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Article

Bathybembix bairdii (Mollusca: Gastropoda: Calliotropidae) as a potential fishery resource off western Mexico

Bathybembix bairdii (Mollusca: Gastropoda: Calliotropidae) como recurso pesquero potencial frente a las costas de México

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Resumen.- *Bathybembix bairdii* es reportado por primera vez para la costa oeste de la península de Baja California y la costa suroeste de México, a una profundidad de 710 a 2.093 m. Las condiciones ambientales medidas cerca del fondo fueron: 2,10 a 5,81 °C, 34,40 a 34,63 (salinidad) y <0,12-0,90 ml L^{-1} de O_2. La especie se encontró principalmente en sedimentos fangosos dominados por limo (56,5-87,0%) (Baja California) o en sedimentos con una proporción significativa de arena (63,5 a 88,5%) (suroeste de México). Las tallas de las conchas variaron de 10,0 a 53,7 mm, con alta proporción de especímenes grandes en aguas menos profundas de Baja California. Las densidades variaron de 1,75 a 207,45 org. ha^{-1} en Baja California y de 5,25 a 50,72 org. ha^{-1} en el Suroeste de México. La biomasa máxima estimada se produjo en el suroeste de México (2,2 kg ha^{-1}). La relación entre la altura y el peso total (concha más parte blanda) y entre la altura y el peso de la parte blanda estuvieron altamente relacionadas (R^2: 0,933 y 0,928, respectivamente). El peso de la parte blanda varió de 29 a 62% del peso total y la proporción aumentó con el tamaño. Las especies de mega invertebrados asociadas con *B. bairdii* incluían el 47% de crustáceos decápodos, 35% de equinodermos y 18% de moluscos. Como especie de captura secundaria encontrada regularmente en las redes de arrastre en aguas profundas, *B. bairdii* podría representar un valioso recurso para el consumo humano.

Palabras clave: Aguas profundas, caracol de Baird, zona de oxígeno mínimo, densidad, pesquería

Abstract.- *Bathybembix bairdii*, the Baird's top shell, is reported for the first time from off the Baja California Peninsula west coast and the southwestern coast of Mexico, at depths of 710-2,093 m. Environmental conditions measured near bottom were: 2.10 to 5.81 °C, 34.40 to 34.63 (salinity), and <0.12-0.90 ml L^{-1} O_2. The species was found mostly in muddy sediments dominated by silt (56.5-87.0%) (Baja California) or in sediments with a significant proportion of sand (63.5 to 88.5%) (southwestern Mexico). Shell height varied from 10.0 to 53.7 mm, with high proportion of large specimens in shallower water off Baja California. Densities varied from 1.75 to 207.45 org. ha^{-1} off Baja California and from 5.25 to 50.72 org. ha^{-1} in southwestern Mexico. Estimated maximum biomass occurred off southwestern Mexico (2.2 kg ha^{-1}). Relationship between height and total weight (shell plus soft part) and between height and soft part weight were both highly correlated (R^2: 0.933 and 0.928, respectively). Soft part weight varied from 29 to 62% of total weight and proportion increased with size. Mega invertebrate species associated with *B. bairdii* included 47% of decapod crustaceans, 35% of echinoderms, and 18% of mollusks. As a by-catch species regularly found in deep-water trawls, *B. bairdii* could represent a valuable resource for human consumption.

Key words: Deep water, Baird's top shell, *Bathybembix bairdii*, oxygen minimum zone, density, fishery

Introduction

With eight recognized species, the genus *Bathybembix* Crosse, 1893, is one of the ten genera of the family Calliotropidae Hickman & McLean, 1990. It is exclusively found in water deeper than the continental shelf. The Baird's top shell, *Bathybembix bairdii* (Dall, 1889), is one of three species occurring in the eastern Pacific and is widely distributed from Alaska to Central America (Hendrickx & López 2006) and further south to Chile (Santhanam 2018). Records for deep-water (> 200 m depth) mollusks are usually scarce due to sampling difficulties and cost, but a large series of specimens of *B. bairdii* was recently made available from research cruises in the southern Gulf of California and off El Salvador, thus bringing new information on this species abundance, distribution and tolerance to hypoxic environment (Hendrickx & López 2006). These authors reported material from 25 localities, in depth from 778 to 2140 m and dissolved oxygen concentrations from 0.07 to 1.98 ml L^{-1}, and estimated densities of up to 25 kg ha^{-1} with higher values registered off El Salvador.

Due to recent interest for deep-water resources in the region, particularly fishes and shrimps (*e.g.*, Kameya *et al.* 1997, Ramírez-Rodríguez *et al.* 2003, Wehrtmann & Nielsen-Muñoz 2009, Hendrickx 2012), *B. bairdii* could represent an attractive by-catch species if a deep-water fishery is developed on a regular basis. It is a locally abundant large species (up to 55 mm height), with a taste adequate for consumption, and it has been considered as a potential, yet unexploited resource (Hendrickx & López 2006). Additionally, this information on *B. bairdii* occurrence and abundance is very valuable to shell collectors. Price ranges for this species from 20 to 35 US$ (Rice 1994).

Species of *Bathybembix* are known to occur in areas with oxygen deficiency, known as the Oxygen Minimum Zone (OMZ) (Hendrickx & López 2006, Sellanes *et al.* 2008). The OMZ off the west coast of Mexico is the largest worldwide. It is remarkably wide and encompasses a depth range of up to 1200 m in some areas. Oxygen concentrations in the Mexican Pacific OMZ core are also often critically low (<0.2 ml L^{-1}) and represent a physiological barrier for many benthic and pelagic species (Helly & Levin 2004; Hendrickx & Serrano 2010, 2014; Hendrickx 2015). Recent research dealing with deep-water species of mollusks and decapod crustaceans from off the west coast of the Baja California Peninsula (Suárez-Mozo & Hendrickx 2016, Hendrickx *et al.* 2016, Papiol *et al.* 2016) have emphasized the effect of the OMZ on composition, abundance and distribution of deep-water invertebrates communities. However, detailed information on the abundance and tolerance to hypoxia of many species living close to the OMZ is still lacking. A large series of specimens of *B. bairdii* was collected off the west coast of the Baja California Peninsula and southwestern Mexico, between Jalisco and Guerrero. This study is aimed at providing additional information on the distribution, abundance and ecology of this species in the eastern Pacific. This information will be useful for future investigations dealing with this potential fishery resource in the region and emphasizes the wide distribution of the target species.

Materials and methods

Study species

Bathybembix bairdii is a medium size (maximum known size, 55 mm shell height) deep-water species of Calliotropidae recently reported as very abundant off El Salvador (Hendrickx & López 2006). As other species of this genus, and in other genera within the family Calliotropidae, it is a deposit feeder (Hickman 1981) in muddy environment with evidence of consumption of plant debris and occurrence in deep-water kelp and wood falls (Gage & Tyler 1991, Miller *et al*. 2000, Kiel & Goedert 2006). It has been reported from off Queen Charlotte Islands, BC, Canada (Austin 1985). There is also a series of 28 records available at Global Biodiversity Information Facility (GBIF 2016) for the eastern Pacific, from Canada and the U.S.A., from off the northern tip of Prince of Wales Island (55°44'N-135°22'W) to off San Diego (32°38'N-117°29'W), and one isolated record from off Costa Rica (9°09'N-84°49'W). It has been reported for Ecuador by Keen (1971). Ramírez *et al.* (2003) reported *B. bairdii* in Peru in a checklist of species occurring in this area and Santhanam (2018) included it for Chile. In addition, there are numerous records from the Gulf of California (Fig. 1) and off El Salvador (Hendrickx & López 2006). The mollusks collections holdings of SCRIPPS Institution of Oceanography (SIO), of the Los Angeles Museum of Natural History (LAMNH), and of the Santa Barbara Museum of Natural History (SBMNH) include several records for this species. SIO has two records, the first from off San Pedro Island, central Gulf of California (931 m depth), and the second from off the Bay of Chamela, southwestern (SW) Mexico (66 m depth). The first record fit well with the known geographic and depth distribution of *B. bairdii* as described by Hendrickx & López (2006); the second, however, is rather surprising in what concerns the recorded depth and is probably erroneous. Records in the SBMNH are all from off California, and include both catalogued and un-catalogued lots. Records in the LAMNH holdings are exclusively from the San Catalina Island area, thus fitting the known distribution of the species off northwestern America.

Data collection

The material on which this study is based was collected by the Research Vessel 'El Puma' of the Universidad Nacional Autónoma de México (UNAM), in 2012 and 2014 (TALUD project). The TALUD project (named after the

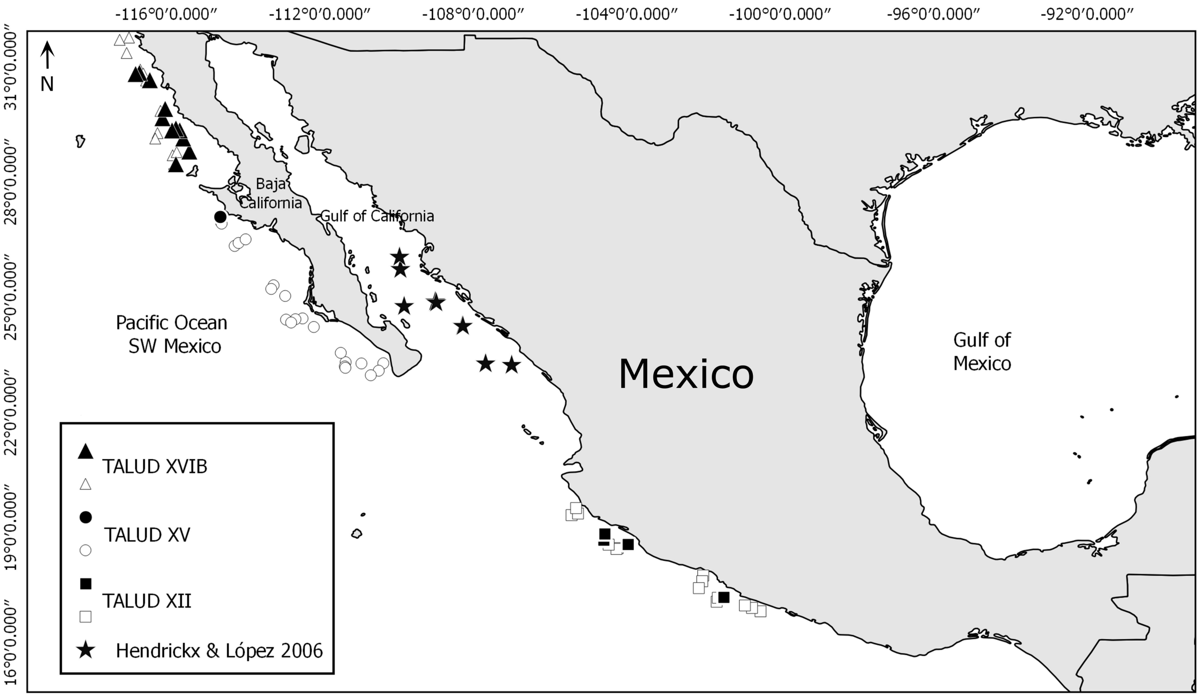

Figure 1. Localities off western Mexico where *Bathybembix bairdii* was collected (solid symbols) during the TALUD XII, XV and XVI-B cruises. Records provided by Hendrickx & López (2006) are indicated for comparative purposes. Localities with no specimens of *B. bairdii* are also indicated (empty symbols) / Localidades frente a la costa oeste de México donde *Bathybembix bairdii* fue recolectado (símbolos sólidos) durante las campañas TALUD XII, XV y XVI-B. A título comparativo se incluyen los registros de Hendrickx & López (2006). Se indican también las localidades sin especímenes (símbolos vacíos) de *B. bairdii*

word 'TALUD', meaning 'slope' in Spanish) was implemented in order to sample deep-water communities off western Mexico. Specimens of *Bathybembix bairdii* were captured during sampling operations off the southwestern coast of Mexico (one cruise: Jalisco to Guerrero; TALUD XII, March-April 2008) and off the west coast of the Baja California Peninsula (BC) (two cruises: TALUD XV, July-August 2012; TALUD XVI-B, May-June 2014). During these three cruises, a total of 63 localities were sampled, from 304 to 2165 m depth (Fig. 1). Positional coordinates for each sampling station were obtained using a GPS navigation system. Depth was measured with a digital recorder. All the specimens were captured with a standard benthic sledge (2.35 m width, 0.9 m high) equipped with a modified shrimp net (*ca*., 5.5 cm stretched mesh size) with a *ca.*, 2.0 cm (3/4") internal lining net. The material collected during this survey was deposited in the Regional Collection of Marine Invertebrates (ICML-EMU), at UNAM in Mazatlán, Mexico. Shell height (standard measure used for all specimens) was measured to the nearest 0.1 mm and specimens weight (whole specimens and soft parts) to the nearest 0.1 g (Sartorius M-power balance). Abundance was estimated as density of organisms per hectare (org. ha^{-1}) using the swept area method (width of the sledge * distance of the haul). Biomass (kg ha^{-1}) was estimated using the total weight of each sample and the values from the swept area method. Environmental data were obtained from measurements at ~20 m above bottom using a CTD-O_2 (Seabird 19 with oxygen probe) and rosette-mounted 10 L Niskin bottles. Near-bottom temperature (T) and salinity (S) data were obtained directly from the CTD records and dissolved oxygen was estimated from water samples using the Winkler titration method (Strickland & Parsons 1972). Sediments were collected with a modified USNEL box core at each sampling station, and samples of the top 3 cm were stored at 4-8 °C. Grain size distribution was determined by laser dispersion (Malvern Mastersizer 2000E) or by traditional method of sieving and sedimentation (Folk 1968).

Results

Distribution

In southwestern Mexico (TALUD XII), *Bathybembix bairdii* was caught in 4 out of 18 sampling stations. Off Baja California, it was found in only one sample out of 22 during the TALUD XV cruise and in 11 out of 23 samples during the TALUD XVI-B cruise (Fig. 1, Table 1). The distribution of *B. bairdii* in western Mexico also includes the series of stations reported by Hendrickx & López (2006) in the Gulf of California (Fig. 1).

Habitat

Specimens were collected from 710 to 2,093 m depth, in a wide range of water temperature, from 2.10 to 5.81 °C, thus indicating the eurythermic character of the species. Salinity values (34.40 to 34.63) were very similar and should not affect significantly the distribution of the species. Environmental data indicate that the specimens of *B. bairdii* from off Baja California were almost always (except one locality) associated with muddy sediments dominated by silt (56.5-87.0% silt content), with 9 out of 12 localities with silt proportion >70% (Table 2). However, off SW Mexico, 3 out of 4 samples were associated with sediments containing a significant larger proportion of sand (63.5 to 88.5% sand content), and in one case with mixed sediments. All captures from off southwestern Mexico (TALUD XII) were associated with very low (0.22, 0.26 and 0.27 ml L^{-1}) or low (0.51 ml L^{-1}) oxygen concentrations. Off Baja California, a sizable number of large specimens (24) were associated with hypoxic environment (O_2 concentrations <0.12-0.90 ml L^{-1}), in depths near the lower boundary of the OMZ. Smaller specimens of *B. bairdii* were almost invariably (97 specimens) found in deeper water, with much higher oxygen concentrations (>1.4 ml L^{-1}) (Table 2).

Minimum and maximum sizes (shell height) of the material examined were 10.0 and 53.7 mm, respectively. Off Baja California, size distribution of the examined material varied according to depth (Fig. 2), with a high proportion of large specimens found in shallower water and of small specimens found in deeper water. Off southwestern Mexico, all samples of *B. bairdii* came from a narrow depth range (1,058 to 1,299 m), thus making comparative depth-distribution impossible.

Table 1. Date and geographic location of TALUD cruises stations where *Bathybembix bairdii* was captured during this survey / Fecha y ubicación geográfica de las estaciones de muestreo donde se capturó *Bathybembix bairdii* durante este estudio

Cruise-station	Date	Latitud (N)	Longitud (W)
XII-10	March 28, 2008	17°11'03"	101°28'05"
XII-23	April1, 2008	18°33'43"	103°57'45"
XII-27	April 2, 2008	18°40'28"	104°35'51"
XII-28	April 2, 2008	18°50'19"	104°34'14"
XV-24	August 1, 2012	27°05'42"	114°35'30"
XVI-B-1	May 23, 2014	28º28'18"	115º45'12"
XVIB-5	May 24, 2014	28º48'	115º24'06"
XVI-B-6	May 24, 2014	29º08'09"	115º33'26"
XVI-B-7	May 31, 2014	29º21'12"	115º39'08"
XVI-B-8	May 31, 2014	29º23'48"	115º45'12"
XVI-B-9	May 30, 2014	29º20'54"	115º51'
XVI-B-15	May 29, 2014	29º40'24"	116º06'
XVI-B-17	May 29, 2014	29º54'18"	116º01'30"
XVI-B-18	May 25, 2014	30º39'18"	116º25'54"
XVI-B-20	May 26, 2014	30º51'17"	116º42'11"
XVI-B-21	May 28, 2014	30º49'24"	116º47''48"

Table 2. Capture of *Bathybembix bairdii* off western Baja California and SW Mexico / Capturas de *Bathybembix bairdii* frente a la costa oeste de Baja California y en el SO de México

Cruise-Station	N	Density (org. ha^{-1})	Depth (m)	Environmental parameters (O_2 ml l^{-1}/T°C/Sal/% Cl-Si-Sa)	Size range (height, mm)	Catalogue number (ICML-EMU)
XII-10	2	5.25	1,180-1,299	0.51/3.66/34.56/27.3-43.4-29.4	43.8-47.1	11406
XII-23	54	50.72	1,058-1,088	0.22/4.39/34.54/5.1-6.4-88.5	41.6-54.7	11407
XII-27	18	15.77	1040-1095	0.26/ND/34.53/17.7-12.4-69.9	18.2-41.5	11408
XII-28	13	34.16	1101-1106	0.27/4.11/34.53/18.6-17.8-63.5	44.0-51.7	11409
XV-24	1	5.25	772-786	0.12/5.24/34.53/7.9-56.5-35.5	18.9	11337
XVIB-7	35	137.86	710-750	0.28/5.81/34.44/11.2-77.7-11.1	11.4-53.7	11331
XVIB-17	16	50.42	734-774	0.25/5.33/34.42/3.65-40.9-55.4	41.8-49.6	11011
XVIB-18	3	5.25	740-785	0.23/5.46/34.4/9.0-84.5-6.6	31.3-51.9	11335
XVIB-5	10	17.51	772-776	0.22/5.34/34.42/11.8-72.6-15.5	23.8-48.4	11012
XVIB-6	1	2.63	1,004-1,102	0.4/4.38/34.47/12.1-82.6-5.3	51.0	11333-B
XVIB-8	1	2.63	1,416-1,480	0.9/3.14/34.55/11.8-84.9-3.3	11.1	11334-A
XVIB-1	2	3.50	2,038-2,054	1.83/2.1/34.63/10.5-52.1-37.4	20.1-22.7	11333-A
XVIB-9	6	15.76	1,838-1,860	1.52/2.31/34.61/15.5-84.5-0.0	12.1-21.1	11334-B
XVIB-15	79	207.45	2,010-2,046	1.6/2.26/34.62/10.9-87.0-2.2	10.0-27.9	11015
	(+7)	ND				(11332)
XVIB-20	2	5.25	2,075-2,090	1.47/2.37/34.61/12.5-86.3-1.2	23.7-24.3	11336-A
XVIB-21	1	1.75	2,018-2,093	1.43/2.43/34.60/12.5-86.4-1.1	21.4	11336-B

N, number of specimens. O_2, epibenthic dissolved oxygen (ml L^{-1}); T°C, epibenthic water temperature; Sal, epibenthic salinity; Cl, clay, Si, silt, Sa, sand, all in %. ( ), empty shells. ND, no data

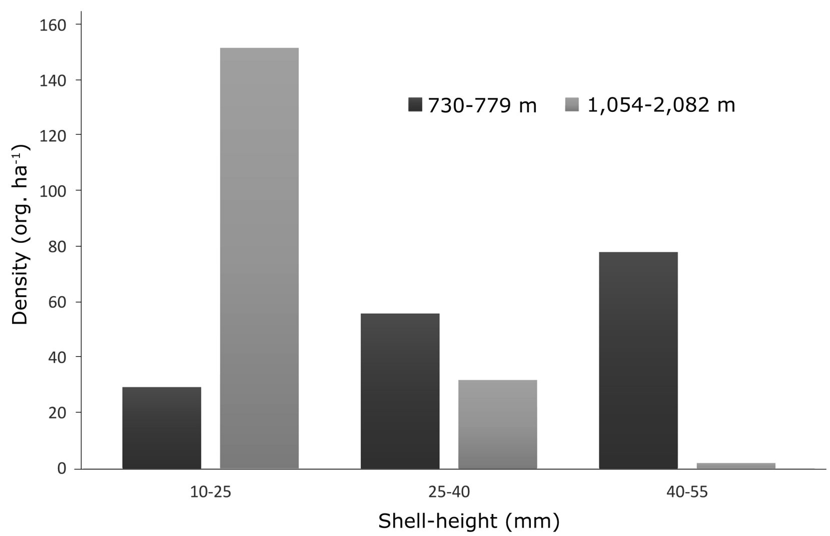

Figure 2. Size (shell-height, mm) distribution of specimens of *Bathybembix bairdii* collected during the TALUD XVI-B cruise by bathymetric fringes (730-779 and 1,054-2,082 m) / Distribución de tallas (altura de la concha, mm) de los especímenes de *Bathybembix bairdii* recolectados durante la campaña TALUD XVI-B por franjas batimétricas (730-779 y 1.054-2.082 m)

Relationship with environmental parameters

Due to scarcity of records, strong variation in densities among sampling stations and heterogeneous distribution of samples, no significant relationship was detected when comparing densities of organisms and environmental parameters associated with each sampling station. According to Papiol *et al*. (2016), parameters that partly explained the occurrence and density of decapod crustaceans collected in the same area during the same cruises were depth and oxygen concentration. In the case of *B. bairdii*, however, simple correlations between density and these two parameters were very weak, with R^2 values lower than 0.01 in both cases. This is due to the heterogeneous dispersion of the species and very variable abundance of specimens.

Abundance and fishery

Only one specimen in one sample was collected during the TALUD XV cruise, off Baja California Sur, in the northern limit of the area covered during this cruise (Fig. 1; solid). On the contrary, a total of 149 specimens were obtained in 11 samples during the Baja California northern cruise (TALUD XVI-B); in the southernmost sampling area, off southwestern Mexico, 87 specimens were caught in 4 samples (TALUD XII) (Table 2). In the later cruise, one station (XII-23) contained 62% (54 specimens) of the total catch for this area. In this southernmost area, density varied from 5.25 to 50.72 org. ha^{-1}, with an average of 26.48 org. ha^{-1} (Table 2). Biomass per hectare of the two largest samples (TALUD XII, 23 and 27) was estimated at 2.2 and 0.4 kg ha^{-1}, respectively. Off the Baja California Peninsula, density varied from a low 1.75 to a maximum of 207.45 org. ha^{-1}. Biomass per hectare of the two largest samples (XVI-B 7 and 15) (Table 2) was estimated at 0.79 and 0.24 kg ha^{-1}, respectively. Relationship between height and total weight (shell plus soft part) and between height and soft part weight were both highly correlated (R^2: 0.9332 y 0.9281 respectively) (Fig. 3a y b). For *B. bairdii*, shell (not including the operculum) represents 38 to 71% of total weight, generally according to size of the individuals. The body (or soft part) weight of examined specimens (including the operculum) varied from 29 to 62% of total weight (Fig. 3b).

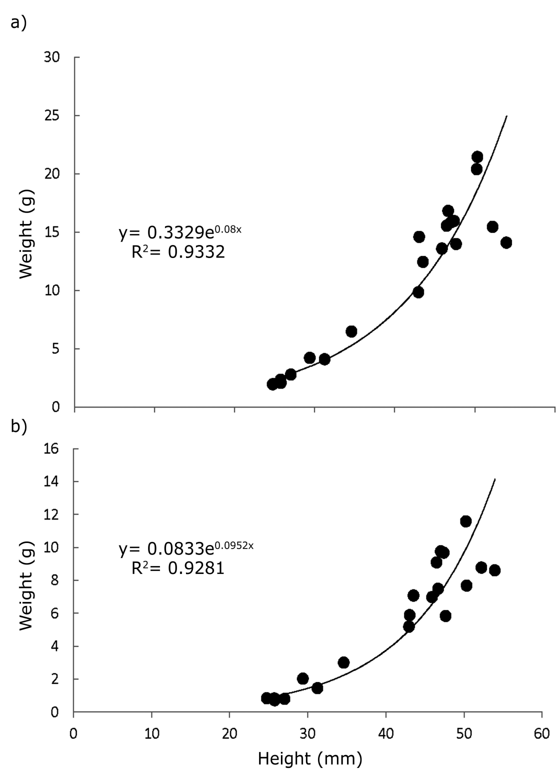

Figure 3. Relationship between a) shell height and total weight and b) shell height and soft parts weight of *Bathybembix bairdii* (n= 20) / Relación entre a) la altura de la concha y el peso total y b) la altura de la concha y el peso de las partes blandas en *Bathybembix bairdii* (n= 20)

Associated fauna

Sampling data available for stations where *B. bairdii* was collected indicated a rich by-catch invertebrate fauna including 110 macrobenthic species: 52 decapod crustaceans (47% of total), 38 echinoderms (35%), and 20 mollusks (18%); data for fish are not available.

Discussion

Although *B. bairdii* is widely distributed in the eastern Pacific, we were not able to trace any previously published record of this species from off the west coast of the Baja California Peninsula or from off southwestern Mexico. Therefore, all records of *B. bairdii* in these areas represent first reports and partly fill the distribution gap between California and Costa Rica. As in the case of *Cardiomya planetica* (Dall, 1908) and *Astyris permodesta* (Dall, 1890) (Levin *et al*. 2000, Gracia & Valentich-Scott 2014), *B. bairdii* could be even more commonly distributed to the south in the eastern Pacific but there is a significant lack of information for deep-water mollusks off western Colombia, Ecuador, Peru and Chile.

In this survey, a strong patchiness tendency was detected, with isolated captures of *B. bairdii* and absence of records in localities where environmental conditions were essentially similar. It is noteworthy, for example, that during this survey no specimens were found in three other stations with a similar depth range (*i.e*., 865-1,100 m) and similar environmental conditions (*i.e.,* oxygen concentration, temperature), or in the 11 deeper stations (depth range, 1,380-2,165 m) where oxygen concentration were higher (see Papiol *et al*. 2016). *Bathybembix bairdii* might therefore belong to a group of macrobenthic species that show a preference for low oxygen environment with high supply of detritus in the sediments, conditions that are typically found below the OMZ in the study area (see Papiol *et al*. 2016).

Bathybembix species are mostly deposit feeders in muddy sediments (Gage & Tyler 1991). Throughout the study area food supply (*i.e*., deposits of organic detritus originating from the euphotic zone) is abundant (Papiol *et al*. 2016) and benefit deposit feeders. Our material was essentially found associated with muddy bottoms, except off southwestern Mexico. Feeding habits of these two sub-populations, off Baja California and off southwestern Mexico, might therefore be different but we have no information on this. Tolerance to mild (<0.5 ml L^{-1} O_2) to severe (<0.2 ml L^{-1} O_2) hypoxia is remarkable but not surprising, as similar tolerance has been documented for several species of deep-water mollusks (Williams *et al*. 2004, Vaquer-Sunyer & Duarte 2008, Zamorano & Hendrickx 2012). The absence of specimens (either small or large) of *B. bairdii* in deeper water off southwestern Mexico (*i.e*., in depths >1299 m), where there is a significant increase of dissolved oxygen with increasing depth (Hendrickx & Serrano 2010, Serrano 2012), is rather puzzling and other factors (*e.g*., food availability, recruitment patterns) might affect species distribution in that area. Absence of specimens might also be related to patchy distribution patterns that characterize deep-water invertebrate fauna below the OMZ (Jumars & Eckman 1983, Levin *et al*. 2000, Papiol & Hendrickx 2016).

Size segregation by depth observed off Baja California might be due to the presence of two separate populations with distinct growing rhythm or to ontogenic migrations with larger, mature specimens migrating to shallower water. Changes in ontogenetic niche has been documented for shallow water species (*e.g*., Peel & Aldana-Aranda 2013) but is virtually undocumented for deep-water species. The narrow depth range at which *B. bairdii* was observed off southwestern Mexico (1,058 to 1,299 m), however, seems contradictory with the Baja California observations and further sampling is needed to establish the bathymetric distribution of this species, particularly trying to define where smaller specimens occur.

Size range of the material reported by Hendrickx & López (2006) was 10-54 mm (mostly >30 mm) for the Gulf of California and 32-44 mm for El Salvador, values that are similar to what was observed during this survey (*i.e*., 10.0 to 53.7 mm). Biomass data observed during this survey are far from the captures reported from off El Salvador (average of 25 kg ha^{-1}) (Hendrickx & López 2006). Smith & Hamilton (1983) reported an average density of 0.024 org. m^{-2} off southern California, equivalent to about 240 org. ha^{-1}, very close to the maximum density registered in this study (*i.e*., 207.45 org. ha^{-1}) off Baja California. Densities ranging from 14 to 769 kg trawl hour were recorded off El Salvador (Hendrickx & López 2006) which would represent an estimate of up to $71.2 \cdot 10^3$ specimens per hour of trawl considering individual weight between 18.0 g (large) and 3.6 g (medium-sized) for this species (10.8 on the average) (individual weight obtained from Mexican material). In this study, *B. bairdii* exhibited a meat (or soft part) content from 29 to 62% of total weight. Comparatively, meat content of *Hexaplex trunculus* (Linnaeus, 1758), represents about 38% of total weight (Vasconcelos *et al.* 2009). In other species of Gastropoda, however, meat content can be as high as 67-85% of total weight (Price *et al*. 1976). Although there is a clear relationship between size-total weight-age and meat weight in gastropods (Borulya & Bregman 2002), proportion of meat may vary according to reproductive cycle, stomach content and degree of erosion of the shell (Vasconcelos *et al*. 2009). As far as we know, there is no study on the nutritive value of *B. bairdii*. Kesavan *et al*. (2013) provided information related to the amino and fatty acids, the vitamins and minerals content of *Babylonia zeylanica* (Bruguière, 1789), noting that this abundant commercial species might provide an alternative source of meat in human diet; a similar study with *B. bardii* would be highly desirable. Associated fauna collected with *B. bairdii* was rather diverse (*i.e*., 110 species). The only comparative data available are those provided by Hendrickx & López (2006) from off El Salvador: decapod crustaceans (42.5%) and fishes (16%) largely dominated the by-catch, made of 33.0% of *B. bairdii*.

Gastropods have long been considered an emerging resource in the shrimp by-catch (Appukkutan & Babu-Philip 1994). *Bathybembix bairdii* has been recorded as a by-catch product of the 'Tanner' crab, *Chionoecetes tanneri* Rathbun, 1893, fishery by Phillips & Lauzier (1997) in British Columbia. These authors emphasized the dependence of the ecosystem where *C. tanneri* and the associated fauna live directly or indirectly from transfer of energy generated by near-surface primary production, a trend which has also been detected off the west coast of the Baja California Peninsula and in the Gulf of California, where *B. bairdii* is also known to occur (Papiol & Hendrickx 2016, Papiol *et al*. 2016). The presence of another species, *Bathybembix humboldti* has been reported from deep-water (200-1,480 m) by-catch off Chile, associated to *Heterocarpus reedi* Bahamonde, 1955, the 'chilean nylon shrimp' (Veliz & Vasquez 2000, Pérez *et al*. 2005) but no additional data were provided by these authors. Up to 2015, however, exploitation rate of species of *Bathybembix* occurring off Chile was not defined (Reyes & Hüne 2015).

Fishery potential of deep-water mollusks in the Mexican pacific is hard to evaluate due to their habitat (often below 500 m depth) and the time-consuming, costly fishing operations and need for specific gear (Hendrickx 2012). In addition, population dynamics and reproductive patterns of deep-water resources need to be thoroughly studied before regular fishery operations are to be considered and stocks should be adequately estimated (Phillips & Lauzier 1997, Koslow *et al*. 2000).

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Literature cited

Appukuttan KK & M Babu-Philip. 1994. Gastropods-an emerging resource in the by-catch of shrimp trawlers at Sakthikulangara-Neendakara area. Seafood Export Journal India 25(21): 5-18.

Austin WC. 1985. An annotated checklist of marine invertebrates in the cold temperate northeast Pacific. 686 pp. Khoyatan Marine Laboratory, British Colombia.

Borulya EM & YE Bregman. 2002. Growth and life span of the commercial gastropods of Buccinidae family in Peter the Great Bay, Sea of Japan. Journal of Marine Biology 28(4): 270-273.

Folk RL. 1968. Petrology of sedimentary rocks, 170 pp. Hemphill Publishing, Austin.

Gage JD & PA Tyler. 1991. Deep-sea Biology. A natural history of organisms at the deep-sea floor, 504 pp. Cambridge University Press, Cambridge.

GBIF. 2016. *Bathybembix*. GBIF.org. GBFI Home Page. The Global Biodiversity Information Facility.<http://www.gbif.org/species/2292805>

Gracia A & P Valentich-Scott. 2014. New records of soft bottom bivalves (Mollusca) from the continental shelf and upper slope of the northern Pacific Ocean of Colombia. Marine Biodiversity Records 7: 1-15. <doi:10.1017/S1755267214000566>

Helly JJ & LA Levin. 2004. Global distribution of naturally occurring marine hypoxia on continental margins. Deep-Sea Research I 51: 1159-1168.

Hendrickx ME. 2012. Operaciones oceanográficas en aguas profundas: los retos del pasado, del presente y del proyecto TALUD en el Pacífico mexicano (1989-2009). In: Zamorano P, ME Hendrickx & M Caso (eds). Biodiversidad y comunidades del talud continental del Pacífico mexicano, pp. 23-104. Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT), Instituto Nacional de Ecología (INE), Ciudad de México.

Hendrickx ME. 2015. Further records of species of *Gennadas* (Crustacea, Decapoda, Dendrobranchiata, Benthesicymidae) in the Mexican Pacific. Zootaxa 3980(3): 417-426.

Hendrickx ME & J López. 2006. Geographic and depth distribution of *Bathybembix bairdii* (Dall, 1889) (Mollusca, Gastropoda, Trochidae) in the East Pacific. Oceanides México 21(1-2): 93-99.

Hendrickx ME & D Serrano. 2010. Impacto de la zona de mínimo de oxígeno sobre los corredores pesqueros en el Pacífico mexicano. Interciencia 35(1): 12-18.

Hendrickx ME & D Serrano. 2014. Effects of the oxygen minimum zone on squat lobsters distribution in the Gulf of California, Mexico. Central European Journal of Biology 9(1): 92-103. <doi: 10.2478/s11535-013-0165-6>

Hendrickx ME, P Valentich-Scott & NY Suárez-Mozo. 2016. Deep-water bivalve mollusks collected during the TALUD XV cruise off the west coast of the southern Baja California Peninsula, Mexico. Biodiversity Data Journal 4: 1-22. <doi: 10.3897/BDJ.4.e8661>

Hickman CS. 1981. Selective deposit feeding by the deep-sea archaeogastropod *Bathybembix aeola*. Marine Ecology Progress Series 6: 339-342.

Jumars PA & JA Eckman. 1983. Spatial structure within deep-sea benthic communities. In: Rowe GT (ed). The sea, pp. 399-451. Wiley, New York.

Kameya A, RR Castillo, L Escudero, E Tello, V Blaskovc, J Córdova, Y Hooker, M Gutiérrez & S Mayor. 1997. Localización, distribución y concentración de langostinos rojos de profundidad Crucero BIC Humboldt 9607-08. 18 de julio a 06 de agosto de 1996. Publicación Especial, Instituto del Mar de Perú, pp. 7-47.

Keen AM. 1971. Sea shells of tropical West America, 1064 pp. Stanford University Press, Stanford.

Kesavan K, A Murugan & V Venkatesan. 2013. Nutritive Profile of Ivory Shell *Babylonia zeylanica* (Bruguière, 1789) (Mollusca: Gastropoda: Babyloniidae). National Academy Science Letters 36(3): 343-348.

Kiel S & JL Goedert. 2006. A wood-fall association from Late Eocene deep-water sediments of Washington State, USA. Palaios 21(6): 548-556.

Koslow J, GW Boehlert, JDM Gordon, RL Haedrich, P Lorance & N Parin. 2000. Continental slope and deep-sea fisheries: implications for a fragile ecosystem. ICES Journal of Marine Science: Journal du Conseil 57(3): 548-557.

Levin LA, JD Gage, C Martin & P Lamont. 2000. Macrobenthic community structure within and beneath the oxygen minimum zone, NW Arabian Sea. Deep-sea Research II 47: 189-226.

Miller RJ, CR Smith, DJ DeMaster & WL Fornes. 2000. Feeding selectivity and rapid particle processing by deep-sea megafaunal deposit feeders: A ^{234}Th tracer approach. Journal of Marine Research 58(4): 653-673.

Papiol V & ME Hendrickx. 2016. Community structure and ecology of deep-water decapod crustaceans below the Oxygen Minimum Zone in the SE Gulf of California, Mexico. Marine and Freshwater Research 67(12): 1862-1879.

Papiol V, ME Hendrickx & D Serrano. 2016. Effects of latitudinal changes in the oxygen minimum zone of the northeast Pacific on the distribution of bathyal benthic decapod crustaceans. Deep-Sea Research II 1-19. <doi: 10.1016/j.dsr2.2016.04.023>

Peel JR & D Aldana-Aranda. 2013. Size related distribution and mobility of the queen conch *Strombus gigas* in the Xel-Há Park, Mexican Caribbean. Proceedings of the 65th Gulf and Caribbean Fisheries Institute, pp. 421-426.

Pérez A, C Cortés & AH Buschmann. 2005. Bycatch en Chile. Amenaza a la biodiversidad marina, 60 pp. Oceana, Santiago de Chile.

Phillips AC & R Lauzier. 1997. Biological background for the development of a new fishery for the grooved Tanner crab (*Chionoecetes tanneri*) off British Columbia. Department of Fisheries and Oceans Canadian Stock Assessment Secretariat Research, Nanaimo. Document 97/148: 1-87. <http://waves-vagues.dfo-mpo.gc.ca/Library/236089.pdf>

Price TJ, GW Thayer, MW La Croix & GP Montgomery. 1976. The organic content of shells and soft tissues of selected estuarine gastropods and pelecypods. Proceedings of the National Shellfisheries Association 65: 26-32.

Ramírez R, C Paredes & J Arenas. 2003. Moluscos del Perú. Revista de Biología Tropical 51(3): 225-284.

Ramírez-Rodríguez M, F Arreguín-Sánchez, G de la Cruz-Agüero & E Balart-Páez. 2003. Distribución de *Cancer johngarthi* Carvacho, 1989 (Decapoda: Brachyura: Cancridae), en la costa occidental de Baja California Sur, México. In: Hendrickx ME (ed). Contribuciones al estudio de los crustáceos del Pacífico Este 2: 165-168. Instituto de Ciencias del Mar y Limnología, UNAM, Ciudad de México.

Reyes P & M Hüne. 2015. Mi guía de especies marinas chilenas: guías de reconocimiento de especies objetivo, fauna acompañante y especies incidentales capturadas en las pesquerías industriales de arrastre de merluza común, merluza de cola y crustáceos bento-demersales, en la pesquería artesanal de merluza común y en la pesquería de cerco de sardina común y anchoveta, 128 pp. Instituto de Fomento Pesquero, Valparaíso.

Rice T. 1994. A catalog of Dealer´s Prices for marine shells, 131 pp. Sea and Shore Publications, Port Gamble.

Santhanam R. 2018. Biology and ecology of edible marine gastropod molluscs. Biology and ecology of marine life, 460 pp. Apple Academic Press, Oakville / Waretown.

Sellanes J, E Quiroga & C Neira. 2008. Megafauna community structure and trophic relationships at the recently discovered Concepción Methane Seep Area, Chile, ~36°S. ICES Journal of Marine Science 65(7): 1102-1111.

Serrano D. 2012. La zona del mínimo de oxígeno en el Pacífico mexicano. In: Zamorano P, ME Hendrickx & M Caso (eds). Biodiversidad y comunidades del talud continental del Pacífico mexicano, pp. 105-119. Secretaría del Medio Ambiente y Recursos Naturales (SEMARNAT), Instituto Nacional de Ecología (INE), Ciudad de México.

Smith CR & SC Hamilton. 1983. Epibenthic megafauna of a bathyal basin off southern California: patterns of abundance, biomass, and dispersion. Deep Sea Research Part A 30(9): 907-928.

Strickland JDH & TR Parsons. 1972. A practical handbook of seawater analysis. Fisheries Research Board of Canada, Bulletin 167: 1-310.

Suárez-Mozo NY & ME Hendrickx. 2016. New record for the deep-sea genus *Tripoplax* (Mollusca: Polyplacophora) in the eastern Pacific. Marine Biodiversity Records 9:10: 1-6. <doi 10.1186/s41200-016-0011-z>

Vaquer-Sunyer R & CM Duarte. 2008. Thresholds of hypoxia for marine biodiversity. Proceedings of the National Academy of Sciences 105(40): 15452-15457.

Vasconcelos P, MB Gaspar, M Castro & ML Nunes. 2009. Influence of growth and reproductive cycle on the meat yield and proximate composition of *Hexaplex trunculus* (Gastropoda: Muricidae). Journal of the Marine Biological Association of the United Kingdom 89(6): 1223-1231.

Veliz D & JA Vasquez. 2000. La Familia Trochidae (Mollusca: Gastropoda) en el norte de Chile: consideraciones ecológicas y taxonómicas. Revista Chilena de Historia Natural 73(4): 757-769.

Wehrtmann IS & V Nielsen-Muñoz. 2009. The deepwater fishery along the Pacific coast of Costa Rica, Central America. Latin America Journal of Aquatic Research 37: 543-554.

Williams ST, JD Taylor & EA Glover. 2004. Molecular phylogeny of the Lucinoidea (Bivalvia): Non-monophyly and separate acquisition of bacterial chemosymbiosis. Journal of Molluscan Studies 70: 187-202.

Zamorano P & ME Hendrickx. 2012. Distribution of *Lucinoma heroica* (Dall, 1901) in the minimum oxygen zone in the Gulf of California, Mexico. Marine Biodiversity Records 5: 1-8. <doi: 10.1017/S1755267212000644>

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