concentrations are several times higher than in adjacent oceanic waters (Andrade *et al.*, 2014b, 2014c). The formation of these structures could be essential for supporting biological activity during the periods in which minimal Chl-*a* concentrations are observed in the region.

Low levels of nutrients, biomass and primary production as well as scant seasonal variation in biomass and planktonic community composition are observed in extremely oligotrophic regions of the ocean. The south Pacific subtropical gyre, where Easter and Salas y Gómez islands are located, has the lowest concentrations of pigments and dissolved organic matter in the world, making them the clearest ocean waters on the planet. Von Dassow & Collado-Fabri (2014) reviewed key aspects of the plankton ecosystem and biogeochemical functions relevant to the understanding of marine environments around Easter and Salas y Gómez islands. The scarce information available (only 10 biological oceanographic expeditions have entered this zone in 105 years, 1905-2010), suggests that plankton production is limited by a lack of dissolved inorganic fixed nitrogen, not phosphorous (Von Dassow & Collado-Fabri, 2014). The availability of phosphates allows for nitrogen fixation, unless another necessary element, such as iron, is limiting. Short-term experiments have suggested iron is not limiting, yet iron still likely limits nitrogen fixation, and thus production, at longer time scales, as the presence of nitrogen-fixers is exceptionally low compared with that of other ocean gyres. Although diatoms known to contain nitrogen-fixing cyanobacteria (*Rhizosolenia* and *Hemiaulus*) appear to be well represented in the waters near Easter and Salas y Gómez islands, a diverse group of heterotrophic, nitrogen-fixing bacteria or photoheterotrophic cyanobacteria may dominate nitrogen fixation in the south Pacific subtropical gyre (Von Dassow & Collado-Fabbri, 2014). The prevalence of these nitrogen-fixing organisms could explain the region's lack of response to iron injection, given their functional differences from autotrophic fixers. Despite the low rate of nitrogen fixation, plankton communities are maintained in the euphotic zone (Von Dassow & Collado-Fabbri, 2014).

The south Pacific sub tropical gyre represents a center of high biodiversity for picoplankton, as well as heterotrophic organisms such as tinntinids, siphonophores, and possibly amphipods, although data for key zooplankton, such as copepods, are lacking. Bacterioplankton and small detritus particulates account for up to 83% of the organic carbon and small unicellular organisms, picoplankton (<3 µm), dominate the plankton in this region (Von Dassow & Collado-Fabbri, 2014). In the waters near Easter and Salas y Gómez islands picophytoplankton represents only 3% of the organisms present on average, while the green cyanobacteria *Prochlorococcus* represents up to 27%. In this area, the abundance of diatoms and dinoflagellates (>15 µm) is lower than that of bacterioplankton (10 millon times less), that of *Prochlorococcus* (4 million times less), and that of picophytoeukaryotes (50-250,000 times less; Von Dassow & Collado-Fabbri, 2014). Furthermore the biomass of mesozooplankton (>200 µm) is extremely low, 10% lower than that recorded in areas of coastal upwelling and in the Humboldt Current System (Von Dassow & Collado-Fabbri, 2014).

Although the marine environments surrounding the oceanic islands of Chile are characterized by the presence of seamounts (Rodrigo *et al.*, 2014; Rodrigo & Lara, 2014) and to a lesser extent, of hydrothermal vents, both types of ecosystems have been poorly studied. Only during the last decade were conducted the first explorations to characterize the biodiversity of marine communities associated with seamounts in the Juan Fernández Archipelago (Yañez *et al.*, 2009) and Salas y Gómez Island (Friedlander *et al.,* 2013). Although we highlight these contributions within the EEZ of Chile, the review by Fernández *et al.* (2014) suggests that sampling effort is still poor for this area. This low sampling effort explains why the species richness of seamounts inside the EEZ is only 7% of that found on seamounts near Salas y Gómez Island, outside the EEZ (Fernández *et al.*, 2014). The same pattern is found when analysing different taxa individually (7.4% fishes, 2.6% for crustaceans; in Fernández *et al.*, 2014, estimated from Parin *et al.*, 1997; Stocks, 2009; Friedlander *et al.,* 2013). These results show how little we currently know about biodiversity on seamounts. However, our knowledge about hydrothermal vents is even more limited. To the southwest of the EEZ of Easter and Salas y Gómez islands there is a series of hydrothermal vents on top of a dynamic fault system that shows the highest rate of plate dispersion in the world (Rappaport *et al.,* 1997; Hey *et al.,* 2006). These environments remain completely unexplored within Chile's EEZ, despite the fact that they could represent a break in species' dispersal in this area (Won *et al.*, 2003).

The coastal areas in this region are better studied. Fernández *et al.* (2014) compiled, synthesized and analyzed published information about the biodiversity of macroalgae, macroinvertebrates and fishes associated with Easter and Salas y Gómez islands, advancing the characterization of this biogeographic province. Species richness in Eastern Island has increased over time, as sampling effort has increased, suggesting that more studies are needed to characterize marine biodiversity even in the most studied areas (Fernández *et al.*, 2014) and even for conspicuous groups, such as seabirds (Flores *et al.,* 2014). Clearly, this pattern shows, on one side, the important contribution of recent studies, and, on the other hand, the need to focus research efforts on oceanic islands. Easter and Salas y Gómez region shows higher species richness of mollusks, fishes and total (all taxa) than the Juan Fernández Archipelago, although only 6.4% of the species are shared, suggesting a different colonization origin between both groups of oceanic islands (Fernández *et al.*, 2014). However, when compared with other oceanic Pacific islands, species richness is low (*e.g.*, fish; Fernández *et al.*, 2014, based on Randall & Cea, 2011), which is explained by a combination of factors, including the geological age of the island (relatively young), the low diversity of habitats, and the location at intermediate latitudes. Species richness of seabirds and marine mammals is also low, most likely related to the small sampling effort directed towards these conspicuous groups. Flores *et al.* (2014) reviewed published and grey literature on seabirds inhabiting Easter, Salas y Gómez and Desventuradas islands and their adjacent waters and found only 37 species reported. As for other taxa, more species of birds have been reported in Easter Island (25 spp.) than in Salas y Gómez Island (16 spp.; Flores *et al.*, 2014; Fernández *et al.,* 2014, for other taxa). Easter and Salas y Gómez islands share a significant number of species of birds while fewer species are shared between Salas y Gómez and Desventuradas islands, supporting the hypothesis that Desventuradas Islands belong to a different biogeographic province and that the waters surrounding Easter and Salas y Gómez islands can be considered a single biogeographic province. This kind of analysis cannot yet be conducted with other taxa due to the enormous differences in sampling effort among islands (Fernández *et al.*, 2014).

Marine mammals have received more attention than seabirds. Five cruises focusing on marine mammals were carried out between 1993 and 1995 in the Easter and Salas y Gómez region (Aguayo *et al.*, 1998a). Hucke *et al.* (2014) reviewed the results of these expeditions as well as other sources of information and confirmed the presence of 12 species belonging to five marine mammal families (Balaenopteridae, Physeteridae, Ziphiidae, Delphinidae and Phocidae) within the area of Easter and Salas y Gómez islands. However, more species are expected to use the oceanic waters surrounding Easter and Salas y Gómez islands since the area falls within their distributional range.

The isolation of these oceanic islands explains the high levels of endemism reported thus far. Fernández *et al.* (2014) analyzes the updated list of species reported for Easter and Salas y Gómez islands and shows high levels of endemism for the majority of the taxonomic groups, with mollusks and poriferans exhibiting the highest levels overall (33%-34%). Fewer species are shared between Easter and Salas y Gómez islands and continental Chile (Fernández *et al.,* 2014) than between these islands and Juan Fernández Archipelago, or between the archipelago and continental Chile (Pérez-Matus, 2014; Rodríguez-Ruiz *et al.,* 2014). These findings, based on the limited information available, suggest the need to increase research efforts and science-based conservation plans to preserve the unique species in oceanic island ecosystems.

In spite of the gaps in knowledge characterizing marine biodiversity, recent research directed towards coastal communities has expanded our knowledge beyond simple lists of species. Recent studies in Easter, Salas y Gómez, and Robinson Crusoe islands have focused on community structure. Additionally to the comparative work by Friedlander *et al.* (2013), Pérez-Matus *et al.* (2014), Wieters *et al.* (2014) and Rodríguez-Ruiz *et al.* (2014) report the most recent studies conducted in the inter and subtidal in the representative habitats of Juan Fernández Archipelago and Easter Island that characterize community structure. Pérez- Matus *et al.* (2014) characterized the coastal ichthyofauna of Robinson Crusoe Island, presenting the first analysis of reef fish and macrobenthic community structure in Juan Fernández Archipelago. Rodríguez-Ruiz *et al.* (2014) also conducted recent research in Juan Fernández Archipelago, characterizing coastal communities, from the intertidal to the subtidal zone, studying the three recently created Marine Parks: Tierras Blancas, El Arenal and El Palillo. Among the most relevant patterns in coastal communities at Robinson Crusoe Island, we highlight: a) the dominance of foliose brown and red macroalgae at protected sites, while sessile species (*i.e.*, cnidarians, vermetids, barnacles) structure the substratum at exposed sites (Pérez-Matus *et al.*, 2014), b) high algal species richness and abundance, both in the intertidal and subtidal zones, and particularly high abundance of filamentous algae at sites exhibiting high disturbance (extensive sand dynamics), in comparison with corticated algae and a greater diversity of functional groups at low disturbance sites, c) herbivorous invertebrates, particularly gastropods, dominate the intertidal, while the subtidal is dominated by detritivores, especially at sites were fur seal colonies were present, d) the highest fish abundance was recorded in subtidal habitats of the site were fur seal colonies were not present (El Palillo), and e) carnivorous fish, consumers of benthic invertebrates, dominated Robinson Crusoe's coastal habitats, where a negative relationship between fish abundance and benthic invertebrate abundance was found (Rodríguez-Ruiz *et al.*, 2014).

The characterization of the inter-and subtidal coastal habitats of Robinson Crusoe Island also allowed the advance of hypotheses about processes affecting community structure (Pérez-Matus *et al.*, 2014; Rodríguez-Ruiz *et al.*, 2014). Pérez-Matus *et al.* (2014) suggest that habitat-structuring species (*e.g.*, brown algae) explain fish species composition, since differences in the composition of substratum species and architectural complexity, rather than changes in abiotic factors such as depth, drive species composition and abundance. To explain the patterns of species abundance and distribution in inter and subtidal areas reported above, Rodríguez-Ruiz *et al.* (2014) suggest the following processes structuring coastal communities: a) low grazing levels in intertidal zones (explained by low richness and abundance of grazers, which cannot control primary producers, thus the community is dominated by algae), b) a potential trophic cascade (which may explain the negative correlation between invertebrate abundance and fish abundance, which in turn is negatively correlated with fur seal abundances), c) sediments enrichment (biodeposits from the fur seal colonies in coastal sediments may support the higher biomass of deposit-feeding sea cucumbers at sites hosting fur seals, compared with sites farther away from such naturally-enriched habitats; *i.e.*, El Palillo), and d) disturbance (specifically sand dynamics, which may explain the dominance of different functional groups of algae among sites).

Wieters *et al.* (2014) focused on the most prominent habitat in the coastal areas of Easter Island, coral reefs, using a trait-based view of communities rather than the traditional species-based approach, to study ecological responses to environmental change in a system undergoing degradation. Among their results, Wieters *et al.* (2014) highlight the lack of zonation in coral reef abundance, in contrast to the common reduction in total coral abundance in deeper sites (>20 m), which is explained by the persistently clear oceanic waters characterizing Easter Island. It is also remarkable that spatial patterns of distribution of functional community structure did not follow geographic characteristics, but rather showed a strong similarity in benthic and fish functional groups among sites, suggesting a strong coupling with coastal oceanographic conditions that varies on small scales. Wieters *et al.* (2014) not only analyze spatial patterns, but also report temporal variability in the functional structure of shallow hard bottom communities, showing a consistent increase in coral abundance in shallow habitats over the past 15 years despite the deterioration of fish assemblages (low fish abundances and small body sizes due to fishing pressure; Friedlander *et al.*, 2013). Disturbance, changes in coral settlement, released competition and escape from predation are some of the processes proposed by Wieters *et al.* (2014) to explain the observed patterns. These studies (Pérez-Matus *et al.*, 2014; Rodríguez-Ruiz *et al.*, 2014; Wieters *et al.*, 2014) have significantly advanced the study of and proposed processes structuring coastal communities. However, we know very little on the important and increasing human effects on coastal marine communities in ocean islands, such as fishing.

Arana (2014) nicely describes ancient fishing boats and gears, though it is difficult to establish a concrete idea of the real importance of fishing on this island before the arrival of Europeans. Nonetheless, the numbers of fish hooks found in caves and archeological excavations, the abundant representation of marine animals in petroglyphs and the frequent inclusion of sea-related themes in the island's folklore suggest the use of fish protein from ancient times. In fact, the islanders identified distinct fishing zones (Arana, 2014). The tactics and methods used bear close relation to the systems of other Polynesian islands, demonstrating notable adaptation to the resources available on this island. Aside from tuna, the islanders consumed several snails species, sea urchins, crabs, octopus and anemones. Under the influence of European customs, the introduction of domesticated animals and the farming of foreign species, fishing declined. At present, the old traditions have been lost and fishing is now more of a complementary contribution to the diet of island dwellers, allowing them to vary their daily menu, which is mainly based on land products. However, fishing effort has increased to meet the demands of a growing tourist industry.

The increase in fishing effort is, in part, reflected in studies by Castilla *et al.* (2014) and Zylich *et al.* (2014). Using anecdotal information, historical descriptions and the limited quantitative information available, Zylich *et al.* (2014) reconstructed fisheries catches in the EEZ of Easter and Salas y Gómez islands between 1950-2010, identifying two fisheries: the local, domestic, small scale fisheries, and the foreign, large scale fisheries. Castilla *et al.* (2014) report that the local, domestic, small-scale fisheries can be deconstructed in three groups of fisheries depending on the use of boats and gear. Although 29 species are exploited in Easter Island, the main species targeted were Pacific chub (*Kyphosus sandwicensis*) and yellowfin tuna (*Thunnus albacares*), with spiny lobster (*Panulirus pascuensis*) as the most exploited invertebrate species (Castilla *et al.,* 2014). The reconstructed fishing history suggests that domestic fisheries catches have increased substantially since the late 1970s, mostly explained by the increase in offshore catches, specifically of *T. albacares*, which in turn may be related to the five-time growth in tourist arrivals on the island in the last 40 years. The estimated legal catches (Zylich *et al.,* 2014) match the annual landing reported by Castilla *et al.* (2014), ranging between 109 and 171 ton yr^{-1} during 2000-2009. Using different approaches Castilla *et al.* (2014) and Zylich *et al.* (2014) also conclude that a) yellowfin tuna is the main exploited species, and b) in spite temporal fluctuation, total catch has remained stable during the last decade. However, fishery data collection is poor and there appears to be a lack of scientific rigor in the information collected, affecting the estimates of total catch. Castilla *et al.* (2014) report that annual landings from SERNAPESCA (Servicio Nacional de Pesca, Chile) show serious flaws, including catches of species that are not found in the region. Additionally, there is no official information for intertidal or subtidal marine organisms extracted by food-gathers. Both studies also emphasize that illegal fishing by industrial vessels in this oligotrophic system is substantial and a probable cause in the declining artisanal catch of tuna by Rapa Nui fishers (Castilla *et al.,* 2014; Zylich *et al.,* 2014). However, signs of overexploitation have also been observed for resources exploited by the domestic fleet.

The studies included in this volume conclude that, in spite of the advances in our knowledge of the marine ecosystems associated with oceanic islands in the last decades, more efforts are needed to fully understand ecosystem functioning. Multiple approaches, which are not mutually exclusive, are suggested: a) take advantage of local knowledge and interest, b) optimize sampling efforts and broaden research opportunities to include multiple fields in each expedition to the area, c) enhance the temporal scale of the studies, and d) create local facilities to develop a permanent research program, offering opportunities to local and visiting scientists, for interdisciplinary work, for involvement of the local community, and for development of science-based outreach programs. The development of a marine research laboratory on the islands would improve the management and conservation of these unique, fragile marine environments associated with oceanic islands, and since it would be locally-based, has the potential to incorporate local fisheries practices and knowledge.

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