Lat. Am. J. Aquat. Res., 37(3): 555-570, 2009
"Deep-sea fisheries off Latin America"
P. Arana, J.A.A. Perez & P.R. Pezzuto (eds.)
DOI: 10.3856/vol37-issue3-fulltext-20

Review

Seamounts in the southeastern Pacific Ocean and biodiversity on Juan Fernandez seamounts, Chile

Eleuterio Yáñez[1], Claudio Silva[1], Rodrigo Vega[2], Fernando Espíndola[3], Lorena Álvarez[1], Nelson Silva[1], Sergio Palma[1], Sergio Salinas[1], Eduardo Menschel[2], Verena Häussermann[4], Daniela Soto[1] & Nadín Ramírez[1]

[1]Pontificia Universidad Católica de Valparaíso, P.O. Box 1020, Valparaíso, Chile
[2]Universidad Austral de Chile, P.O. Box 567, Valdivia, Chile
[3]Instituto de Fomento Pesquero, P.O. Box 8-V, Valparaíso, Chile
[4]Fundación Huinay, P.O. Box 462, Puerto Montt, Chile

ABSTRACT. Seamounts are vulnerable marine ecosystems. In Chile, information on these ecosystems is quite scarce; thus, a compilation of information on their geographical distribution and biodiversity is presented herein. A total of 118 seamounts distributed in the Chilean EEZ are identified and characterized. Additionally, an *in situ* assessment was carried out on the Juan Fernandez seamounts 1 and 2 (JF1 and JF2), which were also oceanographically characterized. Phytoplankton, zooplankton, and marine invertebrate samples were collected and an exploratory fishing survey was executed using different gears. According to the bibliographical review, a total of 82 species have been collected on the JF1 and JF2 seamounts, highlighting findings of black coral species caught in lobster traps at the Juan Fernandez Archipelago. Submarine images of the marine substrate at JF1 and JF2 reveal characteristics attributable to the impact of bottom dredges, coinciding with the information obtained from the trawling fleet. The fishing activity was carried out primarily at JF2 (4,667 km of trawling). The monthly fishing effort increased considerably in 2002, 2003, and 2005, reaching values above 500 km of trawling and, thus, modifying the spatial structure of the resource aggregates on the JF2 seamount.

Keywords: seamounts, identification, biodiversity, fishing impact, Juan Fernández Archipelago, southeastern Pacific.

Montes submarinos en el océano Pacífico suroriental y biodiversidad en el cordón de Juan Fernández, Chile

RESUMEN. Los montes submarinos constituyen ecosistemas marinos vulnerables. Chile presenta una escasa información acerca de estos ecosistemas, por lo que este trabajo recopila información sobre distribución geográfica y biodiversidad. Se identifican y caracterizan 118 montes en la ZEE de Chile. Adicionalmente, una evaluación *in situ* se desarrolló sobre los montes Juan Fernández 1 y 2 (JF1, JF2), caracterizándolos oceanográficamente. Se recolectaron muestras de fitoplancton, zooplancton e invertebrados marinos, y se realizó pesca exploratoria con diversos artes. La revisión bibliográfica establece que en JF1 y JF2, se han capturado un total de 82 especies, destacándose la presencia de corales negros en trampas langosteras en el archipiélago de Juan Fernández. Fotografías submarinas de los montes JF1 y JF2 presentan características atribuibles al impacto de artes de arrastre de fondo, concordante con información de la flota. El esfuerzo de pesca se realizó mayormente en JF2 (4.667 km arrastrados). El esfuerzo de pesca mensual se incrementó considerablemente durante el 2002, 2003 y 2005, alcanzando valores sobre 500 km arrastrados, modificando la estructura espacial de las agregaciones de recursos en el monte JF2.

Palabras clave: montes submarinos, identificación, biodiversidad, impacto pesquero, archipiélago de Juan Fernández, Pacífico suroriental.

INTRODUCTION

The marine environment is currently under serious depletion as a result of overfishing, contamination, and the direct and indirect impacts of climate changes. The anthropogenic and climate impacts observed in many places have caused dramatic changes in ecosystems. This is the case of seamounts, vulnerable marine ecosystems in which a decrease of biostructure-forming species and a collapse of oceanic fisheries have been observed. The vulnerability of these ecosystems is related to the possibility that a population, community, or habitat will experience a substantial alteration, which may be irreversible or of slow restoration (FAO, 2007). The international information on seamount biodiversity and ecology is limited, especially for those at depths exceeding 300 m (Tracey *et al.*, 2004). Therefore, although thousands of seamounts are estimated to exist around the world, only around 200 have been biologically sampled, in most cases, during commercial fishing activities (Probert *et al.*, 1997; Gálvez *et al.*, 2006).

In Chile, there is lack of information for an undetermined number of seamounts in the Economic Exclusive Zone (EEZ). Research on seamount biodiversity along the Chilean coast has been carried out since 1950, mainly by the Russian government on the Nazca and Salas and Gomez ridges, beyond the EEZs of Chile and Peru (Parin *et al.*, 1997). The information on the Juan Fernandez Archipelago (33ºS-78ºW) is limited to the H.M.S. Challenger scientific expedition (1873-1876), the Pacific Swedish expedition (1916-1917), and the B/I Anton Bruun expedition (1966) (Rozbaczylo & Castilla, 1987), as well as the oceanographic cruises MARCHILE VIII and IX of 1972 and 1973, respectively (Cerda, 1977), the CIMAR 5 and 6 Oceanic Islands cruises in 1999 and 2000 (Rojas *et al.*, 2004), and the scientific survey of B/I Koyo Maru in 2004 (Zuleta & Hamano, 2004). Furthermore, information has been systematically collected on fauna associated with bottom dredges over Chilean seamounts (Gálvez *et al.*, 2006).

The objective of this work, considering the international demand for information on vulnerable marine ecosystems such as seamounts (Resolution 59/25 of the ONU General Assembly), is to determine the geographical distribution of seamounts in the Chilean EEZ, including a biodiversity and fishing impact study on some seamounts of the Juan Fernandez Archipelago.

MATERIALS AND METHODS

The geographical seamount identification and distribution was determined through the analysis of images generated using 2' x 2' resolution satellite altimetry data (Smith & Sandwell, 1997) and 1' x 1' resolution sounding data (GEBCO, 2003), according to the Kitchingman & Lai methodology (2004). Furthermore, *in situ* assessments were carried out on two seamounts of the Juan Fernandez Archipelago – Juan Fernandez 1 (JF1) and Juan Fernandez 2 (JF2) – through two exploratory campaigns at 247 and 292 m depth, the respective depths of their tops. The first was executed aboard the PAM Portugal II in July-August 2007, and the second was carried out aboard two artisanal boats in November-December 2007: Boat No. 58 Cumberland and L/M Alborada. All the relatively flat area accessible for fishing and sampling systems (over 700 m deep) was systematically gridded (0.5 x 0.5 tenths of degrees), and a grid was randomly selected for sampling.

Three different depth strata were analyzed: pelagic, demersal, and benthic. Different fishing systems were also used: vertical longlines (1,264 hooks), handlines (12 hooks), fishing pots (108 traps), surface longlines (440 hooks), zooplankton nets (10 haul), dredging (5 haul), submarine camera observations (4 observation periods), and oceanographic surveys of the water column (CTD and Niskin Bottles). The surface oceanographic characteristics were analyzed using satellite information (NOAA, TOPEX, SeaWins, SeaWifs).

Additionally, a bibliographical analysis was done to determine the different species previously collected during surveys, cruises, and commercial fishing activities carried out on these seamounts. Finally, an evaluation of the fishing effects index (FEI) (O'Driscoll & Clark, 2005) was done in the same area of study. This index involves data on the fishing effort executed on each seamount, the direction of the trawling, and the seamount area. On one hand, this index measures the fishing density on a seamount as a proportion of its area; on the other hand, it reflects a scale factor that is proportional to the directions the seamount was trawled. A high FEI value may be explained through a heavy effort relative to the seamount size and the fact it was trawled in all directions. The information used for this analysis corresponds to data from fishing binnacles of the industrial trawling fleet operating over orange roughy (*Hoplostethus atlanticus*) and alfonsino (*Beryx splendens*) between 2000 and 2006. The same data was used to analyze the spatial structure dynamics of the resources in 2001 and 2003 through geostatistical techniques.

RESULTS

A total of 118 seamounts were identified in seven areas of the Chilean EEZ (Fig. 1): 35 around Easter Island (25º-30°S, 105º-112°W) (Fig. 2), 21 near San

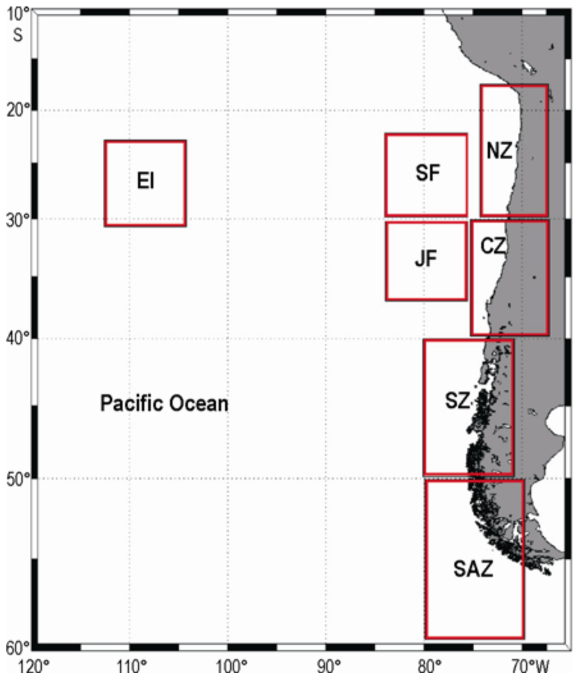

Figure 1. Areas where seamounts were identified in the southeastern Pacific Ocean. NZ: northern zone, EI: eastern island, SF: San Félix island, ZC: central zone, JF: Juan Fernández Archipelago, SZ: southern zone, SAZ: far-southern zone.

Figura 1. Localización de áreas donde se identificaron montes submarinos en el océano Pacífico suroriental. NZ: zona norte, EI: isla de Pascua, SF: isla San Félix, ZC: zona central, JF: archipiélago de Juan Fernández, SZ: zona sur, SAZ: zona sur austral.

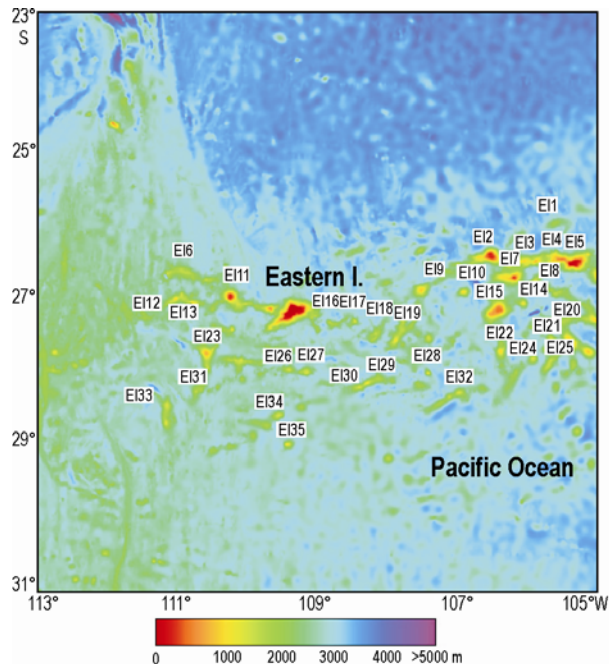

Figure 2. Locations and codes assigned the seamounts identified in the Easter Island area (EI).

Figura 2. Localización y código asignado a los montes submarinos identificados en la zona de Isla de Pascua (EI).

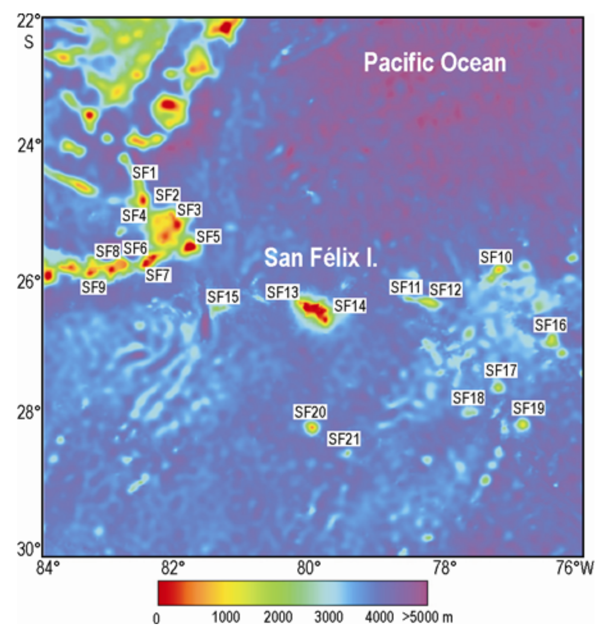

Figure 3. Locations and codes assigned the seamounts identified in the area of San Felix Island (SF).

Figura 3. Localización y código asignado a los montes submarinos identificados en la zona de isla San Félix (SF).

Felix Island (24°-29°S, 76°-84°W) (Fig. 3), 21 off northern Chile (18°-30°S, 71°-75°W) (Fig. 4), 15 around the Juan Fernandez Archipelago (30°-35°S, 76°-82°W) (Fig. 5), eight in the central area of the country (30°-40°S, 71°-76°W) (Fig. 6), nine in the southern area (40°-50°S, 73°-79°W) (Fig. 7), and 10 off far-southern Chile (50°-58°S, 70°-77°W) (Fig. 8). This identification included the geographical location, surface area, and depth of these seamount tops and the designation of codified names (see Yañez *et al.* 2008 for details).

Seamounts JF1 and JF2 have volcanic substrate, which is mainly constituted by bare rock and sand. These seamounts are influenced by several water masses: Subtropical Water (STW), Subantarctic Water (SAAW), Equatorial Subsurface Water (ESSW), and Antarctic Intermediate Water (AAIW), but are predominantly influenced by SAAW and STW (Fig. 9).

The vertical distribution of dissolved oxygen showed a two-layer structure. The well-oxygenated surface structure of approximately 100 m with concen-

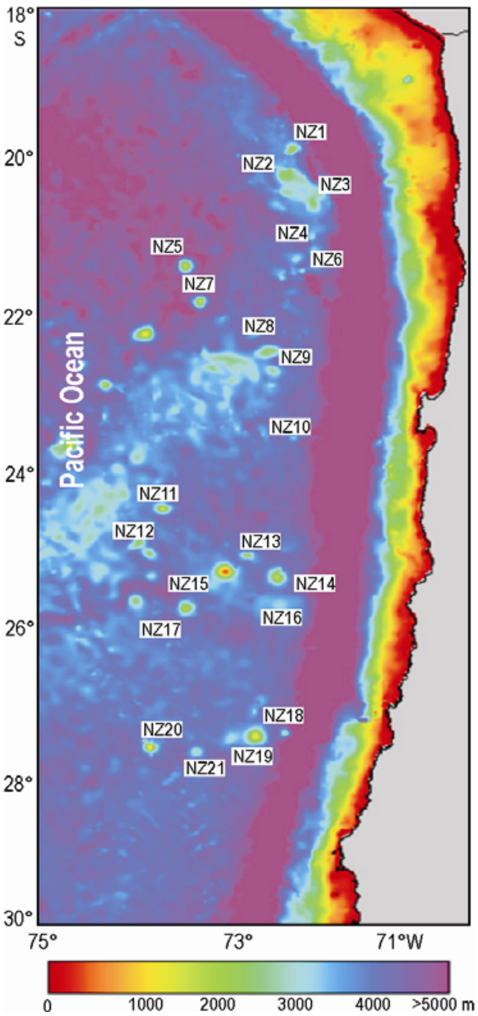

Figure 4. Locations and codes assigned the seamounts identified in the northern zone (NZ) (18°-30°S).

Figura 4. Localización y código asignado a los montes submarinos identificados en la zona norte (NZ) (18°-30°S).

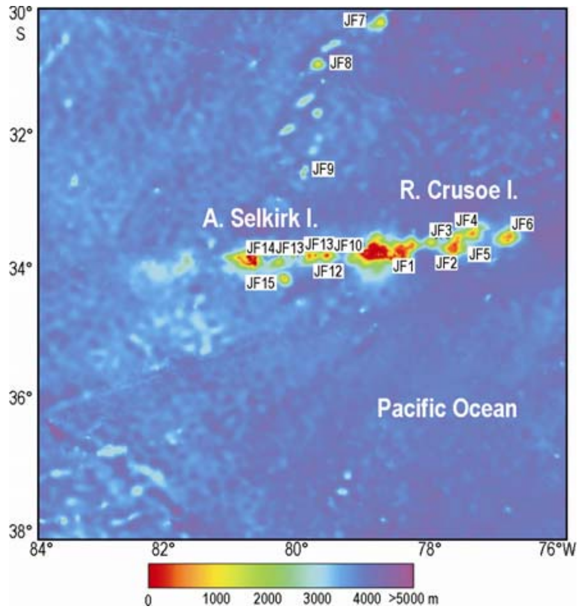

Figure 5. Locations and codes assigned the seamounts identified in the area of the Juan Fernandez Archipelago (JF).

Figura 5. Localización y código asignado a los montes submarinos identificados en el cordón de Juan Fernández (JF).

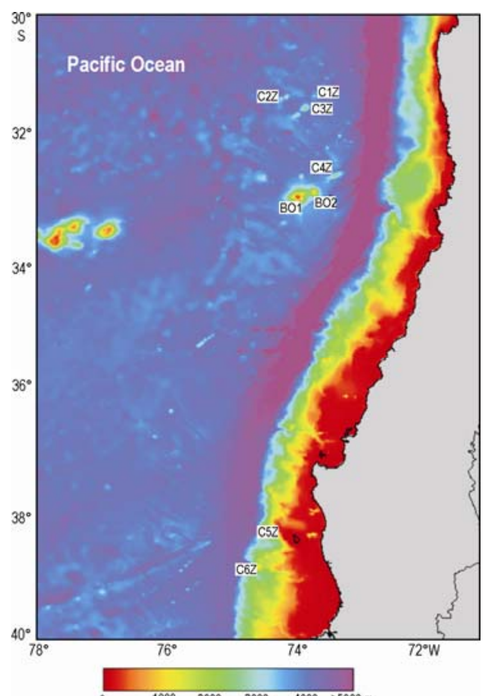

Figure 6. Locations and codes assigned the seamounts identified in the central zone (CZ) (30°-40°S).

Figura 6. Localización y código asignado a los montes submarinos identificados en la zona central (CZ) (30°-40°S).

trations greater than 5 mL L^{-1} (90-100% saturation) is the result of oxygen-atmosphere exchange and primary production in the area. Beneath this layer and at approximately 200 to 300 m depth, the dissolved oxygen was quickly reduced to concentrations of less than 1 mL L^{-1} (5-20% saturation); the latter drop was caused by the presence of ESSW coming from off Peru (Fig. 10). A slight current system was observed in July-August (winter) with sea surface temperature (SST) anomalies that were negative at JF1 and positive at JF2. The SST showed a typical cold condition of 10° to 17°C, surface salinity of approximately 34.3, and chlorophyll concentrations between 0.09 and 1 mg m^{-3}. In November-December (spring), however, a greater amount of mesoscale structures such as shifts

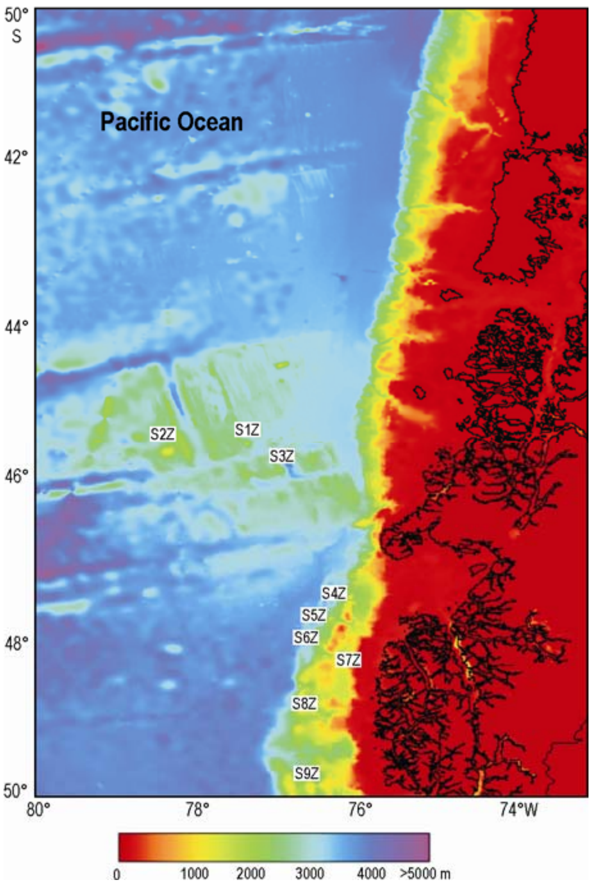

Figure 7. Locations and codes assigned the seamounts identified in the southern zone (SZ) (40°-50°S).

Figura 7. Localización y código asignado a los montes submarinos identificados en la zona sur (SZ) (40°-50°S).

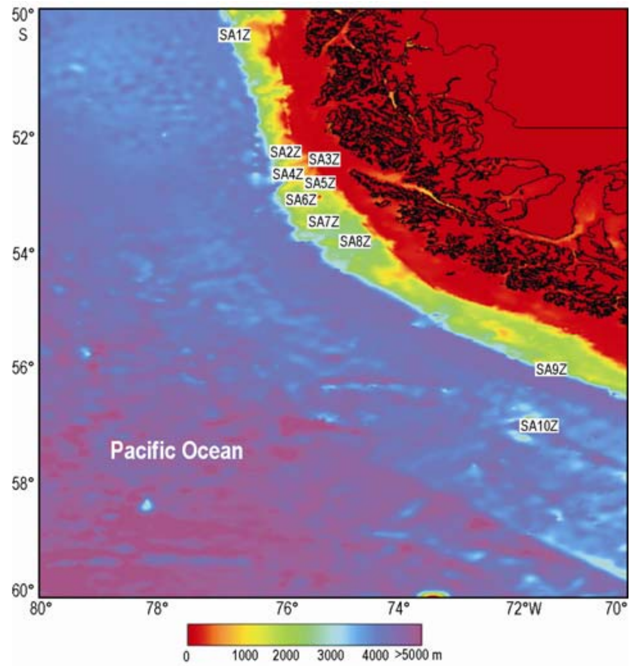

Figure 8. Locations and codes assigned the seamounts identified in the far-southern zone (SAZ) (50°-58°S).

Figura 8. Localización y código asignado a los montes submarinos identificados en la zona sur-austral (SAZ) (50°-58°S).

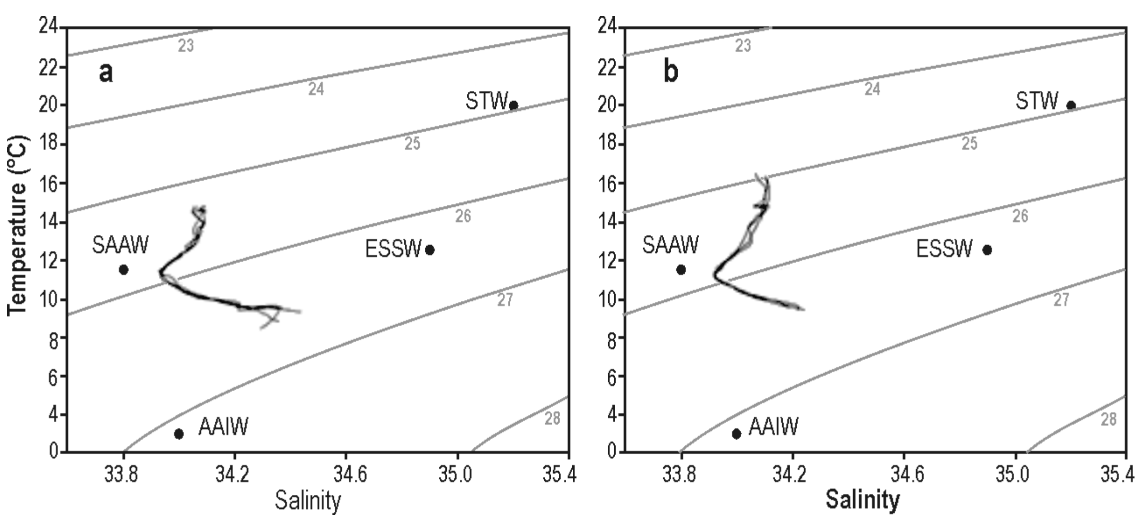

Figure 9. T-S diagram of the oceanographic stations for the seamounts a) JF1 and b) JF2.

Figura 9. Diagrama T-S de estaciones oceanográficas para los montes a) JF1 y b) JF2.

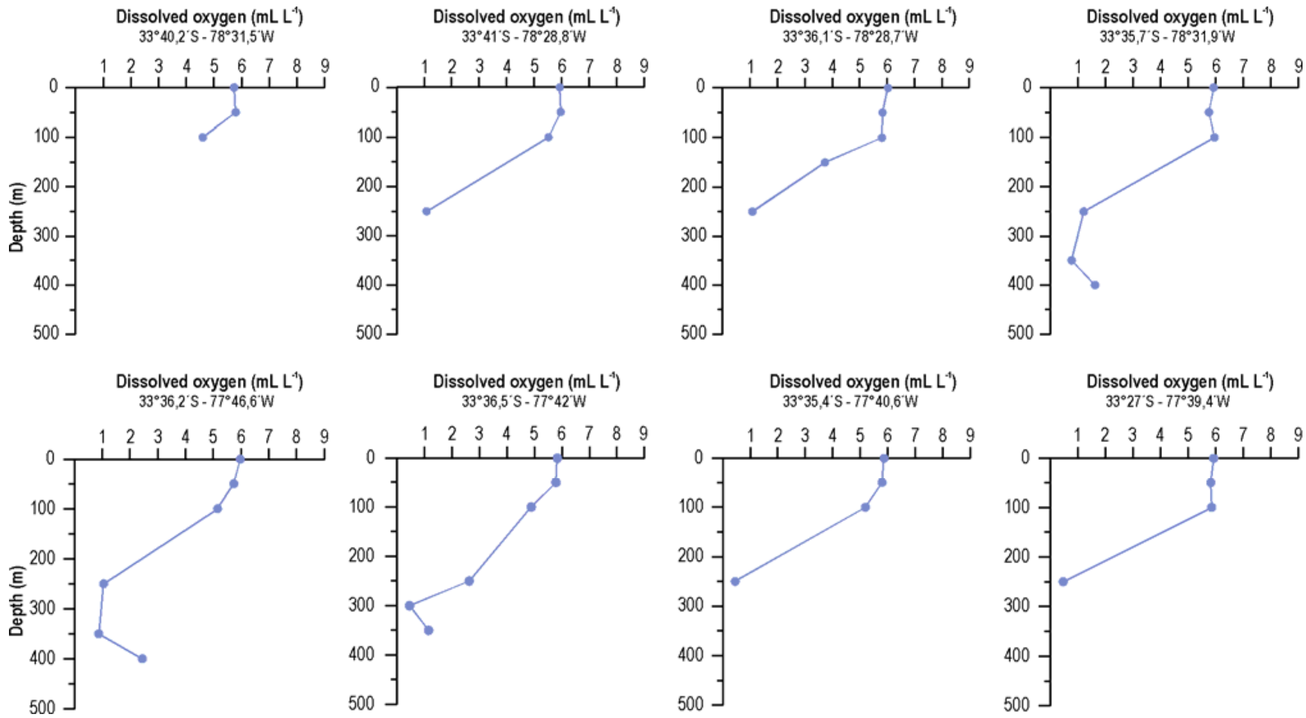

Figure 10. Vertical distribution of dissolved oxygen at eight oceanographic stations.
Figura 10. Distribución vertical de oxígeno disuelto en ocho estaciones oceanográficas.

and currents were observed. The STW showed a cold condition that is typical of the season, with SST of 13 to 18°C; surface salinity close to 34.1, and a chlorophyll-*a* concentration around 4 mg m^{-3}.

The phytoplankton collected on the surveyed seamounts involved seven classes of organisms that were classified into 31 genera, 23 species, and other non-identified species. Fifty percent of the organisms were classified as "other flagellates", another 40% corresponded to the Dinophyceae class, and the remaining 7% included the Bacillariophyceae (3.3%), Ciliata (2.1%), Cianophyceae (1.4%), Dictyochophyceae (0.15%), Chlorophyceae (0.04%), and Acantharia (0.01%) (Table 1). Meanwhile, a total of 52,309 organisms were identified as zooplankton; these were distributed among 16 taxonomic groups belonging to the phyla Cnidaria, Ctenophora, Chaetognatha, Annelida, Nemertina, Arthropoda, Tunicata, and Vertebrata. An 87.8% of the organisms were chitinous (euphausiids, mysids, amphipods, ostracods, copepods, cirripedia, decapod crustacean larvae), 11.6% were gelatinous and semi-gelatinous (jellyfish, siphonophores, ctenophores, chaetognaths, salps, appendicularians, polychaetes, nemertins) and the remaining 0.6% corresponded to ichthyoplankton (*Hygophum brunni*, *Sardinops sagax*) (Table 2).

The fishing methods allowed catches of two pelagic species, blue shark (*Prionace glauca*) and snoek (*Thyrsites atun*); two demersal species, croaker (*Helicolenus lengerichi*) and depth conger (*Pseudoxenomystax nielseni*); and two crustacean species, golden crab (*Chaceon chilensis*) and Juan Fernandez king crab (*Paromola rathbuni*). A total of 409 invertebrates were collected using a dredge. These represented important groups of species such as Echinoidea (Echinacea), Polychaeta, Porifera, Actinaria, and Asteroidea (Table 3). Due to the complexity of the identification, only two taxa have been identified to this date: 1) Asteroidea new species of *Smilasterias* and 2) Gorgonia species *Callogorgia kinoshitae* (Kükenthal, 1913). Only preliminary results are available for other species.

The bibliographical review established that, during the 2001 to 2006 fishing activities, a total of 82 species were collected from the JF1 and JF2 seamounts; these belonged to four phyla (Chordata, Arthropoda, Mollusca, Echinodermata) and the families Macrouridae (9), Moridae (6), and Dalatiidae (4) stood out. The presence of black coral species (*Parantipahes fernandenzii*, *Trisopathes* spp., *Leiopathes* spp.) in lobster traps used around the Juan Fernandez Archipelago deserve mention (Arana *et al*., 2006).

Table 1. Composition and abundance of nano-microplankton (cel L^{-1}) on the seamounts Juan Fernández 1 and Juan Fernández 2. Only the mean of each taxonomic group is indicated.

Tabla 1. Composición y abundancia de nano-microplancton (cel L^{-1}) en los montes submarinos Juan Fernández 1 y Juan Fernández 2. Se indica el promedio de cada grupo.

Station	1		2		3		4		5		6		7		8		Mean
Species / Depth (m)	0	50	0	50	0	50	0	50	0	50	0	50	0	50	0	50	
Acantharia	0	20	0	0	0	0	0	-	0	0	0	0	0	0	0	80	7
Nasselaria	0	20	0	0	0	0	0	s/i	0	0	0	0	0	0	0	80	
Bacillariophyceae	60	140	1040	180	880	960	320	-	620	540	20	160	0	240	2720	1760	643
Bacteriastrum sp.	0	0	0	0	80	0	0	s/i	0	0	0	0	0	0	320	0	
Chaetoceros atlanticus	0	0	0	0	0	0	0	s/i	120	0	0	0	0	0	0	0	
Chaetoceros peruvianus	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	40	0	
Chaetoceros spp.	0	0	0	0	0	0	0	s/i	40	0	0	0	0	0	160	40	
Cylindrotheca closterium	0	0	40	0	0	0	0	s/i	20	20	0	0	0	0	320	160	
Dactyliosolen sp.	20	0	0	0	0	80	0	s/i	20	0	0	0	0	20	280	200	
Nitszchia longissima	0	0	40	0	40	0	0	s/i	0	0	0	0	0	0	0	0	
Nitszchia spp.	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	0	
Pennadas indeterminates	20	80	80	40	180	80	80	s/i	40	320	20	40	0	20	320	160	
Pleurosigma spp.	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	0	
Pseudonitzschia spp.	0	60	840	140	500	760	200	s/i	140	0	0	40	0	160	1040	1200	
Rhizosolenia alata	0	0	0	0	20	0	0	s/i	0	0	0	0	0	0	0	0	
Rhizosolenia bergonii	0	0	40	0	40	0	0	s/i	20	0	0	0	0	0	0	0	
Rhizosolenia spp.	20	0	0	0	0	40	0	s/i	220	200	0	80	0	40	240	0	
Thalassiothrix sp.	0	0	0	0	20	0	40	s/i	0	0	0	0	0	0	0	0	
Cianophyceae	0	0	480	1820	0	0	780	s/i	0	0	0	0	0	0	0	0	205
Ciliata	140	160	600	160	540	200	320	-	1837	3299	560	80	300	420	240	960	654
Acanthostomella norvegica ?	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	0	
Ascampbeliella sp.	0	0	0	0	0	0	20	s/i	0	0	0	0	0	0	0	0	
Ciliates (> 15 μm)	40	60	200	140	320	0	160	s/i	740	440	500	80	280	340	120	600	
Ciliates (< 15 μm)	0	0	0	0	0	0	0	s/i	920	2759	0	0	0	0	0	0	
Dictiocysta elegans	0	20	40	20	0	0	0	s/i	0	0	0	0	0	0	0	0	
Dictiocysta mitra	0	0	0	0	0	0	40	s/i	40	40	0	0	0	60	0	0	
Dictiocysta sp.	40	0	80	0	20	0	0	s/i	0	0	0	0	0	0	0	40	
Eutintinnus fraknoi	0	20	0	0	40	0	0	s/i	0	0	0	0	0	0	0	0	
Eutintinnus lusus-undae	20	20	200	0	80	160	40	s/i	20	40	0	0	0	20	0	40	

Laboea spp.	0	0	0	0	40	0	20	s/i	0	0	20	0	0	0	0	0	
Parundela caudata	0	20	0	0	0	0	0	s/i	40	0	20	0	20	0	120	80	
Protorhabdonella curta	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	40	
Rhabdonella chilensis	20	0	40	0	0	0	40	s/i	0	0	0	0	0	0	0	0	
Rhabdonella sp.	20	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	40	
Salpinguella sp.	0	20	0	0	40	40	0	s/i	0	0	0	0	0	0	0	80	
Steentrupiella pozzi	0	0	40	0	0	0	0	s/i	20	20	20	0	0	0	0	0	
Undella sp.	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	40	
Undella claparedei	0	0	0	0	0	0	0	s/i	20	0	0	0	0	0	0	0	
Xystonella treforti	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	0	
Dictyochophyceae	20	0	40	20	40	0	0	-	20	20	60	0	20	0	80	80	27
Dictyocha fibula	20	0	0	0	40	0	0	s/i	0	20	0	0	0	0	0	0	
Dictyocha sp.	0	0	40	20	0	0	0	s/i	0	0	40	0	20	0	80	0	
Dictyocha speculum	0	0	0	0	0	0	0	s/i	20	0	20	0	0	0	0	80	
Dinophyceae	2039	5038	8677	8937	7897	3959	10417	-	11456	16336	6438	5958	14495	10756	13616	15215	9416
Ceratium extensum	0	0	0	0	0	0	0	s/i	0	20	20	0	40	0	0	0	
Ceratium furca	40	40	0	40	40	40	0	s/i	20	40	20	20	120	20	0	0	
Ceratium fusus	40	40	80	20	80	80	120	s/i	40	160	0	80	160	60	0	40	
Ceratium tripos	0	0	0	0	0	0	0	s/i	20	0	0	0	0	0	40	0	
Athecate dinoflagellates (> 15 µm)	100	280	200	380	320	40	460	s/i	240	380	580	300	340	380	1840	560	
Athecate dinoflagellates (< 15 µm)	1839	4598	8277	8277	7357	3679	9657	s/i	11036	11956	5518	5518	13795	10116	11496	14255	
Thecate dinoflagellates	0	0	0	20	0	0	0	s/i	20	0	0	0	0	0	0	0	
Dinophysis sp.	0	0	0	0	0	0	0	s/i	20	0	0	0	0	40	0	0	
Dissodinium sp.	0	0	40	0	0	0	0	s/i	0	0	0	0	0	0	0	0	
Gonyaulax polygramma	0	20	0	0	0	0	0	s/i	20	0	0	0	0	0	0	0	
Ornithocercus sp.	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	40	0	
Oxytosum sp.1	20	60	40	100	80	0	20	s/i	20	40	160	20	20	120	120	120	
Oxytosum sp.2	0	0	40	60	20	120	160	s/i	0	40	140	20	20	20	80	0	
Podolampas sp.	0	0	0	40	0	0	0	s/i	0	0	0	0	0	0	0	0	
Prorocentrum sp.	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	40	
Protoperidinium conicum	0	0	0	0	0	0	0	s/i	20	0	0	0	0	0	0	0	
Protoperidinium sp.	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	40	
Scripsiella sp.	0	0	0	0	0	0	0	s/i	0	0	0	0	0	0	0	160	
Flagellata	2759	2759	2759	4139	5058	4598	13795	-	22072	203249	4598	22992	12876	32189	1839	6898	22839
Flagellates/Ciliates (< 10 µm)	0	0	0	0	0	0	0	s/i	0	46904	0	0	0	0	0	0	
Flagellates (< 10 µm)	2759	2759	2759	4139	5058	4598	13795	s/i	22072	156346	4598	22992	12876	32189	1839	6898	

Table 2. Composition and abundance of zooplankton (ind 1000 m^{-3}) on the seamounts Juan Fernandez 1 and Juan Fernandez 2. Only the percentage of each taxonomic group is indicated.

Tabla 2. Composición y abundancia de zooplancton (ind 1000 m^{-3}) en los montes submarinos Juan Fernández 1 y Juan Fernández 2. Se indica solamente el porcentaje de cada grupo taxonómico.

Species \ Station	1	2	3	4	5	6	7	8	Total	Percentage (%)
Stratum (m)	(0-250)	(0-250)	(0-300)	(0-300)	(0-350)	(0-268)	(0-250)	(0-250)		
Euphausiacea	2	4	118	35	7	9	158	9	342	1.29
Euphausia gibba	0	0	12	0	0	0	0	0	12	
Euphausia gibboides	0	0	20	11	0	0	14	0	45	
Euphausia mucronata	2	0	47	13	7	0	77	9	155	
Euphausia sp.	0	0	12	0	0	0	24	0	36	
Nematoscelis sp.	0	4	27	11	0	9	43	0	94	
Mysidacea	0	0	0	11	11	0	5	0	27	0.10
Amphipoda	12	49	71	19	22	28	62	77	340	1.29
Vibilia armata	12	41	67	13	11	23	62	77	306	
Acanthoscina acanthodes	0	4	4	3	7	0	0	0	18	
Platyscelus sp.	0	4	0	3	4	5	0	0	16	
Ostracoda	0	3	32	52	54	19	9	12	181	0.68
Copepoda	337	864	4338	2490	8917	1429	2766	1165	22306	84.38
Acartia sp.	4	33	39	21	254	28	38	0	417	
Haloptilus longicornis	0	0	0	0	60	37	0	0	97	
Haloptilus spiniceps	0	0	0	0	30	18	0	0	48	
Haloptilus sp.	4	0	0	0	0	0	0	17	21	
Calanus sp.	0	0	0	0	0	65	19	51	135	
Canthocalanus pauper	24	17	125	118	0	0	0	0	284	
Nannocalanus sp.	20	33	0	0	0	0	0	0	53	
Candacia curta	0	0	8	0	0	0	0	26	34	
Candacia sp.	4	17	0	75	15	18	0	0	129	
Corycaeus sp.	8	17	55	0	30	0	10	0	120	
Eucalanus inermis	0	0	0	0	30	28	0	0	58	
Eucalanus sp.	4	50	16	0	0	9	77	17	173	
Rhincalanus sp.	0	0	424	172	119	0	0	0	715	
Euchaeta sp.	4	0	133	172	45	0	29	9	392	
Heterorhabdus sp.	28	116	55	11	851	65	220	197	1543	
Lucicutia sp.	4	17	24	43	30	111	134	77	440	
Pleuromamma sp.	44	17	2031	0	2657	562	1148	308	6767	
Pleuromamma borealis	4	66	0	976	0	0	0	0	1046	
Oncaea conifera	8	0	149	86	0	9	19	26	297	
Oncaea sp.	4	17	0	0	149	0	0	0	170	
Oithona sp.	8	17	71	21	149	28	115	17	426	
Pontellina sp.	0	0	0	0	0	0	19	0	19	
Clausocalanus sp.	161	364	643	236	3000	378	766	248	5796	
Sapphirina sp.	4	50	0	32	15	18	19	120	258	
Acrocalanus sp.	0	0	0	32	0	0	0	0	32	
Paracalanus sp.	0	33	0	86	0	0	0	0	119	

Euaetideus sp.	0	0	0	0	75	0	0	0	75	
Euchirella sp.	0	0	149	161	478	55	96	43	982	
Gaudius sp.	0	0	165	139	239	0	57	9	609	
Scaphocalanus sp.	0	0	251	97	687	0	0	0	1035	
Scolecithrix sp.	0	0	0	12	4	0	0	0	16	
Cirripedia	4	0	0	0	0	0	0	0	4	0.20
Decapoda (larvae)	0	0	0	3	4	0	0	0	7	0.03
Emerita analoga	0	0	0	3	4	0	0	0	7	
Medusae	0	0	0	3	8	5	0	0	16	0.06
Cunina peregrina	0	0	0	3	0	0	0	0	3	
Obelia spp.	0	0	0	0	4	0	0	0	4	
Rophalonema velatum	0	0	0	0	4	5	0	0	9	
Siphonophorae	6	4	59	59	34	23	101	13	299	1.13
Abylopsis tetragona	0	0	16	5	4	9	5	0	39	
Eudoxoides spiralis	2	0	0	0	0	0	0	0	2	
Dimophyes arctica	0	0	8	3	0	0	0	0	11	
Lensia conoidea	0	0	0	3	7	0	0	0	10	
Lensia hotspur	0	0	0	0	4	0	0	0	4	
Lensia leloupi	0	0	0	0	4	0	5	0	9	
Lensia sp.	0	0	0	0	4	0	5	4	13	
Praya sp.	0	0	0	32	0	0	0	0	32	
Sphaeronectes gracilis	2	0	35	16	11	14	86	9	173	
Sulculeolaria chuni	2	0	0	0	0	0	0	0	2	
Sulculeolaria quadrivalvis	0	4	0	0	0	0	0	0	4	
Ctenophora	0	8	8	0	0	9	5	9	39	0.15
Beroe cucumis	0	4	0	0	0	0	0	0	4	
Pleurobrachia bachei	0	4	8	0	0	9	5	9	35	
Chaetognatha	88	141	393	249	198	216	153	119	1557	5.89
Eukrohnia hamata	8	21	71	32	93	37	19	17	298	
Sagitta decipiens	0	0	0	48	0	0	0	0	48	
Sagitta enflata	30	62	129	113	0	101	67	77	579	
Sagitta hexaptera	8	0	12	0	19	0	0	0	39	
Sagitta minima	0	0	118	5	19	0	5	0	147	
Sagitta tasmanica	0	0	4	8	30	0	0	4	46	
Juvenil individuals	42	58	59	43	37	78	62	21	400	
Salpida	38	62	537	21	70	18	53	17	816	3.09
Ihlea magalhanica	28	17	110	21	63	9	53	0	301	
Pegea confoederata	10	45	427	0	7	9	0	17	515	
Appendicularia	8	8	4	8	45	9	5	4	91	0.34
Polychaeta	8	0	55	56	56	23	48	9	255	0.96
Nemertina	0	0	0	0	0	0	5	0	5	0.02
Pisces (eggs and larvae)	0	74	4	42	7	0	24	0	151	0.57
Hygophum bruuni	0	0	4	8	0	0	19	0	31	
Sardinops sagax	0	74	0	21	7	0	0	0	102	
Myctophidae	0	0	0	13	0	0	5	0	18	
Total	986	2423	11147	5969	18700	3525	6716	2843	52309	100.0

Table 3. Invertebrate species collected with dredging.
Tabla 3. Especies de invertebrados recolectados con rastra.

Phylum/Class/Order	Number of samples	Phylum/Class/Order	Number of samples
Asteroidea	25	Ophiuroidea / Phynophiurida	3
Decapoda (spp.)	5	Polychaeta/ Terebellidae	12
Gastropoda (spp.)	6	Porifera + Ophiuroidea + Polychaeta	1
Echinoidea	38	Actiniaria + Polychaeta	1
Porifera (spp.)	34	Ophiuroidea	1
Gorgonia (spp.)	5	Porifera + Bryozoan + Polychaeta	1
Zoanthidea (spp.)	16	Lophophorates / Bryozoan	1
Holothuroidea	6	Bivalvia / Paleoheterodonta	1
Echinoidea/Echinacea (spp.)	142	Crustacea / Caridea	1
Actiniaria	27	Anthozoa / Actiniaria	3
Polychaeta (spp.)	55	Bivalvia (shell) (spp.)	6
Echinoidea + Ophiuroidea	6	Porifera + Polychaeta	3
Gorgonia / Ophioroida	10		

Submarine images of the JF1 and JF2 marine substrate showed characteristics ascribed to the impact of bottom dredges, coinciding with the information from the trawling fleet, whose activity was primarily executed on the flat surface area of the seamounts (Gálvez *et al*., 2006). When analyzed, this information revealed that the fishing activity was mainly concentrated on the JF2 seamount, reaching 4,667 km of trawling; in comparison, trawling on the JF1 and JF4 seamounts reached values of 1,526 km and 906 km, respectively. In spite of these results, the FEI showed higher values for seamounts JF4 and JF2 (10.5 km^{-1} and 11.7 km^{-1}, respectively) than for JF1. Although heavy fishing activity was executed on the latter, its FEI was 2.51 km^{-1} due to its larger area, which is estimated to be 608 km^2 (Table 4).

Table 4. Name, mean latitude and longitude, and the estimated area, effort, and relative fishing effect index (FEI) of six seamounts where extractive activity was conducted between 2000 and 2006.
Tabla 4. Nombre del monte, latitud y longitud media, área estimada, esfuerzo estimado e índice relativo de pesca (FEI) de seis montes donde se efectuó actividad extractiva durante 2000-2006.

Seamount	Latitude (S)	Longitude (W)	Area (km^2)	Effort (km)	FEI (km^{-1})
JF1	33°39.0'	78°26.4'	608	1.526	2.51
JF2	33°33.6'	77°41.4'	443	4.667	10.54
JF3	33°23.4'	77°25.2'	62	395	6.42
JF4	33°26.4'	76°52.8'	91	906	11.70
JF5	33°43.8'	79°37.2'	17	50	1.52
JF6	34°04.8'	80°15.6'	s/i	s/i	s/i

In general terms, the fishing effort, measured as the total trawling distance, increased considerably in 2002, 2003, and 2005, with values that exceeded the 500 km of trawling. Later, a considerable decrease was observed by the end of the analyzed period (2001-2006), followed by the same values observed at the beginning of the fishing activity. The high level of observed fishing effort seems to have modified the spatial structure of the resource aggregates exploited at the JF2 seamount. In 2001, the aggregates at this seamount showed a symmetrical spatial distribution up to 4 km; however, that value that did not exceed 1 km in 2003 (Fig. 11). The spatial variability was affected by a decrease in the relative abundance of the resources exploited on this seamount (orange roughy and alfonsino) (Fig. 12).

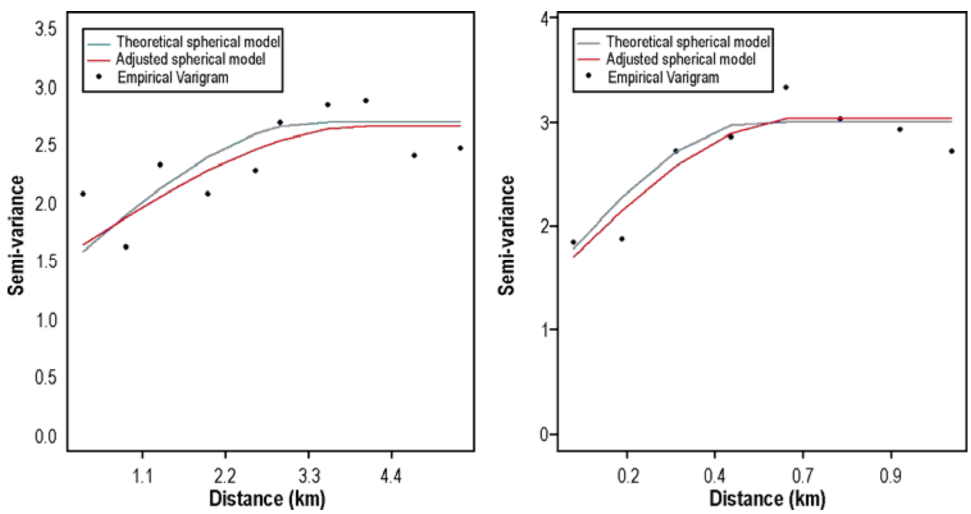

Figure 11. Theoretical and adjusted spherical model for the catch rate variogram on seamount JF2 in 2001 and 2003.

Figura 11. Modelo esférico teórico y ajustado para el variograma de las tasas de captura en el monte submarino JF2 en 2001 y 2003.

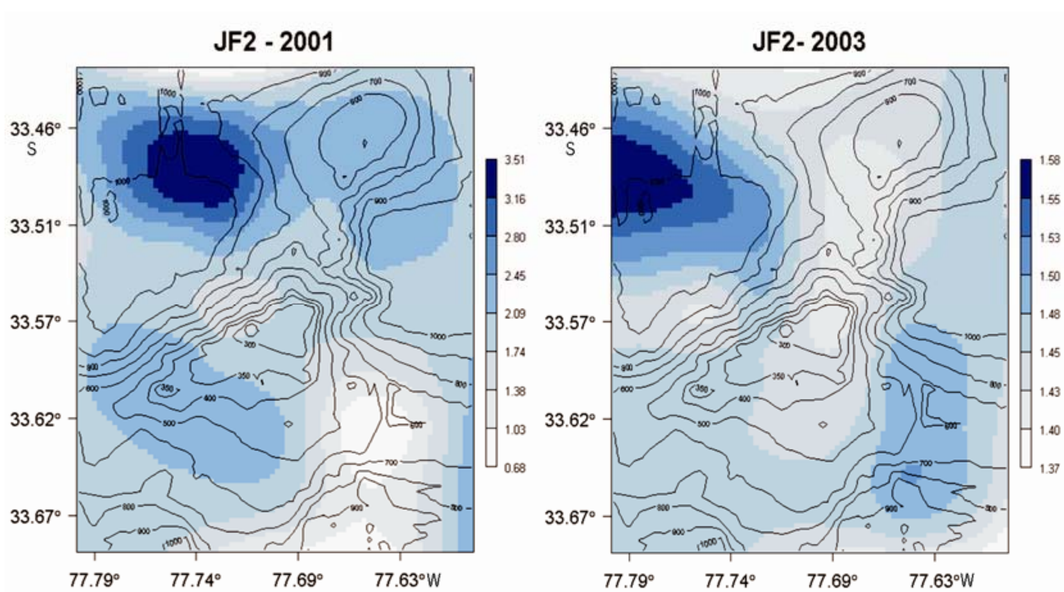

Figure 12. Distribution of the catch rates for the seamount JF2 in 2001 and 2003; maps were generated by ordinary punctual kriging.

Figura 12. Distribución de las tasas de captura para el monte submarino JF2 en 2001 y 2003; mapas generados mediante estimación espacial krigging puntual ordinario.

DISCUSSION

A total of 118 seamounts were identified in the continental and insular EEZ of Chile. A method similar to that used by Kitchingman & Lai (2004) was put into practice, considering statistical (standard deviation, filters, hillshading) and visual (judgment, 3D cartography) analyses for the identification of potential seamounts. The number of identified seamounts is influenced by the depth standard deviation as well as filter size and type (kernel 5*5 nearest-neighbor) and visual analysis criteria. Furthermore, the identification sensitivity is directly affected by the spatial resolution of the bathymetric data.

The information on the diversity of the phytoplankton organisms collected in the area, along with the data analyzed by Pizarro *et al.* (2006), allow the preliminary inference that the nano- and microplankton structure detected with the analysis of the water samples collected in late winter 2007 indicate the presence of a clearly oligotrophic environment. Small organisms predominate such environments and the systems are mainly supported by regenerated production and the probable entry of allochthonous nutrients from adjacent islands or elements advected from the seamounts or the coastal areas of Chile through large upwelling plumes that are generally observed on satellite images. Regarding the diversity of zooplankton organisms, most species and/or genera identified around the seamounts corresponded to organisms that are characteristic of the oceanic waters of the Humboldt Current System, which are found in low densities off the coast. The taxonomic composition of the zooplankton in this area is characterized by the presence of copepods (84.4% zooplankton), which coincides with results for oceanic waters in similar ecosystems of other oceans (Schnack-Schiel & Mizdalski, 2002). The quantity of zooplankton was quite scarce, in agreement with the low densities reported around the Juan Fernandez Archipelago (Palma, 1985) and the oceanic waters along the Chilean coast (Palma & Silva, 2006), and with other studies that have shown low densities on seamounts with abrupt topographies. This contradicts the results of Schwartz (2005) for seamounts from the Eastern Central Pacific. In fact, the biomass values were quite low compared to those detected in Chile's coastal waters.

The diversity of pelagic, demersal, and benthic organisms from this area was restricted to four fish species and two crustacean species. This was basically due to the fishing systems used in the surveys, which prioritized direct, non-intrusive sampling methods such as submarine images and gears like traps and longlines. One fish was the blue shark (*Prionace glauca*), a species considered to be epipelagic and of circumpolar distribution (Compagno, 1984). This shark is abundant in the southeastern Pacific and is captured by multiple fleets using surface longlines. The sawfish (*Thyrsites atun*), on the other hand, is considered to be a benthopelagic fish with a well-known distribution on continental shelves or around islands (Nakamura & Parin, 1993). Among demersal fish, the croaker (*Helicolenus lengerichi*) has been cited as one of the five species of the Scorpaenidae family present around the Juan Fernandez Archipelago (Pequeño & Sáez, 2000), whereas the conger *Bassanago albescens* has been caught with a low incidence (Lillo *et al*., 1999) as part of the by-catch of orange roughy fishing activities on Juan Fernandez seamounts.

The golden crab (*Chaceon chilensis*) and the Juan Fernandez king crab (*Paromola rathbuni*) have been cited as two of the five decapod crustacean species captured during surveys and experimental trap fishing activities around Robinson Crusoe and Santa Clara islands (Retamal & Arana, 2000). The presence of the Juan Fernandez king crab was originally reported for the Juan Fernandez Archipelago (Retamal, 1981) and the Desventuradas Islands (Báez & Ruiz, 1985) and is considered to be endemic to this area of the southeastern Pacific. This decapod is distributed between 100 and 300 m depth, with a greater abundance at 200 m around Robinson Crusoe and Santa Clara islands (Retamal & Arana, 2000). Furthermore, the golden crab has been reported off Zapallar and Quintero, along the central coast of continental Chile (Báez & Andrade, 1977; Andrade & Báez, 1980; Andrade, 1987), the Juan Fernandez Archipelago and San Félix and San Ambrosio islands (Retamal, 1981; Chirino-Gálvez & Manning, 1989), and along the undersea Nazca Ridge mainly at 90°W (Parin *et al*., 1997). The golden crab is generally distributed between 200 m and 2,000 m of depth (Dawson & Webber, 1991). It was found at depths of 400 and 800 m along the undersea Nazca Ridge (Parin *et al*., 1997) and was caught at 100 and 1,000 m around Robinson Crusoe and Santa Clara islands, with a greater abundance at 300 m and between 500 and 600 m (Arana, 2000).

The submarine images of the plains of seamounts JF1 and JF2 (up to 600 m approximately) suggest the presence of a marine substrate with similar characteristics to those reported in the literature for places that have been strongly impacted by trawling gears (FAO, 2007; Clark & Koslow, 2007).

Johnston & Santillo (2004) have suggested that sustainable seamount fisheries require good knowledge of the biology and ecology of the species to be exploited. Regarding the orange roughy fisheries on seamounts within the Chilean EEZ, there has been a trend towards increased global quotas in spite of the ignorance regarding the stock abundance at the Juan Fernandez Archipelago (Young *et al*., 2000; Gálvez *et al*., 2006). Despite this increase, the quota has never been totally extracted and the landing proportion has been observed to decrease.

The FEI provides a measure of relative intensity of the trawling fishing activities on a seamount, thereby allowing the categorization of the seamounts according to trawling density and direction. Due to the fact that the trawling was reported to last close to a minute and the trawling velocity is generally constant, then the trawling length estimation offers an adequate indicator of the scanned area. The distribution of the trawling direction on the studied seamounts was not random, suggesting that the fishermen have some degree of knowledge and, thus, prefer certain areas (trawling routes), whereas other adjacent areas do not seem to be affected by fishing activities. O'Driscoll & Clark (2005) have suggested that the FEI cannot directly assess the fishing impact on a seamount. Therefore, it should be necessarily related to other ecological indexes in order to obtain an ecological impact index of the trawling fishing over the substrate and associated fauna that could vary according to the substrate and fishing intensity.

Furthermore, strong spatial variability of the relative densities of the fishing resources associated with seamount JF2 in 2001 and 2003 was observed. This spatial variability was associated with a decrease in the relative abundance of the two main fishing resources exploited on this seamount (orange roughy and alfonsino) and a strong spatial contraction of said resources, which was represented by a significant change in the variogram range. The effect of the commercial exploitation on seamount JF2 caused an 85% reduction in the range of values between 2001 and 2003. Pankhurst (1998) indicated that orange roughy aggregates in the same period and place on the seamounts of New Zealand, which makes it quite predictable. These dense aggregations cause an elevated backscattered acoustic amplitude that is easily identified. Thus, the resource is highly vulnerable to commercial fishing. Besides, it has also been suggested that, during productive periods, orange roughy aggregations tend to remain still during certain periods or even for many days (Bull *et al*., 2001).

One of the objectives of the current international approach for marine biodiversity conservation is the identification and protection of the discrete areas that are defined from the representativeness of the existing ecosystems and/or their role as an essential habitat for the conservation of vulnerable or threatened species. Therefore, the demand for the identification and prioritization of possible protected marine areas in the Chilean seamounts requires some knowledge of the structure and singularity of its communities and the role such areas play in the life cycle of the species identified as special conservation subjects. In this sense, the extent of the knowledge necessary for the adequate conservation of biodiversity on seamounts in the Chilean EEZ is huge and this study is just one step towards an increase in the available information. Obviously, most attention is directed towards those areas currently under fishing exploitation, where it is crucial to take conservation measures for the development of sustainable activities.

ACKNOWLEDGEMENTS

The authors would like to thank the crews of PAM Portugal II, the L/M Alborada, and the boat Cumberland for their great disposition and assistance with the works carried out on board. Furthermore, we wish to thank the Fondo de Investigación Pesquera de Chile for their support of FIP project No. 2006-57.

REFERENCES

Andrade, H. 1987. Distribución batimétrica y geográfica de macroinvertebrados del talud continental de Chile central. Cienc. Tecnol. Mar, 11: 61-94.

Andrade, H. & P. Báez. 1980. Crustáceos decápodos asociados a la pesquería de *Heterocarpus reedi* Bahamonde 1955 en la zona central de Chile. Bol. Mus. Nac. Hist. Nat. Chil., 37: 261-267.

Arana, P. 2000. Pesca exploratoria con trampas alrededor de las islas Robinson Crusoe y Santa Clara, archipiélago de Juan Fernández, Chile. Invest. Mar., Valparaíso, 28: 39-52.

Arana, P., M. Ahumada, A. Guerrero, V. Espejo, E. Yañez, C. Silva, B. Ernst & J.M. Orensanz. 2006. Evaluación de stock y distribución de la langosta y el cangrejo dorado en el archipiélago de Juan Fernández (Proyecto FIP N°2005-21). Informe final. Pont. Univ. Católica Valparaíso, Estud. Doc., 27/2006: 257 pp.

Báez, P. & H. Andrade. 1977. *Geryon affinis* Milne Edwards & Bouvier, 1894, frente a las costas de Chile (Crustacea, Decapoda, Brachyura, Geryonidae). An. Mus. Hist. Nat., Valparaíso, 10: 215-219.

Báez, P. & R. Ruiz. 1985. Crustáceos de las islas oceánicas de Chile depositados en el Museo Nacional de Historia Natural de Santiago. In: P. Arana (ed.). Investigaciones marinas en el archipiélago de Juan Fernández. Escuela Ciencias del Mar, Universidad Cató lica de Valparaíso, Valparaíso, pp. 93-108.

Bull, B., I. Tracey & A. Hart. 2001. Diel variation in spawning orange roughy (*Hoplostethus atlanticus*) abundance over a seamount feature on the north-west Chatham Rise. N.Z. J. Mar. Freshw. Res., 35: 435-444.

Cerda, R. 1977. Pesca exploratoria con espineles en los montes submarinos situados entre Valparaíso y el archipiélago de Juan Fernández. Cienc. Tecnol. Mar, 3: 3-8.

Chirino-Gálvez, L.A. & R.B. Manning. 1989. A new deep-sea crab of the genus *Chaceon* from Chile (Crustacea, Decapoda, Geryonidae). Proc. Biol. Soc. Wash., 102(2): 401-404.

Clark, M.R. & J.A. Koslow. 2007. Impacts of fisheries on seamounts. In: T.J. Pitcher, T. Morato, P.J.B. Hart, M.R. Clark, N. Haggan & R. Santos (eds.). Seamounts: ecology, fisheries & conservation. Fish and Aquatic Resources Series, 12, Blackwell Publishing, Oxford, 527 pp.

Compagno, L. 1984. FAO species catalogue. Sharks of the world. Part. 2. Carcharhiniformes. FAO Fish. Synop., 125(4): 249 pp.

Dawson, E.W. & W.R. Webber. 1991. The deep-sea red crab *Chaceon* ("*Geryon*"): A guide to information and reference list of the Family Geryonidae. Nat. Mus. New Zealand, Misc. Ser., 24: 83 pp.

Organización de las Naciones Unidas para la Agricultura y la Alimentación (FAO). 2007. Report and documentation of the Expert Consultation on Deep-sea Fisheries in the High Seas, Bangkok, Thailand, 21-23 November 2006. FAO Fish. Rep., 838: 203 pp.

Gálvez, P., J. Sateler, J. González & P. Toledo. 2006. Programa de seguimiento del estado de situación de las principales pesquerías nacionales: Pesquería demersal centro-sur y aguas profundas, 2005. Informe SUBPESCA-IFOP: 70 pp.

General Bathymetric Chart of the Oceans (GEBCO). 2003. IHO-UNESCO, General Bathymetric Chart of the Oceans, Digital Edition. www.ngdc.noaa.gov/mgg/gebco. Revised: 30 April 2009.

Johnston, P & D. Santillo. 2004. Conservation of seamount ecosystems: application of a marine protected areas concept. Arch. Fish. Mar. Res., 51: 305-319.

Kitchingman, A. & S. Lai. 2004. Inferences of potential seamount locations from mid-resolution bathymetric data. In: T. Morato & D. Pauly (eds.). Seamounts: biodiversity and fisheries. Fish. Centre Res. Rep., 12(5): 7-12.

Lillo, S., R. Bahamonde, B. Leiva, M. Rojas, M.A. Barbieri, M. Donoso & R. Gili. 1999. Prospección del recurso orange roughy (*Hoplostethus* spp.) y su fauna acompañante entre la I y la X Región. Informe Técnico FIP 98-05: 141 pp.

Nakamura, I. & N.V. Parin. 1993. FAO species catalogue. Snake mackerels and cutlassfishes of the world (families Gempylidae and Trichiuridae). An annotated and illustrated catalogue of the snake mackerels, snoeks, escolars, gemfishes, sackfishes, domine, oilfish, cutlassfishes, scabbardfishes, hairtails, and frostfishes known to date. FAO Fish. Synop., 125(15): 1-136.

O'Driscoll, R.L. & M.R. Clark. 2005. Quantifying the relative intensity of fishing on New Zealand seamounts. N.Z. J. Mar. Freshw. Res., 39: 839-850.

Palma, S. 1985. Plancton marino de las aguas circundantes al archipiélago de Juan Fernández. En: P. Arana (ed.). Investigaciones Marinas en el archipiélago de Juan Fernández. Escuela de Ciencias del Mar, Universidad Católica de Valparaíso, Valparaíso, pp. 59-69.

Palma, S. & N. Silva. 2006. Epipelagic siphonophore assemblages associated with water masses along a transect between Chile and Easter Island (eastern South Pacific Ocean). J. Plankton Res., 28(12): 1143-1151.

Pankhurst, N. 1998. Spawning dynamics of orange roughy, *Hoplostethus atlanticus* in midslope waters of New Zealand. Environ. Biol. Fish., 21(2): 101-211.

Parin, N., A. Mironov & K. Nesis. 1997. Biology of the Nazca and Sala y Gómez submarine ridges, an outpost of the Indo-West Pacific fauna in the Eastern Pacific Ocean: Composition and distribution of the fauna, its communities and history. Adv. Mar. Biol., 32: 147-242.

Pequeño, G. & S. Sáez. 2000. Los peces litorales del archipiélago de Juan Fernández (Chile): endemismo y relaciones ictiogeográficas. Invest. Mar., Valparaíso, 28: 27-37.

Pizarro, G., V. Montecino, R. Astoreca, G. Alarcón, G. Yuras & L. Guzmán. 2006. Variabilidad espacial de condiciones bio-ópticas de la columna de agua entre las costas de Chile insular y continental. Primavera 1999 y 2000. Cienc. Tecnol. Mar, 29(1): 45-58.

Probert, P., D. McKnight & S. Grove. 1997. Benthic invertebrate bycatch from a deep-water trawl fishery, Chatham Rise, New Zealand. Aquatic Conserv: Mar. Freshw. Ecosyst., 7: 27-40.

Retamal, M. 1981. Catálogo ilustrado de los crustáceos decápodos de Chile. Gayana Zool., 44: 1-110.

Retamal, M. & P. Arana. 2000. Descripción y distribución de cinco crustáceos decápodos recolectados en aguas profundas en torno a las islas Robinson Crusoe y Santa Clara (archipiélago de Juan Fernández, Chile). Invest. Mar., Valparaíso, 28:149-163.

Rojas, R., Y. Guerrero, J. González & N. Silva. 2004. Datos del crucero oceanográfico CIMAR 5 Islas Oceánicas. Centro Nacional de Datos Oceanográficos, Servicio Hidrográfico y Oceanográfico de la Armada de Chile, Valparaíso, CD-ROM.

Rozbaczylo, N. & J.C. Castilla. 1987. Invertebrados marinos del archipiélago del archipiélago de Juan Fernández. In: J.C. Castilla (ed). Islas oceánicas chilenas: conocimiento científico y necesidades de investigaciones. Ediciones Universidad Católica de Chile, Santiago, pp. 167-190.

Schwartz, R. 2005. The effect of deep seamount on zooplankton abundance and biodiversity. Sea Cruise S199 09 june 2005, 15 pp.

Schnack-Schiel, S. & E. Mizdalski. 2002. Occurrence and distribution pattern of copepods in the vicinity of the Great Meteor seamount, northeast Atlantic, in september 1998. Abstracts from Theme Session on Oceanography and Ecology of Seamounts-Indications of Unique Ecosystems (M). ICES CM:2002/M: 35 pp.

Smith, W. & D. Sandwell. 1997. Global seafloor topography from satellite altimetry and ship depth soundings, Science, 277: 1957-1962.

Tracey, D., B. Bull, M. Clark & K. Mackay. 2004. Fish species composition on seamounts and adjacent slope in New Zealand waters. N.Z. J. Mar. Freshw. Res., 38: 163-182.

Yáñez, E., C. Silva, R. Vega, L. Álvarez, N. Silva, S. Palma, S. Salinas, E. Menschel, V. Haussermann, D. Soto & N. Ramírez. 2008. Biodiversidad de montes submarinos. Informe Final Proyecto FIP 2006-57: 246 pp.

Young, Z., A. Zuleta & R. Tasheri. 2000. Investigación CTP de orange roughy. Subsecretaria de Pesca-Instituto de Fomento Pesquero, Valparaíso, 30 pp.

Zuleta, A. & A. Hamano. 2004. Exploración científica del B/E Koyo-Maru al monte submarino bajo O'Higgins frente a Chile. Informe del Crucero, 22 pp.

Received: 11 May 2009; Accepted: 1 October 2009