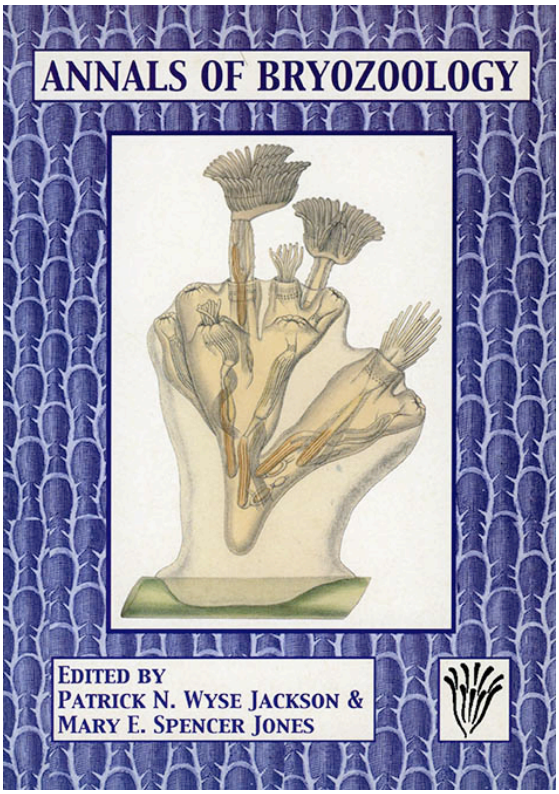

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Towards a general history of the south-eastern Pacific Bryozoa

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1. Introduction: the place

The south-eastern Pacific represents a large oceanic area containing only a few islands like the Galápagos, Easter, Sala y Gómez, Desventuradas and Juan Fernández. Its eastern limit is the relatively straight, western south American coast that extends from the Gulf of Guayaquil to Chiloé Island, where it changes abruptly becoming an intricate collection of thousands of islands, channels and fjords whose coastal line increases greatly. The significance of this is that there is a large area of submarine space available for species to live and to evolve, and this has resulted in a high diversity. This is corroborated by comparing the known diversity of disparate zoological groups, such as Annelida, Polychaeta, Mollusca, Foraminifera and Bryozoa, north of Chiloé Island where the coast line is straight (42°S-6°S) with the diversity of those groups south of Chiloé Island (42°S-56°S) where the coastal line and continental shelf is larger. In this part of the world, the biological diversity seems to decrease to the tropics and to increase to the poles.[1]

Along the almost 50° latitudinal coastal line, from the Gulf of Guayaquil to the area of Cape Horn, most of the zoogeographers that have explored and studied the western south American coast have revealed only two huge faunal provinces: the Peruvian-Chilean (6°S-42°S) and the Magellan (42°S-56°S).[2] This paucity of centers of endemism is due to the uniforming effect of the West Wind Drift cold waters that affects the western coast

of South America at 40°S. It gives rise to two cold currents: the austral Cape Horn current and the northern cold Humboldt current. The translation of this into zoological terms is shown by the presence and range of three of four species in the penguin genus *Spheniscus*: *S. magellanicus* and the Cape Horn current characterize the subantarctic Magellanic province; *S. humboldti* littorally follows the Humbolt current from central Chile to most of the Peruvian coast, and *S. mendiculus* is found on the austral set of the Galápagos islands, that is in the northermost part still influenced by relatively cold waters derived from the Humbold current. Opposing this poor zoogeographical provinciality each island or island group over the Nazca plate might represent a faunal province *per se*. Faunal and zooegeographic studies of them have demonstrated so far, that there are at least four insular provinces: Galápagos, Easter and Sala y Gómez, Juan Fernández and the Desventuradas, and the bathial Nazcaplatensis.[3] This number could be increased to five provinces if the present studies on the marine diversity of the Desventuradas demonstrates a species endemism higher than ten per cent.[4]

The immense marine area of the triangle situated between Easter Island, the Gulf of Guayaquil and the southernmost tip of South America contains part of the eastern Pacific rise which is the western-most natural limit of the South Eastern Pacific. This is a spreading geological submarine zone that generates the Nazca plate eastward and the huge Pacific plate westward. From this submarine rise, emerge Easter and Sala y Gómez Islands near its spreading centre. These islands represent the visible and emerged western part of a large submarine guyot line that encompasses the submersed Sala y Gómez and Nazca ridges.[5] Very close to the eastern end of the Sala y Gómez ridge emerge the Desventuradas Islands and six degrees latitude further south, facing central Chile, lies the Juan Fernández archipelago. These islands: Galápagos, Easter, Sala y Gómez, Desventuradas (San Félix and San Ambrosio) and Juan Fernández archipelago (Róbinson Crusoe, Santa Clara and Alejandro Selkirk), the almost straight western south American coast from the equatorial line to Chiloé Island (42°S), and the huge archipelago area south of 42°S in southern Chilean coast, constitutes the frame, base and core of this paper. From here several bryozoan faunas have been described and studied since the beginning of the nineteenth century.

2. Pre-Hispanic epoch

Littoral conch deposits along the Peruvian and Chilean coasts contain large mytilid and taidiid conchs that are frequently colonized by several encrusting and boring bryozoan species. The earliest collectors of these shells were probably unaware of the existence or significance of the bryozoan encrustations. Further south, nevertheless, there is a greater probability that the indigenous peoples, who lived amid the channels and fjords, and who obtained their meals by diving in the cold subantarctic waters of the Magellan Strait area, had discovered and named large bryozoan colonies. Even today it is possible to collect large pieces of the giant *Alcyonidium australe* d'Hondt & Moyano that measure more than

Figure 1. Chilean postal stamp commemorating Juan Ignacio Molina (1740-1829)

half a metre long, on beaches of Magellanic South America.[6] It has been also possible to buy large specimens of *Aspidostoma giganteum*, that measured up to 30 cm diameter, from a small shop on Chiloé Island.

3. The Hispanic period

From 1536 onwards, the year in which the Spanish discovered Chile, several naturalists or colonial writers have described Chilean natural history from the geographical, ethnic, botanical and zoological points of view.[7] They principally described the most obvious and large terrestrial animals and plants. Marine animals were also surveyed, including mammals, birds, fishes, large molluscs and crustaceans. By the end of this period the Jesuite priest, Juan Ignacio Molina (1740-1829) (Figure 1), who can be regarded as the first "modern" naturalist who adopted the Linnean binomial system in the area, was active. He described for the first time the most common plants and animals from central Chile, including both vertebrate and invertebrate marine faunal elements. His principal contribution, *Saggio sulla storia naturale del Cile* which was written in Bolonia, Italy and published in 1782[8] was based firstly on some notes taken with him when he and all the Jesuites were ejected from the Spanish possessions, but also on his memories of Chilean nature explored in his juvenile years. Although many common invertebrates such as *Loxechinus albus* (Molina) (regular echinoid), *Aulacomya ater* (Molina) and *Choromytilus chorus* (Molina) (large coastal mytilids), and *Pyura chilensis* Molina (edible ascidian) were described, no bryozoans or colonial animals were included in Molina's work. The species *Escharoides molinai* Moyano was erected in his memory in 1983;[9] this represents the only hitherto known member of this bryozoan genus in the south-eastern Pacific Ocean.

4. First half of the nineteenth century

This period saw the development of three large European scientific enterprises that pioneered and greatly promoted the development of marine and terrestrial zoology in western and southern South America.

On 27th December 1831 the H.M.S. *Beagle* commanded by Robert FitzRoy set sail from Devonport, England, on its long five year voyage around the world. On board was the young Charles Darwin. One year later the *Beagle* and its crew spent two months around Tierra del Fuego from 16th December 1832 to 26th February 1833, and one year later again she spent another month in the same place from 29th January to 7th March 1834. Finally, from middle June 1834 to the end of October 1835, the *Beagle* spent more than a year sailing from Tierra del Fuego to Galapagos Islands along the eastern limit of the south western Pacific. During that year Darwin visited and explored coasts, valleys and the Andes of southern and central Chile, and collected plants and animals.[10] Some of the Magellan bryozoan species described by George Busk in three catalogues[11] on the bryozoan collections of the British Museum (Natural History) were collected by Darwin. Almost at the same time the Voyage dans l'Amérique Meridionale (1826-1833) took place. It explored the republics of Brazil, Uruguay, Argentine, Bolivia, Peru and Chile. The zoophytes collected during this French expedition were described by Alcide d'Orbigny and included several common bryozoan species from along the Peruvian and Chilean coasts, such as *Membranipora isabelleana* (d'Orbigny), *Jellyella tuberculata* (Bosc), *Celleporella bougaivillei* (d'Orbigny), *Fenestrulina cornuta* (d'Orbigny), *Cellaria ornata* (d'Orbigny), *Hornera americana* (d'Orbigny), *Galeopsis pentagonus* (d'Orbigny), *Umbonula alvareziana* (d'Orbigny) and *Terebripora gramosa* (d'Orbigny).[12] d'Orbigny's importance issues from having described for the first time littoral bryozoan species affected by the Humboldt cold current from Chiloé Island to the south and central Peruvian coasts. It is also worth mentioning the description of *Terebripora ramosa*, the first known boring bryozoan on Calyptraeidae shells collected in Arica (18°S).

By the end of the first third of 19th century, the Chilean Goverment contracted the French naturalist, Claude Gay, to explore, collect and describe the Chilean nature and to edit the results in Spanish. He arrived in Chile in December 1828. From 1844 to 1865, 30 volumes of the *Historia Física y Política de Chile* were edited and published in Paris; the product of minuciose work of Claude Gay (Gay,1854),[13] and many other French naturalists. This encyclopedic work describes all kind of invertebrates but unfortunately no bryozoans.

5. Second half of the nineteenth century

The final years of this period were marked by a rapid increase in knowledge of the bryozoans from the southern tip of South America, both from Valpara'so on the Pacific side and from Montevideo and Buenos Aires on the Atlantic side to the Cape Horn Area. This was due to the arrival of the first worldwide oceanographic expedition accomplished on board of H.M.S. *Challenger* (1872-1876); it explored for organisms all around the world at depths below 300 fathoms. Results of the extensive and intensive dredging and trawling demonstrated the presence of incredible biological diversity at all depths and latitudes, and refuted Edward Forbes' assumption, that life was wanting under 300

Table I. Challenger *stations in the south eastern Pacific that yielded bryozoans.*

Station number	Latitude; Longitude	Bryozoan species
299	33°31'S; 74°43'W	*Menipea pateriformis*
		Kinetoskias pocillum
		Bugula reticulata
		Flustra biseriata
303	45°31'S; 78°09'W	*Menipea benemunita*
		Carbasea ovoidea
		Menipea aculeata
		Cribrilina monoceros
		Cellepora eatonensis
		Bugula reticulata
304	46°53'S; 75°12'W	*Aetea anguina*
		Salicornaria variabilis
		Salicornaria clavata
		Salicornaria malvinensis
		Cellepora signata
308	50°8'30"S; 74°41'W	*Menipea benemunita*
		Menipea aculeata
		Bugulata reticulata
		Carbasea ovoidea
		Cribrilina monoceros
		Cellepora eatonensis
		Cellepora armata erecta
312	53°37'S; 70°56'W	*Carbasea ovoidea*

fathoms.[14] The *Challenger* expedition sailed to the eastern Pacific via Tahiti, and the Juan Fernández Islands and arrived in Valparaíso in November 1875.

From this point the ship navigated south to enter the Gulf of Penas, a latitude at which glaciers touch sea level, sailed along Messier Channel to pass through the Magellan Strait to the south Atlantic.

Table I shows the *Challenger* collecting stations that yielded bryozoans on the Nazca Plate from near Easter Island to the eastern part of the Magellan Strait. These were described by George Busk in 1884.[15] There are only sixteen species in comparison with more than 200 species known so far today. Curiously, the survey of some *Challenger* stations (*viz.* 320, 314, 315 and 135) in the south western Atlantic gives more information on the actual bryozoan diversity of the southern-most part of the south eastern Pacific. The reason for this apparent bryozoan paucity is probably related to the constant bad weather

conditions in the Chilean fjordland, from 42°S to 56°S, that have constrained the collecting activities of scientific vessels from the *Challenger* times until today. When rare good weather conditions permit dredging and trawling in that area, however, the gathered species indicate a basic common bryozoan fauna in both the south western Atlantic and south eastern Pacific.[16]

In the meantime, the German naturalist, Rudolph Amandus Philippi, who had arrived in Chile on 18th October 1851 at the age of 43 years, had undertaken many investigations on the fauna, flora and fossils which he had collected in several trips in central and northern Chile. In depicting fossils obtained from Tertiary outcrops in the Atacama desert, he described and illustrated a *Lunulites*, the first Chilean fossil bryozoan, in 1887.[17]

6. The end of the nineteenth century and the Antarctic connection

The end of the 19th century was marked by an increase of European interests in southern seas including the Antarctic Ocean and continent. Many scientific ships passed through the Magellanic region or the Cape Horn area collecting or stopping there to explore, draw maps, or collect all kind of scientific data including benthic zoological collections from littoral to the deep sea. As a consequence large and increasing collections of Bryozoa from the south western Atlantic, the subantarctic Magellanic area, the Scotia Arch archipelagos and the Antarctic peninsula begun to accumulate in European natural history museums. Among the scientific expeditions that explored the Magellanic area after the *Challenger* Expedition, the Mission Scientifique du Cap Horn and the Hamburger Magalhaesischen Samelreise stand out. Under the auspice of the "Ministères de la Marine et de l'Instruction Publique" the French carried out the "Mission Scientifique du Cap Horn 1882-1883". This expedition settled for two years in Orange Bay in Hoste Island situated south of Beagle Channel. There, many investigations in zoology, botany and ethnology were made. The bryozoans collected were studied by Jules Jullien and published in 1888.[18] This author, after criticizing the use of the colonial form for stablishing generic entities made by Busk and other authors, decided to fundamentally use the structures of isolated zooecia. Jullien described as new two *Pedicellina* species, five ctenostomes, 22 cheilostomes and one cyclostome totalling 30 new species out of 56 in the whole collection. In 1904 Louis Calvet published in German descriptions of 61 marine and two freshwater bryozoans presented to him by Dr W. Michaelsen of the Komitee der Hamburger Magalhaensischen Sammelreise, that had been obtained from Chiloé (42°S) to Tierra del Fuego (56°S) between 1892 and 1893.[19] Calvet described ten new species: eight cheilostomes and two *Barentsia* (entoprocts) among the 61 marine bryozoans. He recorded ten species of cyclostomes, two ctenostomes and for the first time two phylactolaemates (freshwater bryozoans) in Tierra del Fuego. These reports described up *circa* 100 species - much more than those of the *Challenger* - and this work began to reveal the real nature and diversity of the Magellan Pacific bryozoans.

7. First half of the twentieth century

The increasing European interest in exploring the subantarctic and Antarctic seas, materialized in scientific expeditions such as those of the Swedish Antarctic Expedition (1901-1903) and those of the Discovery Committee, that resulted in monumental and fundamental bryozoological publications. In 1944 Folke Borg published on the stenolaematous Bryozoa as part of the zoological results of the Swedish Antarctic Expedition 1901-1903 directed by Dr Otto Nordenskjöld.[20] However part of these results came from a previous work: his 1926 academical dissertation published in Uppsala.[21] In both works many species described before by d'Orbigny and Busk plus the new ones depicted by Borg have been discovered later in the Magellanic south Pacific. Borg's work[22] plus those of d'Orbigny,[23] Busk,[24] Jullien[25] and Calvet[26] constitute the framework and basis of the present bryozoan knowledge in both the south western Atlantic and south eastern Pacific. Nevertheless this fundamental base was lacking the survey of the enormous collections amassed by the ships of the *Discovery* Committee in many years of exploring and collecting in the southern seas. A first attempt to study those collections and others obtained by several British ships was carried out by Anna Hastings who in 1943 published an important monograph which included 120 species of 6 families of cellularine bryozoans.[27] Although most collecting stations are in the south western Atlantic, many cellularine species are also present in the south eastern Pacific. On the other hand, in the first quarter of the twentieth century scientific exploration of the sporadic islands and archipelagos of the Nazca plate in the south eastern Pacific began. The first two archipelagos to be surveyed were Galápagos and Juan Fernández. The Galápagos Islands that represent the northernmost island set on the Nazca Plate and also the northernmost outcrop of tropical bryozoans of the eastern south Pacific were investigated by the *Albatross* of the U.S. Fisheries Commission in 1888 and 1891 that collected 50 species studied by Canu and Bassler.[28] Hastings in 1930 added other 37 taxa[29] and Osburn[30] and Soule in Osburn[31] in the 1950s aggregated several new records issued from the collecting activities of the *Velero* III expeditions of the Allan Hancock Foundation. Finally, Banta and Redden[32] in 1990 listed 184 bryozoan species whose zoogeographical affinities are with the Panamanian faunas more than with the Peruvian or Magellanic ones. The first survey of bryozoans obtained from the Juan Fernández area by several German collectors was published by Marcus in 1921. The nineteen species studied were collected during the Swedish Juan Fernández Expedition 1916-1917 commanded by Carl Skottsberg. Although only two new species were described, subsequent studies[33] have demonstrated that the so-called *Haswellia auriculata* Busk and *Fasciculipora ramosa* d'Orbigny were new species of *Galeopsis* and *Frondipora* respectively.

8. Second half of the twentieth century

Similar to the second half of the foregoing century, this period was marked by an explosive development and diversification of the bryozoan studies in the south eastern Pacific.

Nevertheless, there are significative differences: researchers have not been only European but also Chilean and the scientific vessels - that have collected along the Chilean coasts and the oceanic eastern Pacific islands - have been Chilean, European and American.

Chilean Expeditions: Since 1960 onwards the Chilean Navy has devoted time and efforts to carry out a series of oceanographic expeditions from the border with Peru (18°S) to the Drake Passage (55°S-60°S). The first two named as Mar-Chile I (1960) and Mar-Chile II (1962) were very productive in terms of plankton and benthos collections gathered from Arica to Chiloé area. In 1964 , the Instituto de Fomento Pesquero, a new Goverment Institution dedicated to study the fishery potential of the south American coasts of the south eastern Pacific, organized the IFOP-01 expedition. The collecting stations of this expedition started at Coquimbo (30°S) continued along the Chilean coast to Chiloé island and also some of them were carried out at Juan Fernández archipelago, allowing the gathering of fine and abundant bryozoan samples. By the end of the century the Chilean Navy Oceanographaphic Institute has organized the CIMAR expeditions in which many scientists of the Chilean Universities have participated obtaining bottom samples from Chiloé to the Magellan Strait and also from Easter, Sala y Gómez, Desventuradas and Juan Fernández.

Hero Expeditions: As part of activities of the U.S. National Science Foundation research vessel *Hero* in Antarctic and subantarctic areas, two legs of a general survey of the southern part of the Chilean Fiordland from Golfo de Penas (46°S-47°S) to the Magellan strait were carried out in October 1972. During the second leg (between the Pacific entrance of the Magellan strait and the Golfo de Penas) amid many benthic collecting stations, the original *Challenger* expedition stations were revisited, and rarely seen animals collected previously by the *Challenger*, were examined. These included living specimens of *Cephalodiscus dodecalophus* (Hemichordata, Pterobranchia) and the weird sea urchin *Dermechinus horridus* among many others. The bryozoans were represented by species hitherto known from the western south Atlantic such as *Cellarinella dubia* and new genera such as *Parafigularia* and *Flustrapora*, and many new species.[34]

Italian Magellano I Expedition: This expedition, as an extention to the subantarctic area of the Italian Antarctic Program, was carried out on board of the *Cariboo* between 20th February and 3rd March 1991 along the whole length of the Magellan Strait. The abundant and diverse bryozoan samples yielded 76 species which again demonstrated the similarity and unity of the bryozoan fauna to both sides of southernmost tip of South America.[35]

German Magellanic expeditions: In October 1994 the Joint Chilean-German-Italian Magellan "Victor Hensen" Campaign took place, that made possible the acquisition of a bryozoan collection similar to that collected by the *Cariboo* (see above). Nevertheless the most important source of new and unexpected taxa have been the sporadic collecting stations realized by the Alfred Wegener Institut research vessel *Polarstern* in the shelf and

slope of the Cape Horn area as part of its 1996 subantarctic and Antarctic Program. Part of the bryozoan material collected has been already studied[36] and other material will be published later on. The processed material has revealed both a new familiy, a new genus and several new species, and the presence of families, genera and species already described from the western south Atlantic and also from distant places such as New Zealand and Australia, in the southernmost eastern part of the south Eastern Pacific. This work has revealed an apparent relict bryozoan fauna of tropical affinities due to the presence of genera such as *Sinupetraliella*, *Chiastosella* and *Adeonella*.

Among other collecting trips made along the Chilean coast those of Carlos Viviani deserve special mention.[37] He described 67 species of ectoprocts and seventeen of endoprocts collected by him between Arica (18°S) and Chiloé (42-44°S). These data are found in a doctoral dissertation, unfortunately unpublished so far, with the exception of species in family Hippothoidae.[38] In 1973, Moyano[39] uncovered part of the hitherto unknown bryozoan fauna from Easter Island and in 1982 he defined bryozoogeographically the Magellanic region, and made a comparison of it with the bryozoans of other south American and Antarctic faunas.[40] Later on in 1983, 1985, and 1987 Moyano added new information on bryozoans from Juan Fernández[41] (previously studied by Ernst Marcus in 1921)[42] and from Easter Island, and compared the south eastern Pacific bryozoan fauna with the whole Pacific basin bryozoan fauna. Finally in 1991, 1995 and 1996 he extended this approach to define five bryozoogeographic provinces: Magellanic, Perú-Chilean, Bathyal-Center-Chilean, Juan Fernández and Easter, and compared them with the bryozoan faunas from the Antarctic peninsula and from the New Zealand and Australian realms.[43] Along the last two decades of the twentieth century additional work on the subantarctic Magellanic area and hence of the south western Pacific Ocean was carried out by Peter Hayward and collaborators.[44] They continue the previous and pioneering work of Anna Hastings in describing the immense collections collected by the ships of the Discovery Committee during the first half of the twentieth century.

The collecting activities just reviewed, comprising the last forty years, have raised the known bryozoan diversity from more than 80 species principally from the Magellanic area, the continental slope in front of central Chile and the oceanic islands of the Nazca plate.[45] The total number of known bryozoan species within the Nazca plate boundaries excepting the Galápagos Islands is approximately 400, a figure that would increase to nearer 600, if those of the Galápagos recorded by Banta and Reddin in 1990 are included.[46] The newest approach to bryozoan studies in the south eastern Pacific is an ecological one that has been developed by J.M. Cancino and his collaborators who study the eco-physiology of littoral bryozoans.[47]

9. The future

Four issues are expected to be developed in the near future: (a) to continue the bryozoan

diversity inventory especially along the Peruvian coasts, the western south American continental slope and the oceanic islands on the Nazca plate plus their associate guyot systems; (b) to increase the eco-physiology studies of larvae, colonies and communities of littoral and neritic species; (c) to make regional and Panpacific molecular biological studies of species having ample distribution patterns; and (d) to fortify the until now timid scientific cooperation between bryozoan workers of both western and eastern Pacific Ocean coasts.

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