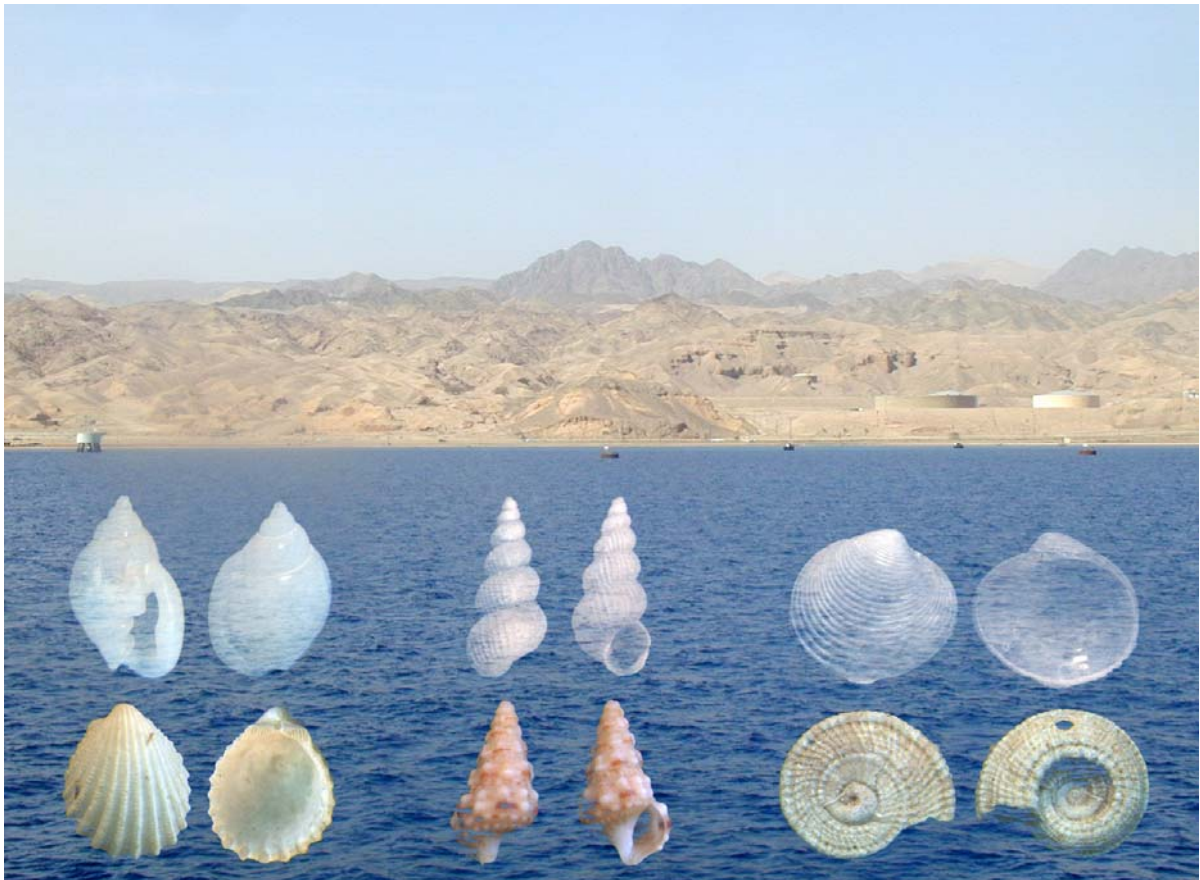




THE MINISTRY OF NATIONAL
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GEOLOGICAL SURVEY OF ISRAEL

Molluscan fauna of the Gulf of Elat: indicators of ecological change

Yael Edelman-Furstenberg and Galina Faershtein





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ABSTRACT

The natural variability of an environment can be characterized correctly only by investigating the historic-geologic past of that specific environment. Only then can the present-day ecological situation be determined as within or outside the natural limits of that environment.

The Gulf of Elat comprises an oligotrophic marine environment. In the past decades man-induced changes have had a strong ecological imprint on the biota, leading to a shifting in baselines, from an unaffected marine ecosystem to a currently stressed one. Despite extensive biological research on the water column and coral communities, the controlling factors for the ecological change are still controversial. An important parameter of the ecological system that has hardly been investigated is the seafloor, especially how variations in seafloor environment influenced benthic community structure in the shallow waters (20- 100 meters depth).

To be able to assess man-induced changes over the last few decades in the Gulf of Elat it is necessary to establish the nature of the pre-anthropogenic baseline, with the main focus on the seafloor. The present study shows how this ecological stress, or nutrient transformation in the water column, is expressed in community-level changes in the molluscan fauna (species richness, evenness, feeding modes, life styles and abundance) as well as in the character of the bottom sediments (grain size, % total organic carbon).

Molluscs are one of the major groups that leave a preservable fossil record and are known to be sensitive recorders of marine seafloor conditions. Molluscan skeletal death assemblages average short-term environmental fluctuations such as seasonality, reproduction and rare species occurrences and thus exceed the quality of information acquired from any single biological census. Investigating the death assemblage record of molluscs (community structure analysis, biodiversity measurements, taphonomic state of shells) offers temporal perspective and a fuller (paleo)ecological picture. Furthermore, molluscs serve as an especially important tool in shallow-intermediate water environments, which corresponds to the water depths that are particularly likely to be affected by societal activities.

Forty seven stations were sampled during the study. This report focuses on 16 shallow-penetrating grab samples of dead mollusks (grab surface 20 cm²) from 8 different sites taken at water depth of 20-100 meters. Grab samples from each location

were taken in two time-slices. Molluscan death assemblages from the top ~2 cm and bottom ~2 cm of sediment were examined and the two assemblages compared.

In addition, 2 short cores from 70 and 50 meters water depth were taken for age estimation and sedimentation rates. First results of ²¹⁰Pb dating of the sediments show that the top sediment represents the last 4-6 years while the bottom sediment represents 32-50 years ago (sedimentation rate between 0.37-0.66 cm/year for the northern part of the Gulf). The preservation state of the molluscan shells range between well preserved shells to bored and encrusted shells.

Variations in abundance, richness, evenness and dominance of the molluscs enabled the grouping of 4 molluscan assemblages associated with differing water depth. No significant differences were found in molluscan community structure, biodiversity or shell preservation state between top and bottom samples in the 8 sites examined. Thus, the ecological change recorded during the past decades in the Gulf does not seem to affect the molluscan assemblages in any significant way and they do not record any environmental change. All the same, the results thus far do show a significant difference between the molluscan death assemblages from the surface sediments and those from the bottom sediments at 50 meters water depth in the area where the fish farms operated.

A high diversity of molluscan taxa was found in the sandy and muddy sediments of the Gulf of Elat, **272** gastropod species and **124** bivalve species. Each taxon in this report was identified and a high-quality image was taken, thus creating the largest documentation of molluscan shells, to date, of the sandy seafloor of the Gulf of Elat. This detailed record generates for the first time a firm basis for further ecological studies on molluscs in this region.

There is a vital need for establishing clear, repeatable and widely accepted biodiversity and ecosystem-function indicators. These will serve as an important baseline for further studies regarding the nature of ecological changes in the Gulf.

ACKNOWLEDGMENT

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INTRODUCTION

The Gulf of Elat is situated at the northern most tip of the Red Sea. It is long (180 km) and narrow (14-26 km), similar to the Red Sea itself (2000 km long, average of 280 km wide) (Braithwaite, 1987). The straits of Tiran (250 meters water depth) and, more importantly, the Straits of Bab-El-Mandeb (137 meters deep) separate this ecological-oceanographic system from the Indian Ocean one (Locke and Thunell, 1988). As a result of this partial separation, today as in the past the Red Sea and Gulf of Elat specifically, experience and are very sensitive to large-term variations in their ecological settings, (e.g., Reiss et al., 1980; Edelman-Furstenberg et al., 2001, 2009; Arz et al., 2003; Almogi-Labin et al., 2008). This makes the Gulf a “natural laboratory” for investigating environmental fluctuations in semi-restricted marine environments (Reiss and Hottinger, 1984).

The Red Sea and its northern Gulf of Elat are surrounded by deserts and situated in the arid climatic zone (Reiss and Hottinger, 1984). Runoff of water into the Gulf is very scarce and originates from winter flash floods of major wadies (Reiss and Hottinger, 1984; Edwards, 1987). These extreme conditions challenged and restricted human activity in the past, thus the ecosystem in the Gulf stayed relatively stable and unspoiled. However, in the past few decades the northern Gulf of Elat has degraded as a result of both anthropogenic and natural environmental factors and the overall oligotrophic marine environment (Reiss and Hottinger, 1984) has been altered. Human activities in the coastal zone such as, urbanization and sewage run-off during 1980-1990, coastal development, phosphate input caused by spills in the Gulf harbor and, in the last decade or so, the building of commercial fish-cages (amongst others, Fishelson, 1995; International Expert Team Report, 2001) have increased sediment, nutrient, and contaminant input into this system.

Recent study on the coral reefs of the Gulf reveal considerable ecological impact on the community structure (Wielgus et al., 2003) and reproduction parameters of the corals as well as in the growth rate of the reefs (Loya et al., 2004; Rosenberg and Loya, 2004, Abelson et al., 2005, but see for example Bongiorno et al., 2003 for contradicting ecological implications). In recent decades, the oligotrophic Gulf has steadily gained nutrients in the water column (Boaz Lazar, International Expert Team Report, 2001). At present, sewage run-off to the Gulf has ceased and the fish-cages have now been removed. Man-induced changes have had a strong ecological imprint

on the biota (e.g., Loya, 1975; Fishelson, 1973; 1995), leading to a shift from an oligotrophic, unaffected marine ecosystem to a currently stressed one; in other words, to a shifting in baselines (*sensu* Jackson et al., 2001). The present study shows how this ecological stress, or nutrient transformation in the water column, is also expressed in community-level changes in the molluscan fauna as well as in the character of the bottom sediments.

An ongoing annual monitoring program carried out by the Inter-University Institute for Marine Sciences (IUI) at Elat, headed by A. Genin, aims at tracing ecological-environmental changes in the Gulf and identifying their causes. The main focus is on the water column and the coral communities (<http://www.iui-eilat.ac.il/NMP/Default.aspx>). A considerable body of biological research has focused mainly on the coral reefs (e.g., Libermann et al., 1995; Wielgus et al., 2004; Perkol-Finkel and Benayahu, 2009) and water column (e.g., Genin et al., 1995; Yahel et al., 1998; Stambler, 2008). Unfortunately, these studies show an ambiguous picture and thus, it is still difficult to identify the timing and controlling factors of the ecological change. A main reason for this is the lack of prolonged ecological monitoring. Little is known of the ecological impact on the benthic system as a whole, including the extent to which variations in seafloor environment influence benthic biodiversity and community structure of fauna in the northern Gulf of Elat. These changes have not been studied in a temporal association; neither for the pre-ecological nor present-ecological stress periods.

Macrobenthic invertebrates such as shelled mollusks, brachiopods, echinoderms, and crustaceans are known to be sensitive indicators of seafloor oxygen levels, water energy and sediment mass properties, based on studies elsewhere (e.g., Rhoads and Morse, 1971; Rhoads and Boyer, 1982; Clarke and Warwick, 1994; Levin et al., 2000; Edelman-Furstenberg, 2008). After death, skeletal macrobenthic material is buried and preserved in the sediment record. Moreover, quantitative tests of “live-dead agreement” in modern environments indicate that molluscan skeletal death assemblages capture the composition and community structure of the local living community to a high degree (Aller, 1995; Kidwell, 2001; 2002a; 2002b), matching or even exceeding the quality of information acquired from any single biological census (Kidwell, 2003). This is due to the summing of seasonal and annual variations (for example, reproduction or rare species occurrences) in time-averaged death assemblages (*cf.*, Walker and Bambach, 1971; Peterson 1977). Thus, ecological

characterizations based on macrobenthic death assemblages can be considered as a more complete "modern" picture than information based on live censuses alone, and are particularly appropriate for comparisons with possible ancient analogs (where fossil assemblages are probably also time-averaged).

Mollusks (seashells, snails and scaphopods) constitute a major, well studied group in both modern and ancient environments. They leave a preservable fossil record and thus are particularly appropriate for comparisons with historic analogs (Kidwell and Bosence, 1991; Kidwell and Flessa, 1995; Sepkoski, 2002). Furthermore, macrofauna invertebrates serve as an especially important tool in shallow water environments, which corresponds to the water depths that are particularly likely to be affected by societal activities.

Mollusk distribution, species richness, lifestyle and feeding strategy are mainly dependant on the amount of available food, oxygen levels and type of substratum (grain size, etc) on the seafloor (see reviews by Rhoads and Boyer, 1982; Hall, 1994; Diaz and Rosenberg, 1995). Species richness and species evenness usually decrease with increasing environmental stress (amongst others, Rosenberg, 1976; Rhoads and Morse, 1971; Gray et al., 1988; Clarke and Warwick, 1994; Levin et al., 2002), such that a low number of species and one dominating mollusc reflect stressed seafloor conditions, while a large number of species and a more evenly distributed assemblage reflect normal seafloor conditions. Pearson and Rosenberg (1978) showed that deposit feeders prefer organically-enriched areas, and therefore a proportional increase in chemosymbionts and deposit-feeders in death assemblages is expected with increasing organic load/oxygen stress. Alternatively, an increase in suspension-feeders points to nutrient particles suspended in the water column rather than in the sediments. In general, infaunal species are capable of tolerating dysaerobic oxygen levels whereas epifauna are associated with higher oxygen levels (Rhoads and Morse, 1971; Tyson and Pearson, 1991) and have lower tolerance to decreased oxygen levels (Rabalais et al., 2002). Indeed, in a study on the fish cages in the Gulf of Elat, Eden and others (2003) found a correlation between the distribution of the mud snail *Nassarius sinusigerus* and food availability, with a peak in abundance associated with moderately enriched sediments in close proximity to the fish cages.

Zaltzman (1970 –M.Sc. in Hebrew) described the distribution of living mollusca in the deep waters of the Gulf of Elat (dredges from 200-1000 meters) and only

briefly described the 0-200 meter water depth mollusks. She found a total of 74 gastropod species and 69 bivalves. A more comprehensive report of living molluscan distribution, given in Fishelson (1971, and references within), describes the shallow benthic fauna (shoreface, shallow subtidal) of the Red Sea. His survey found between 22 and 35 molluscan species for each locality. The distribution pattern of cerithiid gastropods along the western coast of the Gulf of Elat and Sinai were studied by Ayal and Safriel (1982). Recently, the molluscan distribution on Jordanian reefs and hard substrata in the Gulf of Aqaba were studied, with 51 taxa identified (Zuschin and Stachowitsch, 2007). The authors suggest that any substrate changes in the shallow reef area will significantly impact distinct molluscan assemblages. At present, the Jordanian coast is stated to be in good condition as compared to the Israeli reef area (Zuschin and Stachowitsch, 2007).

In general, most studies on the Gulf focused on the rocky shore and coral reef zones even though the main part of the Gulf's seafloor comprises loose sediments (sandy to muddy) and is an entirely different benthic habitat. Thus, there is a great gap of information regarding the shallow-intermediate waters of the Gulf, which constitute the main part of the seafloor. This bulk of the seafloor lacks coral reefs and is dominated by molluscan fauna, yet no significant work on this surface has been done up to date. The Red Sea, especially its northern part, is much better studied in this respect. Molluscs occupy the full array of habitats present in the Red Sea (Mastaller, 1987). The taxonomy of shallow marine molluscan fauna of the Red sea were studied by Oliver (1992, and refs within). In the Bay of Safaga alone (northern Red Sea), 243 species of bivalve were found (Zuschin and Oliver, 2005). Bivalve distribution in the reefs of the Bay of Safaga were studied by Zuschin and Pillar (1997) and Zuschin and Hohenegger (1998). The dead molluscan assemblage in the Bay was shown to be dominated by encrusting bivalves (Zuschin et al., 2000). Bivalve death assemblages ranging from shallow to deep waters in the Red Sea show that the largest number of taxa per site (86) was found from a dredge sample in the deep shelf at ~80 meters water depth (Grill and Zuschin, 2001). At all depths, the most common feeding strategy was suspension feeding, and infauna was the dominant life style (Grill and Zuschin, 2001).

METHODS

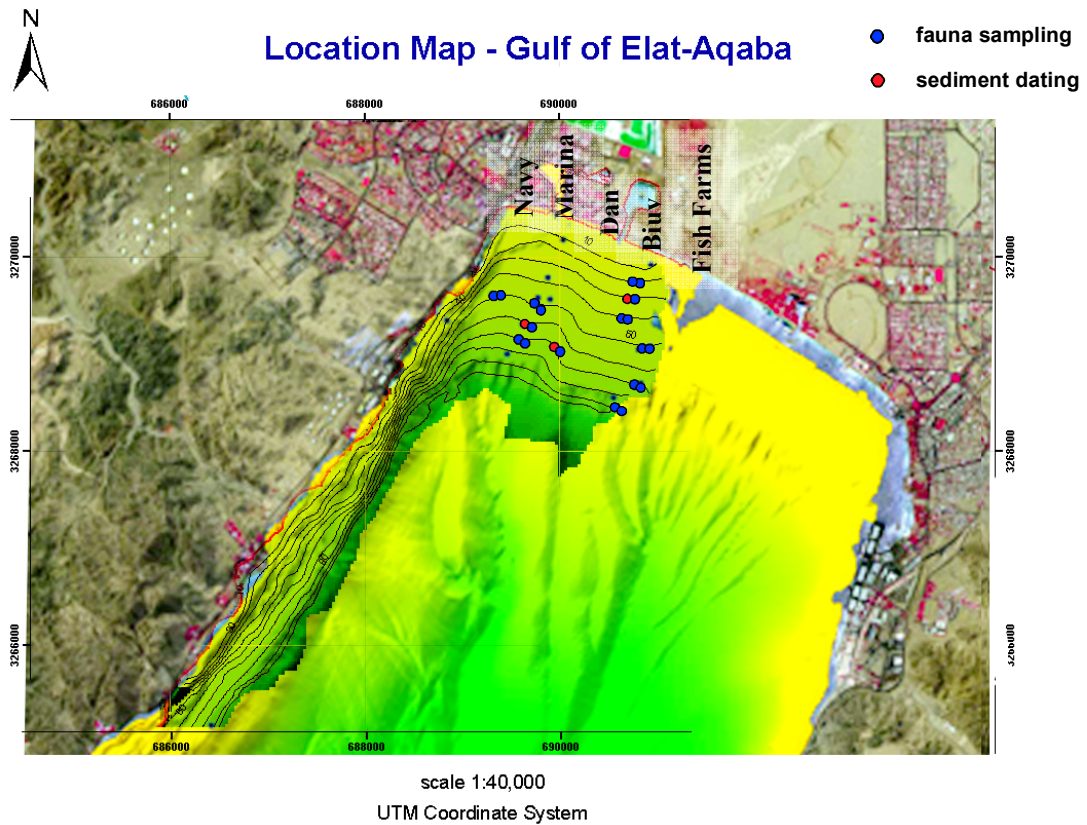
In order to get a better picture of the nature and direction of ecological changes in the Gulf of Elat, 16 shallow-penetrating grab samples of dead mollusca from 20-90 meters water depth were taken as shown in the location map below (Figure 1). Grab samples from each location were taken in two time-slices. Samples were washed and sieved with a 1 mm sieve, oven dried at 50°C and split into sample aliquots containing about at least 100 specimens. Molluscan death assemblages from the top ~2 cm and bottom ~2 cm of sediment were examined and the two assemblages compared to each other. Grab penetration ranged between 6-19 cm sediment depths. The top 2 cm of the grab samples are assumed to represent the past few years, while the bottom 2 cm are assumed to represent the environment before or during ecological change (Figure 2). This depends on the sedimentation rate at each location, which was assessed using the age correlation frame-work obtained by 210-Pb analysis.

Figure 2.



This study of molluscan death assemblages is part of a larger ongoing project on the sediments of the Gulf and can take advantage of the study of the benthic foraminifera from the same grab samples, which will serve as the complementary record for the seafloor sediment-water interface environmental conditions that existed in the Gulf, as opposed to the mollusks that reflect the overlying water conditions. Short cores for microfaunal analysis were taken from water depth of 27-94 meters.

Figure 1: Map of the sample locations in northern Gulf of Elat.



210-Pb sediment dating:

A fundamental and crucial aspect of the study is the need to date specific time-slices using the 210-Pb dating method. Analysis of the faunal assemblage combined with accurate sediment dating will enable the examination in both space and time of the environmental changes.

Diversity metrics: Species richness and species evenness:

Species richness is the number of species per sample, whereas species evenness expresses how uniformly individuals are distributed among the different species and thus the extent to which the community is dominated by a small number of species. Both indices usually decrease with increasing environmental stress (amongst others Rosenberg, 1976; Rhoads and Morse, 1971; Gray et al., 1988; Clarke and Warwick, 1994; Levin et al., 2002). Species richness in particular is sample-size dependent (the larger the sample the more species are likely to be found). Thus, in order to compare between samples in the present analysis, species richness was counted and evenness calculated for a standard number of individuals (100) per sample.

A multivariate analysis was conducted using the package PRIMER v.6 of the Plymouth Marine Laboratory, specifically in order to find associations between samples and biological and ecological variables.

Grain size analysis:

A general sedimentologic analysis was conducted on a sub-set of samples. The granulometric analysis was done in the sedimentologic lab at the Geologic Survey of Israel using a Mastersizer.

Total organic carbon analysis:

The weight percent of the total organic carbon (%TOC) for a sub-set of samples was determined at the Geologic Survey of Israel using an element analyzer. This was also done as a complementary profile for the sediment dating analysis.

RESULTS

Age-correlation:

A 30cm long core from 70 meters water depth (DAN70Pb) was sampled for 210-Pb dating using γ -rays. The samples were sent to Prof. Helmut Fischer at the dating laboratory at Bremen University in Germany. In addition two cores of 25-30 cm long from shallower depths (BIUV 40Pb and MAR 60Pb) were sent to a specialized 210-Pb dating laboratory in Holland - NIOZ (Royal Netherlands Institute for Sea Research), to be dated using the α -ray method. First results of the dating show that the top sediment represents the last 4-6 years while the bottom sediment represents ~30-45 years ago.

Sedimentologic analysis:

The sediments in the northern Gulf of Elat between 27 and 94 meters water depth belong to the textural group of muddy sand. Sand fraction range from 64-95 wt% and mean grain size between 130-200 μ m at ~70 and 83-90 meters, respectively (Perelis-Grossowicz et al., 2008).

Table 1: Stations location and sand content and %TOC (total organic carbon) of the analyzed sediment samples.

| Station | Location | Water depth | %Sand fraction (>63µm) top vs. bottom | %TOC |
|---------------|-------------------------|-------------|---------------------------------------|-----------|
| NAVY-50 | 29°32.444'N/34°57.148'E | 50m | 78.5/74.9 | 0.29/0.24 |
| Marina-50 | 29°32.414'N/34°57.558'E | 50m | 64.1/65.2 | 0.38/0.37 |
| Marina-60 | 29°32.334'N/34°57.460'E | 60m | 66.67/55.38 | N/A |
| Marina-70 | 29°32.254'N/34°57.365'E | 70 m | 63.7 | 0.32 |
| PbDanA70 | 29°32.184'N/34°57.607'E | 70m | N/A | 0.27/0.33 |
| Fish Farm-50B | 29°32.106'N/34°58.178'E | 53m | 69.7/70.9 | 0.38/0.33 |
| Fish Farm-70 | 29°31.897'N/34°58.184'E | 72 m | 73.5 | 0.26 |
| Fish Farm-90 | 29°31.806'N/34°57.994'E | 90 m | 76.0/79.8 | 0.36/0.32 |
| Biuv-20 | 29°32.555'N/34°58.149'E | 20m | N/A | 0.39/0.54 |
| Biuv-40 | 29°32.356'N/34°58.083'E | 40m | 73.19/58.64 | 0.26/0.23 |

Ecologic faunal analysis:

Gulf of Elat taxa were identified to the lowest taxonomic level possible, usually genus or species, using published taxonomic monographs and with the professional help of Henk Mienis curator of the National Mollusc Collection at the Hebrew University of Jerusalem.

259 gastropod species (12 unidentified) and 123 bivalve species (10 unidentified) were found in the sandy and muddy sediments of the Gulf of Elat. Abundance, richness, evenness and dominance of the molluscs vary considerably as a function of water depth. The preservation state of the molluscan shells range between samples with well preserved shells to bored and encrusted shells in samples of low preservation.

The taxonomic composition of the molluscan fauna identified in the samples of the northern Gulf of Elat is given in PLATES: Gastropoda 1-21 and Bivalvia 1-13. There were 12 unidentified gastropods and 14 unidentified bivalve species.

CLASS BIVALVIA: (PLATES 1-13)

Subclass PROTOBRANCHIA

Superfamily Solemyoidea

Solemya sp.

Superfamily Nucinelloidea

Cyrilla diabolica (Jousseume, 1897)

Superfamily Nuculoidea

Nucula inconspicua H. Adams, 1871

Subclass PTERIOMORPHA

Superfamily Arcoidea

Arca accumulata Oliver & Chesney, 1994

Arca navicularis Bruguiere, 1789

Arca sp. NAVY50top

Barbatia cf. *sulcata* (Lamarck, 1819)

Barbatia foliata (Forsskal, 1775)

Barbatia trapezina (Lamarck, 1819)

Anadara

Superfamily Limopsoidea

Limopsis elachista Sturany, 1899

Glycymeris livida (Reeve, 1843)

Superfamily Mytiloidea

Septifer forskali (Dunker, 1855)

Amygdalum peasei (Newcomb, 1870)

Musculus viridulus (H. Adams, 1871)

Crenella striatissima Sowerby, 1904

Mytilid

Mytilid MAR50bot

Superfamily Pinnoidea

Pinnidae sp.

Superfamily Pterioidea

Pteria sp.

Pteria sp. FF50B bottom

Pteria MAR50top

Pteriidae MAR50top

?Pteriid

Pictada radiata (Leach, 1814)

Superfamily Pectinoidea

Pectinidae sp.

Parvamussium thyrideum (Melvill in Melvill & Standen, 1907)

Parvamussium formosum (Melvill in Melvill & Standen, 1907)

Similipecten eous (Melvill & Standen, 1907)

Juxtamusium maldivense (Smith, 1903)

Cryptopecten nux (Reeve, 1853)

Superfamily Limoidea

Limatulella sp.

Limea pectinata H. Adams, 1870
Superfamily Ostreoidea
Ostreidae
Oystreid
Oystreid BIUV40bottom
Saccostrea?
Parahyotissa numisma (Lamarck, 1819)
Superfamily Anomioidea
Anomia sp.

Subclass HETERODONTA

Superfamily Lucinoidea
Anodontia sp.
Cardiolucina semperiana (Issel, 1869)
Ctena divergens (Philippi, 1850)
lucinid sp. BIUV40top
Lucinoidea sp.
Loripes sp.
Superfamily Galeommatoidea
Galeommatidae sp.
Galeommatidae sp. NAVY50top
Galeommatidae sp. MAR50top
Galeommatidae (MAR50bottom)
Superfamily Chamoidea
Chama sp.1
Chama sp.2
Superfamily Carditoidea
Cardites akabana (Sturany, 1899)
Cardites rufa (Labordes & Deshayes, 1834)
Superfamily Cardioidea
Parvicardium sueziensis (Issel, 1869)
Afrocardium richardi (Audouin, 1826)
Fulvia fragilis (Forsskal, 1775)
Fulvia australis (Sowerby, 1834)
Acrosterigma maculosum (Wood, 1815)
Acrosterigma sp.
Frigidocardium torresi
Cardiid sp. (39 ribs)
Cardiid sp. BUIV40top
Cardioidea sp. NAVY50bottom
Superfamily Mactroidea
Mactrotoma ovalina Lamarck, 1818
Superfamily Tellinoidea
Family: Tellinidae
Exotica triradiata H. Adams, 1871
Moerella lactea (H. Adams, 1871)
Semelangulus mesodesmoides Oliver & Zuschin, 2000
Pharaonella perna (Spengler, 1797)
Arcopella isseli (H. Adams, 1871)

Pinguitellia pinguis (Hanley, 1844)
Tellina sp.-FF90bottom
Tellinid sp. NAVY50bottom
Tellinid sp. (smooth) FF50Bbottom
Tellinid unknown sp. FF50Bbottom
Tellinid sp.
Tellinid
Tellinid sp. BIUV40top
Tellinidae 1MAR70top
Tellinidae 2MAR70top
Tellinidae BIUV20B bottom
Tellinoidae BIUV40bottom
Tellinid BIUV40bottom

Family: Macominae

Loxoglypta clathrata (Deshayes, 1835)
Loxoglypta subpallida (Smith, 1891)

Family Semelidae

Semele fragillima (Issel, 1869)
Rocheffurtina cf. *Sandwichensis* (Smith, 1885)
Semele sp.1
Semeleidae sp.
Leptomya sp.

Superfamily Veneroidea

Dorisca nana (Melvill, 1898)
Microcirce dilecta (Gould, 1861)
Microcirce constenans? Oliver & Zuschin, 2001
Lioconcha philippinarum (Hanley, 1844)
Lioconcha sp.1
Lioconcha sp.2
Lioconcha sp.3
Pitar yerburyi (Smith, 1891)
Clementia papyracea (Gray, 1825)
Dosinia erythrea Romer, 1860
Dosinia
Timoclea roemeriana (Issel, 1869)
Timoclea djiboutiensis (Jousseau, 1894)
Venerid unknown
Venerid cf. *Timoclea?*

Superfamily Myoidea

Corbula erythraeensis H. Adams, 1871

Subclass ANOMALODESMATA

Superfamily Pandoroidea

Cardiomya singaporensis (Hinds, 1843)

CLASS GASTROPODA: (PLATES 1-21)

Subclass PROSOBRANCHIA

Superfamily Pleurotomarioidea

?*Scissurella aetheria* (Melvill and Standen, 1903)

Superfamily Neritoidea

Smaragdia purpureomaculata Dekker, 2000

Superfamily Fissurelloidea

Vacerrera nana (H. Adams 1872)

Superfamily Trochoidea

Perrinia stellata (A. Adams, 1864)

Rubritrochus declivis (Farscal, 1775)

Ethalia bellardii (Issel, 1869)

Ethiminolia hemprichii (Issel, 1869)

Pagodatrochus variabilis (H. Adams, 1873)

Pseudominolia biangulosa (A. Adams, 1864)

Pseudominolia gradata (Sowerby, 1895)

Pseudominolia nedyma (Melvill, 1897)

Pseudominolia sp.?

Lodderena sp.

Leucorhynchia crossei Tryon, 1888

Lodderia novemcarinata (Melvill, 1906)

"*Cyclostrema*" *quinquecarinatum* Melvill, 1906

"*Cyclostrema*" sp.10

"*Cyclostrema*" sp.11

?Cyclostrematidae

Bothropoma isseli (Thiele, 1921)

Phasianella solida (Born, 1778)

Calyostoma sp.

Superfamily Cerithioidea

Bittium sp.

Cerithicea NAVY50top

Cerithidium diplax (Watson, 1886)

Cerithidium perpavulum (Watson, 1886)

Cerithidium NAVY50bottom

Cerithidium sp. BIUV40top

Cerithium scabridum Philippi, 1848

Cerithium sp. 1-FF90bottom

Cerithium sp. 2-FF90bottom

Cerithidae sp. FF50Btop

Cerithidae sp. FF50Bbot

Cerithidae sp. FF70-top

Cerithidae sp. MAR70top (encrusted)

Cerithidae sp.1-FF90bottom (sp.1 NAVY50top)

Ceritiid sp.

Ceritiid ? MAR50top

Varicopeza pauxilla (A. Adams, 1855)

Argyropeza divina Melvill & Standen. 1901

Plesiotrochus souverbianus Fischer, 1878

- Rhinoclavis sordidula* (Gould, 1849)
- Diala semistriata* (Philippi, 1849)
- Planaxis savignyi* Deshayes, 1844
- Scaliola elata* Issel, 1869
- Finella pupoides* Adams A., 1860
- Turritella cochlea* Reeve, 1849
- Archimediella maculate* (Reeve, 1849)
- Gazameda alba* (H. Adams, 1872)
- Superfamily Rissoidae
 - Rissoidae sp.
 - Rissoidae sp. (?Setia)
 - Rissoina pachystoma?* Melvill, 1896
 - Pelycidion* cf. *xanthias* (Watson, 1888)
 - Pseudoliotia henjamense* (Melvill & Standen, 1903)
- Superfamily Hipponicoidea
 - Hipponicidae sp.
- Superfamily Crepiduloidea
 - Trichotropidae sp.
- Superfamily Xenophoroidea
 - Xenophora solaroides* (Reeve, 1845)
- Superfamily Cypraeoidea
 - Erosaria macandrewi* (Sowerby, 1870)
- Superfamily Velutinoidea
 - Lamellariidae Orbigny, 1841
- Superfamily Naticoidea
 - Naticid sp.
 - Naticidae
 - Naticidae 1 (operculum)
 - Naticidae 2 (operculum)
 - Naticoidea?BIUV20Bbot
 - Notocochlis gualtieriana* (Récluz, 1844)
- Superfamily Tonnoidea
 - Ranellidae MAR70top
 - Ranellidae?sp. MAR70top
 - Cymatidae sp.1
 - Cymatium* sp.
 - Cymatium trilineatum* (Reeve, 1844)
 - Cymatium aquatile* (Reeve, 1846)
- Superfamily Cerithiopsoidae
 - Cerithiopsidae sp.
- Superfamily Triphoroidea
 - Triphoridae sp.1
 - Triphoridae sp.2
 - Viriola?*
- Superfamily Epitonioidea
 - Cycloscala hyaline* (Sowerby, 1844)
 - Epitonium* cf. *laidlawi* (Melvill & Standen, 1903)
 - Epitonium* sp.1 FF50Btop
 - Epitonium* sp.1 FF50Bbot
 - Epitonium* NAVY50bottom
 - Epitonium* FF90bot

Epitonium 1 NAVY50top
Epitonium replicatum (Sowerby, 1844)
Recluzia jehennei (Petit, 1853)

Superfamily Eulimoidea

Aclis Lovén, 1846
Eulima sp.2 FF50Bbot
Eulima sp.1 NAVY50top
Eulimidae sp.1 MAR50bot
Eulimidae sp.BIUV40top
Eulimidae BIUV40bottom
Pelseneeria Kohler and Vaney, 1908

Superfamily Muricoidea

Muricid
Muricidae sp.1 MAR50top
Muricoidae? MAR50top
Muricoidae sp. 1 NAVY50bottom
Muricoidae sp. 2 NAVY50bottom
Muricoidae sp. 3 NAVY50bottom
Muricoidae sp. 4 NAVY50bottom
Muricoidae sp. 5 NAVY50bottom
Muricoidae sp. 6 NAVY50bottom
Muricoidae sp. 7 NAVY50bottom
Muricidae sp.1 MAR50bot
Muricidae sp.2 MAR50 bot
Muricidae BIUV40bottom
Favartia sp.
Ergalatax contracta (Reeve, 1846)
Buccinidae NAVY50top
Collumbillidae NAVY50bottom
Collumbillidae MAR70top
Colombilidae sp.
Mitrella nympha (Kiener, 1841)
Mitrella sp. 1
Mitrella sp. 2-FF50Btop
Mitrella sp. 4-FF50Bbot
Mitrella sp.1-FF90bottom
Mitrella sp.2-FF90bottom
Mitrella sp.2
Mitrella sp.MAR70top
Mitrella sp.2 MAR50bot
Zafra savignyi (Moazzo, 1939)
Zafra sp 1
Nassarius conoidalis labordei Mari, 1929
Nassarius sinusigerus (A. Adams, 1852)
Nassarius splendidulus (Dunker, 1846)
Nassarius sp.1
Nassarius sp.2
Nassarius sp.3 MAR70top
Fasciolaridae sp. 1FF50Bbot
Fasciolaridae sp. 2 FF50Bbot
Fasciolaridae sp. 3 FF50Bbot

Fasciolaridae NAVY50bottom
Fasciolaridae spp?MAR70top
Fusinidae sp.1 NAVY50top
Fusinidae sp.2 NAVY50top
Fusinidae sp.3 NAVY50top
Fusinus NAVY50bottom
Fusinus sp.1-FF90bottom
Fusinus sp.2-FF90bottom
Fusinus sp.3-FF90bottom
Fusinus sp.4-FF90bottom
Fusinus sp.3- MAR50top
Latirus sp.
Ancilla sp.
Granulina sp.
Mitra sp.
Domiporta sp.
Neocancilla circula (Kiener, 1838)
Costellaria cf. *malcolmensis* (Melvill & Standen, 1901)
Costellaria sp.1
Costellaria sp.2
Costellaria sp.3
Costellaria large MAR50top
Costellaria sp.4 MAR50top
Costellaria BIUV40bottom
Costelloridae sp.3
Costellaridae/Mytridae? MAR50top
Vexillum sp.1
Vexillum sp.3
Superfamily Cancellarioidea
Tritonoharpa antiquate (Reeve, 1844)
Superfamily Conoidea
Conus sp.
Conus acutangulus Lamarck, 1810
Turridae sp.6-FF50Btop
Turridae sp.1-FF50Btop
Turridae sp.3-FF50Btop
Turridae sp. (cf. 2 FF90bot)
Turridae sp.10-FF50Bbot
Turridae sp.1-FF50Bbot
Turridae sp.3-FF50Bbot
Turridae sp. 3 FF90top
Turridae sp.1-FF90bottom
Turridae sp.3-FF90bottom
Turridae sp.22
Turridae sp.5-FF90bottom
Turridae sp.6-FF90bottom
Turridae sp.8-FF90bottom
Turridae sp.1 NAVY50top
Turridae sp. 6
Turridae sp.3 NAVY50top
Turridae sp.5 NAVY50top

Turridae sp.7 NAVY50top
Turridae sp.8 NAVY50top
Turridae sp.1 NAVY50bottom
Turridae sp.2 NAVY50bottom
Turridae sp.3 NAVY50bottom
Turridae sp. 8
Turridae sp.1-MAR50top
Turridae sp.3MAR50top(2mm)
Turridae sp.4-MAR50top
Turridae sp.5-MAR50top
Turridae sp.6-MAR50top
Turridae sp.7-MAR50top
Turridae sp.8-MAR50top
Turridae sp.9-MAR50top
Turridae sp.10-MAR50top
Turridae/Fusiniidae?
?Turridae FF90bot
Turridae MAR70top(cf. NAVY50top)
Turridae sp.2 MAR70top
Turridae sp.3 MAR70top
Turridae sp.4 MAR70top
Turridae sp.5 MAR70top
Turridae sp.5 BIUV40bottom
Turridae sp.6 BIUV40bottom
Turridae sp. 18
Turridae sp. 21
Turridae sp. 10
Turridae sp. 11
Turridae1 MAR70top (juvenile)
Turridae MAR50bot1
Turridae sp.2 MAR50bot
Turridae sp.1 BIUV40top
Turridae sp.2 BIUV40top
Turridae sp.3 BIUV40top
Turridae sp.4 BIUV40top
Turridae sp.3 BIUV40bottom
Turridae sp.4 BIUV40bottom

Terebra sp.

Eucithara sp.

Pseudorhaphitoma idolabiata (Hornung & Mermod, 1928)

Superfamily Architectonicoidea

Heliacus implexus (Mighels, 1845)

Spirolaxis sp.

Superfamily Pyramidelloidea

Chrysallida sp. 1 NAVY50bottom

Chrysallida sp.2 BIUV40bottom

Miralda noduslosa (Hornung & Mermod, 1924)

Odostomia sp.

Syrnola sp.2

Syrnola sp.

Tiberia fasciata (Jickeli, 1882)

Pyramidellidae sp.1 FF50Btop
Pyramidellidae sp.2 FF50Btop (**specimen fell**)
Pyramidellidae sp.3 FF50Bbot
Pyramidellinae sp. FF90bot
Pyramidellidae NAVY50bottom
Pyramidellidae sp. MAR70top
Turbonilla nitidissima Issel, 1869
Turbonilla sp. 3 FF90bot (MAR70top)
Turbonilla sp.1 FF90bot
Turbonilla sp.4-FF50Btop
Turbonilla sp.2 FF90bot
Turbonilla sp.4 MAR50top
Turbonilla sp.4 FF90bot
Leucotina sp.

Subclass OPISTHOBRANCHIA

Superfamily Philinoidea

Acteocina inconspicua (H. Adams, 1872)
Pupa affinis (A. Adams, 1854)
Atys angustatus Smith, 1872
Weinkauffia Monterosato, 1884
Philine vaillanti Issel, 1869
Philinoidea
Cylichnia sp.1
Cylichnia sp.2
Cylichnia sp.3
Cylichnia sp.4
Eocylichna villersii (Audouin, 1826)
Retusa desgenettii (Audouin, 1826)
Retusa tarutana Smyth, 1979
Rhizorus sp.
Ventomnestia girardi (Audouin, 1826)
Ringicula acuta Philippi, 1849
Ringicula minuta H. Adams 1872

The community structure of the different samples is illustrated in figure 3. The cumulative abundance of all the species in the sample, such that they reach 100% of the abundance is shown. Note that in four of the six sampling sites the molluscan species richness is much lower in top sediments than in bottom sediments (MAR50 and BIUV20 are the exceptions that show higher species richness in top sediment samples; Figure 3).

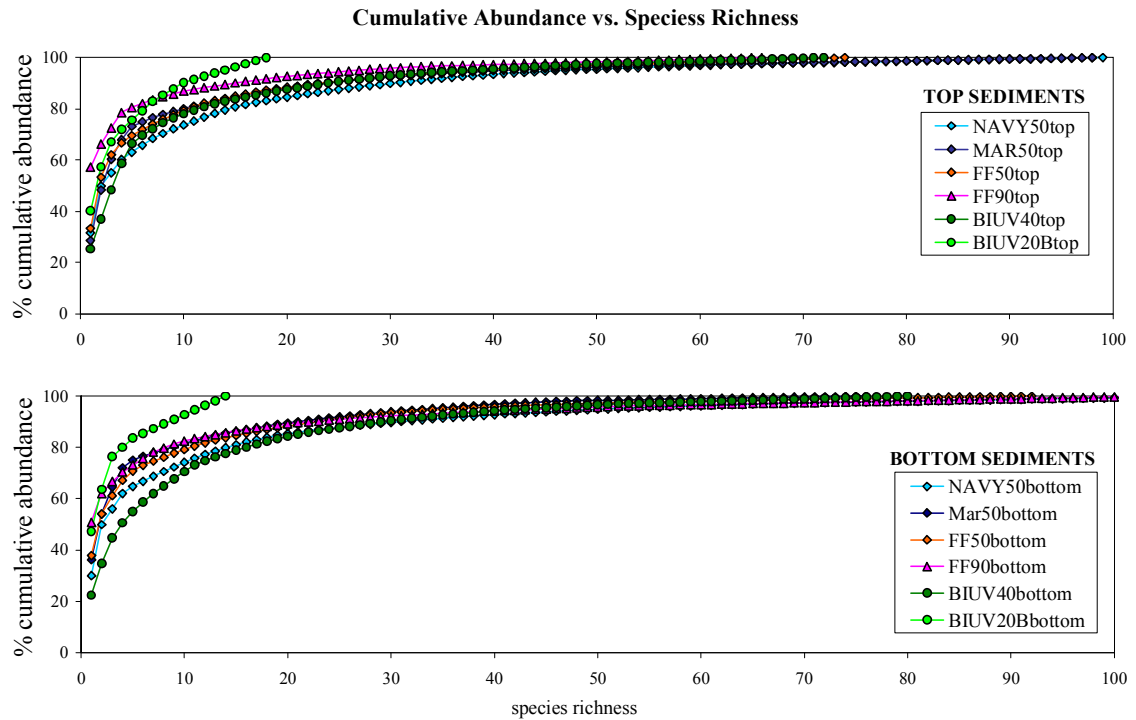


Figure 3: Ranking of species in decreasing order of abundance is plotted in relation to the cumulative abundance of the species for top 2 cm of the sediments vs. the bottom cm of the sediment grab-samples.

The clustering derived from the Bray-Curtis distance reveals 4 major biological associations shown in the dendrogram below. Depth-related clusters group the shallow (BIUV20m cluster) vs. deeper samples. Top and bottom samples of all location are similar showing no significant differences within (red lines of SIMPROF test). A single exception is the fish farm station at 50 meters water depth (FF50B). At this location the bottom sediments cluster together with the Marina station of the same water depths (MAR 50 top & bottom), while the top sediments of FF50B are similar to the top sediments of MAR70 with no significant difference between them (Figure 4). Note the separate clustering of FF70m as well. At 70 meters water depth

only top sediments were sampled (MAR70 and FF72) due to shallow penetration of the sediment grab.

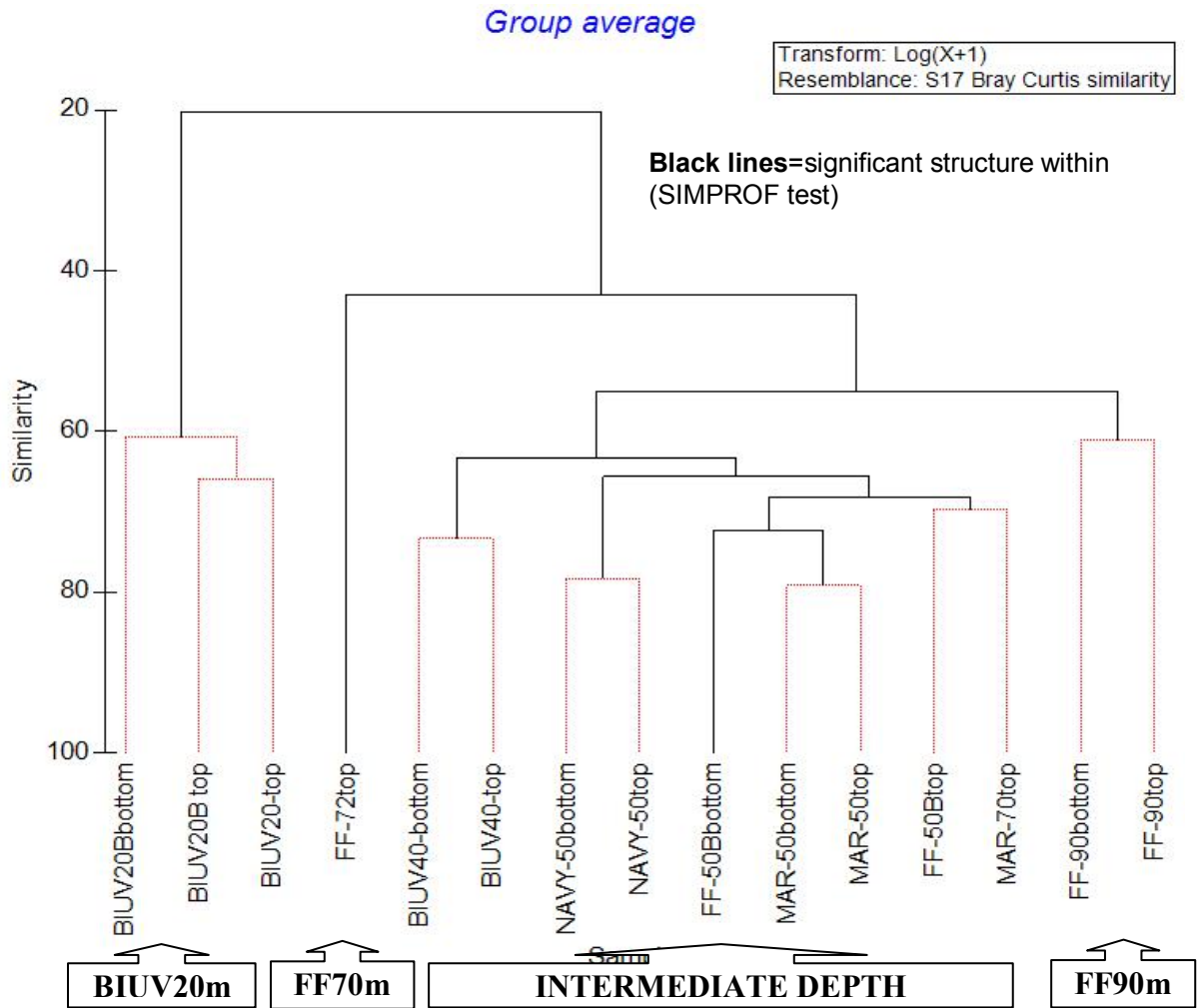


Figure 4: Cluster analysis of association between the different samples examined.

The ordination of the samples using multi-dimensional scaling (MDS) shows that the samples from BIUV station at 20 meters water depth are very similar to each other and very different than the rest of the stations. Within the larger group of the rest of the stations, the sample from the fish farms at 70 meters water depth stands out as the relatively most different (Figure 5).

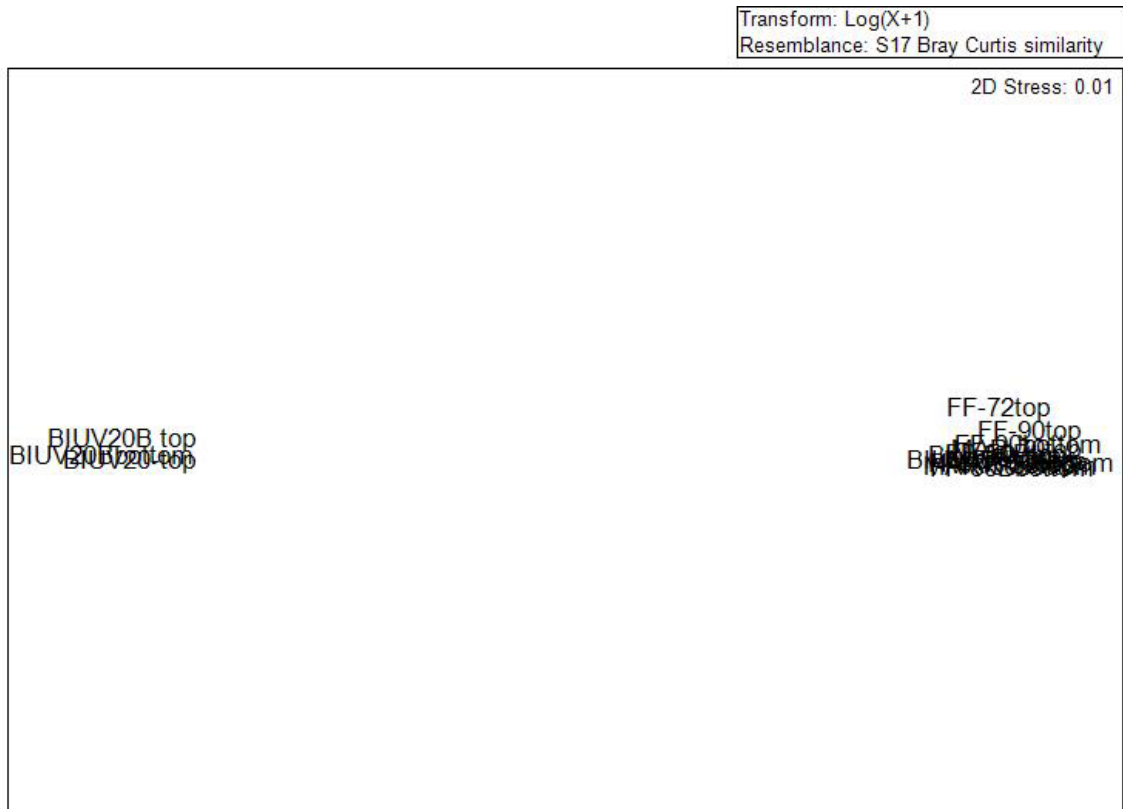


Figure 5: Ordination of the samples.

Biofacies description:

In order to compare between samples of different sizes species richness was calculated as Margalef (d) = (S-1)/logN, where S is the number of species in the sample and N is the total number of specimens for the same sample.

Cluster BIUV20m biological association-

Grab penetration for samples at this location were 6-7 cm deep. An average of 9 gastropod and 7 bivalve species compose the death assemblage, comprising 40% and 60% of the total abundance, respectively. A list of the fauna is given in Appendix 1. The highest percent of articulated shells is found in this biological association, 3.5 ± 1.2 , but no shells were encrusted (Table 2). The lowest species richness was recorded at the 20m water depth BIUV-station, Margalef (d) = 7.9 ± 0.7 .

Cluster FF70m biological association-

Sample FF 70 top was collected from 72 meters water depth. Due to sample mixing of the bottom of the grab, only the top 2 cm of the mud were examined for

molluscan fauna. Seventeen gastropod and 20 bivalve species compose the death assemblage at this station. The bivalves are by far the most dominant group comprising 94% of the total abundance. A list of the fauna is given in Appendix 2. 2.2% of the bivalve shells were articulated. Species richness was low, Margalef (d) = 12.4.

Cluster FF90m biological association-

A full sediment grab sample of 15 cm height was collected from 90 meters water depth. An average of 53 gastropod and 32 bivalve species compose the death assemblage at this station. The bivalves are the dominant group comprising 82% of the total abundance with gastropods only 18%. A list of the fauna is given in Appendix 3. ~1% of the bivalve shells were articulated and none were encrusted. Species richness was high, Margalef (d) = 27.4 ± 5.6 .

Cluster INTERMEDIATE biological association-

Grab penetration for samples at this location were 7-19 cm deep. An average of 55 gastropod and 32 bivalve species compose the death assemblage, comprising 60% and 40% of the total abundance, respectively. A list of the fauna is given in Appendix 4. The lowest percent of articulated shells is found in this biological association, practically zero. This is the only association that exhibits encrusted shells (Table 2), which imply that the molluscan fauna in the northern Gulf of Elat experienced “normal” seafloor conditions. Similar to FF90m association, high species richness was calculated for the intermediate association, Margalef (d) = 27.7 ± 3.6 .

Table 2: Community structure characteristics for the benthic molluscan assemblages of samples taken from station NAVY, MAR, BIUV and FF. Highest values are highlighted in BLUE, lowest values in YELLOW.

| CLUSTER PARAMETERS | BIUV 20m | FF 70m | FF 90m | INTERMEDIATE |
|---|----------|--------|----------|--------------|
| number of counted specimens | 81±21 | 545 | 1136±184 | 1309±320 |
| number of species [R] | 16±2 | 35 | 85±19 | 87±13 |
| <i>d</i> Margalef [richness] | 7.9±0.7 | 12.4 | 27.4±5.6 | 27.7±3.6 |
| abundance / gr. sediment | 0.2 | 7.6 | 10.9±1 | 10.6±5.3 |
| % articulated shells | 3.5±1.2 | 2 | 0.8±0.7 | 0.3±0.3 |
| % encrusted shells | 0 | 0 | 0 | 0.4±0.5 |
| gastropod species / (bivalve+gastropod) | 0.5±0.03 | 0.43 | 0.6±0.04 | 0.6±0.04 |
| gastropod abundance / (bivalve+gastropod) | 0.4±0.03 | 0.06 | 0.2±0.03 | 0.4±0.1 |

DISCUSSION

The community structure of the different biological clusters (Figure 6) show that the lowest species richness was recorded in samples from the shallow water nearest to the BIUV station. The most dominant species comprises ~47% of the total assemblage and ~7 species comprise 85% of the assemblage (Figure 6).

Low richness was calculated for the fish farm (FF) station at 70 meters water depth, which is also the station that has the highest dominance (73%) of a single species, the epifaunal bivalve *Pictada radiata*. Only 3 species comprise 85% of the total assemblage at 70 meters water depth.

The FF station at 90 meters water depth record very high species richness and show an intermediate dominance value for the most abundant species (~54%) with ~11 species comprise 85% of the total assemblage (Figure 6).

The intermediate water-depth (50-70 m) biological association shows very high species richness with highest evenness (the most abundant species comprising 33% of the total assemblage).

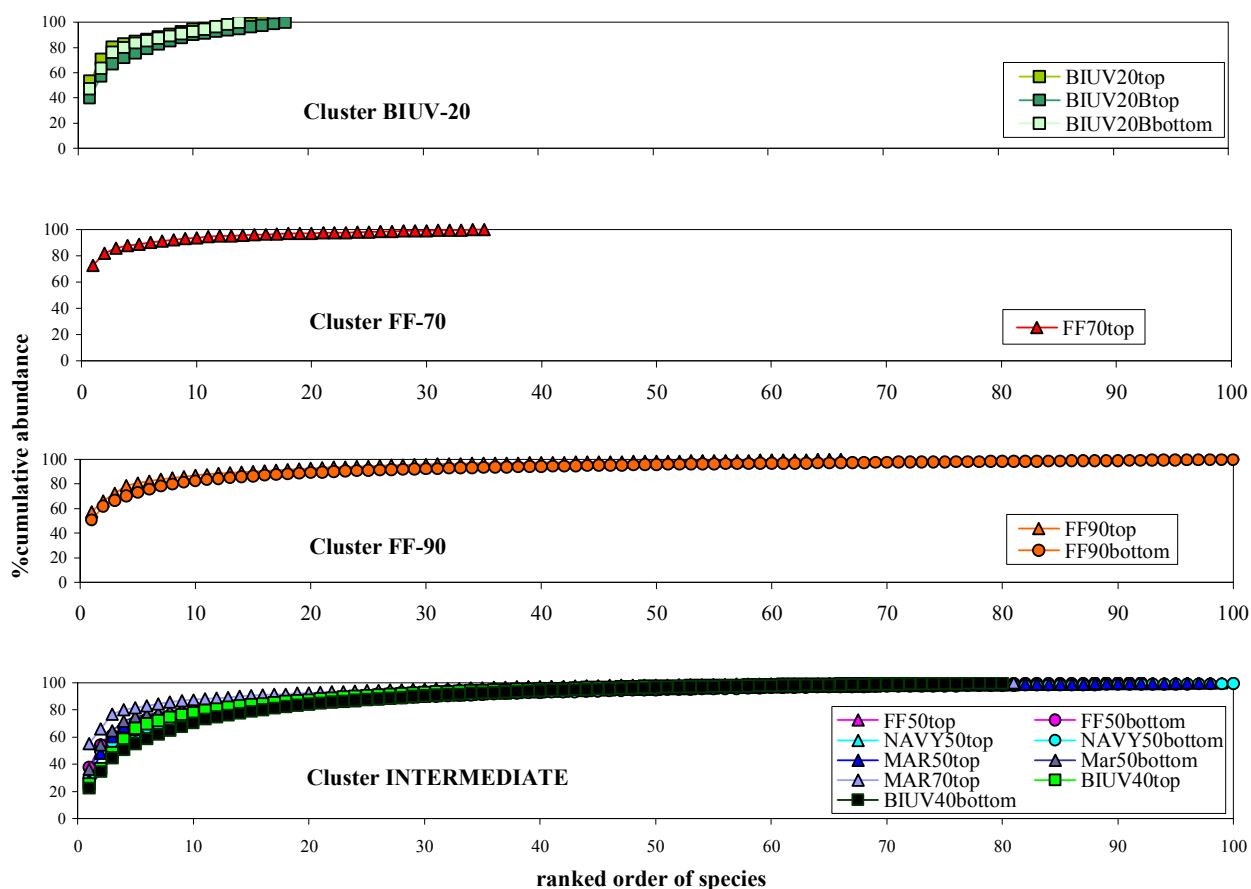


Figure 6: The community structure of the different biological clusters.

Thus, it seems that stations BIUV20 (top and bottom) and FF70 (top) show the most stressed seafloor conditions sampled examined so far, while the deepest stations at 90 meters water depth opposite the fish farms records an “equilibrium” assemblage implying a relatively undisturbed seafloor environment. The coarse grained seafloor imposes a stressful seafloor substratum, which is hostile to many mollusks that employ an infaunal life strategy. Pteriid molluscs attach themselves to a hard substratum. The coarse grain-size substratum (Table 1) recorded for this station has a direct affect on the high abundances of the byssus-attached pteriid *Pinctada radiata*. Moreover, foraminiferal evidence for the same location show that, like the mollusca, the foraminifera assemblage is characterized by low richness and evenness with 1-2 dominating species and relatively low numerical abundance.

The FF70 molluscan biological association follows the pattern of ecologically stressed assemblages (e.g., Clarke and Warwick, 1994) with low species richness and 1-3 dominating species that can comprise up to 85% of the total assemblage. A sea floor “pavement” of larger foraminifera and small mollusks may be the cause for the assemblage anomaly (see Reiss and Hottinger, 1984). The dominance of the larger symbiont-bearing foraminifera in this assemblage suppresses the colonization by other benthic foraminifera taxa because their large tests may form a carpet on the seafloor (Perelis-Grossowicz et al., 2008).

There were no significant differences between top and bottom sediments at each station implying that there was no major environmental change in bottom water conditions in the northern Gulf of Elat in the past decade (SIMPROF test, figure 4). The one exception is the fish farm station at 50 meters water depth. At this station there is a significant difference in the biological association that comprises each sample, thus showing evidence of a change in seafloor environment between the period before and after the ecological change in the Gulf of Elat. In addition, initial results of percent total organic carbon in the samples also show that there are no major differences between the top and bottom sediments at each station. The one exception is BIUV 20 that show a significant increase between the %TOC measured in the top sediments as compared to the measured from sediments representing the periods before the ecological change (Table 1).

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APPENDICES 1-4

Appendix 1: CLUSTER BIUV-20

| <u>BIUV 20top</u> | <u>No. individuals</u> |
|--|------------------------|
| <i>Anodontia</i> | 2 |
| <i>Ctena divergens</i> | 57 |
| <i>Exotica triradiata</i> | 1 |
| <i>Lioconcha philippinarum</i> | 2 |
| <i>Lioconcha</i> sp.2 | 2 |
| <i>Pinguitellia pinguis</i> | 1 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 2 |
| <i>Diala semistriata</i> | 3 |
| <i>Leucorhynchia crossei</i> | 2 |
| <i>Nassarius sinusigerus</i> | 18 |
| <i>Nassarius</i> sp. | 1 |
| <i>Odostomia</i> | 10 |
| <i>Pelseneeria</i> | 1 |
| <i>Smaragidia purpureomaculata</i> | 1 |
| <i>Varicopeza pauxilla</i> | 2 |
| <i>Ventomnestia girardi</i> | 1 |

| <u>BIUV 20Btop</u> | <u>No. individuals</u> |
|--|------------------------|
| <i>Anodontia</i> | 1 |
| <i>Ctena divergens</i> | 33 |
| <i>Exotica triradiata</i> | 1 |
| <i>Frigidocardium</i> sp. | 1 |
| <i>Lioconcha philippinarum</i> | 4 |
| <i>Lioconcha</i> sp.1 | 2 |
| <i>Loxoglypta subpallida</i> | 2 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 1 |
| <i>Seleme fragillima</i> | 2 |
| <i>Atys</i> | 3 |
| <i>Diala semistriata</i> | 3 |
| <i>Mitrella</i> sp.1 | 1 |
| <i>Nassarius sinusigerus</i> | 8 |
| <i>Odostomia</i> | 14 |
| <i>Pupa affinis</i> | 1 |
| <i>Rhinoclavis sordidula</i> | 3 |
| unidentified gastropod BIUV20Btop | 1 |
| <i>Varicopeza pauxilla</i> | 1 |

| <u>BIUV 20Bbottom</u> | <u>No. individuals</u> |
|--|------------------------|
| <i>Ctena divergens</i> | 26 |
| <i>Huxleyia diabolica</i> | 1 |
| <i>Lioconcha philippinarum</i> | 1 |
| <i>Lioconcha</i> sp.1 | 2 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 1 |
| Tellinidae BIUV20B bot | 1 |
| <i>Diala semistriata</i> | 1 |
| <i>Ethalia bellardii</i> | 1 |
| <i>Ethiminolia hemprichii</i> | 1 |
| <i>Nassarius</i> Biuv 20B bot | 2 |
| <i>Nassarius sinusigerus</i> | 7 |
| Naticoidea? | 1 |
| <i>Odostomia</i> | 9 |
| <i>Smaragidia purpureomaculata</i> | 1 |

Appendix 2: CLUSTER FF-70

| <u>FF 70top</u> | <u>No. individuals</u> |
|--|------------------------|
| <i>Amygdalum peasei</i> | 20 |
| <i>Anodontia</i> sp. | 1 |
| <i>Arca navicularis</i> | 3 |
| <i>Barbatia foliata</i> | 2 |
| <i>Corbula</i> | 51 |
| <i>Ctena divergens</i> | 2 |
| <i>Frigidocardium torresi</i> | 5 |
| <i>Limea pectinata</i> | 3 |
| <i>Lioconcha philippinarum</i> | 1 |
| <i>Lioconcha?</i> | 9 |
| <i>Nucula inconspicua</i> | 6 |
| Ostreidae | 1 |
| <i>Pharaonella perna</i> | 2 |
| <i>Pictada radiata</i> | 397 |
| <i>Pinguitellia pinguis</i> | 1 |
| <i>Pteria</i> sp. | 1 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 1 |
| <i>Semele fragillima</i> | 1 |
| <i>Similipecten eous</i> | 1 |
| Tellinid sp. | 2 |
| <i>Atys</i> | 1 |
| <i>Bothropoma isseli</i> | 1 |
| Cerithidae sp. | 1 |
| <i>Eulima</i> | 2 |
| gastropod unknown 1 | 1 |
| <i>Leucotina</i> sp. | 1 |
| <i>Nassarius sinusigerus</i> | 7 |
| <i>Notocochlis gualtieriana</i> | 1 |
| <i>Pseudominolia biangulosa</i> | 1 |
| <i>Retusa desgenettii</i> | 1 |
| <i>Syrnola</i> | 1 |
| Turridae sp. 1 | 3 |
| Turridae sp. 2 | 1 |
| <i>Varicopeza pauxilla</i> | 7 |
| <i>Zafra</i> sp. | 6 |

Appendix 3: CLUSTER FF-90

| FF 90top | No. individuals | | |
|--|-----------------|------------------------------------|----|
| <i>Amygdalum peasei</i> | 6 | <i>Diala semistriata</i> | 3 |
| <i>Anodontia</i> sp. | 1 | <i>Conus</i> (juvenile) | 1 |
| <i>Arca acuminata</i> | 3 | <i>Domiporta</i> sp. | 2 |
| <i>Arca navicularis</i> | 57 | <i>Ethiminolia hemprichii</i> | 1 |
| <i>Barbatia trapezina</i> | 1 | <i>Eucithara</i> sp. | 1 |
| <i>Corbula</i> | 86 | <i>Fusinus</i> sp.? | 1 |
| <i>Cryptopecten nux</i> | 1 | <i>Gazameda alba</i> | 4 |
| <i>Ctena divergens</i> | 4 | <i>Lodderia novemcarinata</i> | 4 |
| <i>Cyrella diabolica</i> | 2 | <i>Minolia gradata</i> | 1 |
| <i>Dorisca nana</i> | 2 | <i>Mitrella</i> sp.1 | 3 |
| <i>Frigidocardium torresi</i> | 11 | <i>Mitrella</i> sp.2 | 1 |
| <i>Limatulella</i> sp. | 1 | Muricid | 1 |
| <i>Linea pectinata</i> | 3 | Naticidae | 6 |
| <i>Lioconcha philippinarum</i> | 19 | <i>Notocochlis gualtieriana</i> | 1 |
| <i>Moerella lactea</i> | 1 | <i>Perrinia stellata</i> | 1 |
| Mytilid | 2 | <i>Philine vaillanti</i> | 1 |
| <i>Nucula inconspicua</i> | 7 | Philinoidea | 1 |
| Oystreid | 2 | <i>Pseudorhaphitoma idolabiata</i> | 1 |
| <i>Parvamussium formosum</i> | 13 | <i>Retusa</i> sp. | 5 |
| <i>Parvamussium thyrideum</i> | 1 | <i>Rhinoclavis sordidula</i> | 1 |
| <i>Pictada radiata</i> | 544 | <i>Ringicula minuta</i> | 1 |
| <i>Pinguitellia pinguis</i> | 6 | <i>Scissurella oetheria</i> | 5 |
| Pinnidae | 15 | <i>Tiberia fasciata</i> | 1 |
| <i>Pitar yerburyi</i> | 1 | Triphoridae sp.1 | 1 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 10 | Triphoridae sp.2 | 1 |
| <i>Septifer forskali</i> | 3 | <i>Turbonilla</i> | 1 |
| <i>Similipecten eous</i> | 5 | Turridae sp. 3 | 1 |
| Tellinid | 1 | Turridae sp. 4 | 5 |
| <i>Ancilla</i> | 1 | <i>Varicopeza pauxilla</i> | 61 |
| <i>Archimediella maculata</i> | 3 | <i>Costellaria</i> sp.1 | 7 |
| <i>Atys</i> | 2 | <i>Costellaria</i> sp.2 | 1 |
| <i>Cerithidium diplax</i> | 1 | <i>Vexillum</i> sp.3 | 1 |
| | | <i>Zafra</i> sp. | 11 |

| <u>FF 90bottom</u> | <u>No. individuals</u> | | |
|--|------------------------|------------------------------------|----|
| <i>Amygdalum peasei</i> | 9 | <i>Eocylichna villersii</i> | 10 |
| <i>Anodontia</i> sp. | 2 | <i>Epitonium</i> sp. | 1 |
| <i>Arca navicularis</i> | 36 | <i>Ergalatax contracta</i> | 1 |
| <i>Barbatia foliata</i> | 49 | <i>Ethiminolia hemprichii</i> | 3 |
| <i>Chama</i> sp.1 | 1 | <i>Fusinus</i> sp.1-90bottom | 2 |
| <i>Chama</i> sp.2 | 1 | <i>Fusinus</i> sp.2-90bottom | 2 |
| <i>Clementia papyracea</i> | 1 | <i>Fusinus</i> sp.3-90bottom | 1 |
| <i>Corbula</i> | 147 | <i>Fusinus</i> sp.4-90bottom | 1 |
| <i>Cryptopecten nux</i> | 7 | <i>Granulina</i> sp. | 3 |
| <i>Ctena divergens</i> | 7 | <i>Lodderia novemcarinata</i> | 2 |
| <i>Cyrella diabolica</i> | 1 | <i>Miralda noduslosa</i> | 1 |
| <i>Dorisca nana</i> | 3 | <i>Mitra</i> | 1 |
| <i>Dosinia erythrea</i> | 1 | <i>Mitrella</i> sp.1 | 2 |
| <i>Parvicardium sueziensis</i> | 1 | <i>Mitrella</i> sp.2 | 2 |
| <i>Frigidocardium torresi</i> | 22 | <i>Nassarius sinusigerus</i> | 1 |
| Galeommatidae | 1 | <i>Nassarius</i> sp.1 | 1 |
| <i>Limea pectinata</i> | 4 | <i>Nassarius splendidulus</i> | 2 |
| <i>Limopsis elachista</i> | 1 | Naticid | 2 |
| <i>Lioconcha</i> sp.1 | 33 | <i>Neocancilla circula</i> | 2 |
| <i>Lioconcha</i> sp.2 | 2 | <i>Notocochlis gualtieriana</i> | 8 |
| <i>Loxoglypta clathrata</i> | 2 | <i>Pagodatrochus variabilis</i> | 2 |
| <i>Musculus viridulus</i> | 1 | <i>Perrinia stellata</i> | 2 |
| Mytilid | 1 | <i>Pseudominolia biangulosa</i> | 1 |
| <i>Nucula inconspicua</i> | 5 | <i>Pseudominolia gradata</i> | 3 |
| <i>Parahyotissa numisma</i> | 1 | Pyramidellinae sp. | 1 |
| <i>Parvamussium formosum</i> | 7 | <i>Retusa desgenettii</i> | 3 |
| <i>Parvamussium thyrideum</i> | 11 | <i>Rhinoclavis sordidula</i> | 4 |
| Pectinidae sp. | 1 | <i>Ringicula acuta</i> | 3 |
| <i>Pictada radiata</i> | 671 | <i>Ringicula minuta</i> | 1 |
| <i>Pinguitellia pinguis</i> | 7 | <i>Smaragidia purpureomaculata</i> | 1 |
| Pinnidae | 33 | <i>Terebra</i> sp. | 1 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 10 | <i>Triphoridae</i> sp. 2 | 1 |
| <i>Semele fragillima</i> | 4 | <i>Triphoridae</i> sp.1 | 1 |
| <i>Septifer forskali</i> | 3 | <i>Turbonilla nitidissima</i> | 1 |
| <i>Tellina</i> sp.-FF90bottom | 1 | <i>Turbonilla</i> sp.1 | 2 |
| Venerid cf. <i>Timoclea</i> ? | 1 | <i>Turbonilla</i> sp.2 | 2 |
| ?Turridae | 1 | <i>Turbonilla</i> sp.3 | 1 |
| <i>Archimediella maculata</i> | 3 | <i>Turbonilla</i> sp.4 | 1 |
| <i>Atys angustatus</i> | 1 | Turridae sp.1-90bottom | 1 |
| <i>Cerithidium</i> sp. | 1 | Turridae sp.2-90bottom | 1 |
| <i>Cerithium scabridum</i> | 1 | Turridae sp.3-90bottom | 1 |
| <i>Cerithium</i> sp. 1-FF90bottom | 1 | Turridae sp.4-90bottom | 2 |
| <i>Cerithium</i> sp. 2-FF90bottom | 1 | Turridae sp.5-90bottom | 1 |
| Cerithidae sp.1-FF90bottom | 1 | Turridae sp.6-90bottom | 1 |
| <i>Conus</i> | 1 | Turridae sp.7-90bottom | 1 |
| <i>Costellaria</i> sp.1 | 20 | Turridae sp.8-90bottom | 1 |
| <i>Costellaria</i> sp.2 | 4 | <i>Turritella cochlea</i> | 6 |
| Cymatidae sp.1 | 1 | <i>Vacerrena nana</i> | 3 |
| <i>Cymatium aquatile</i> | 1 | <i>Varicopeza pauxilla</i> | 62 |
| <i>Cymatium</i> sp. | 1 | <i>Vexillum</i> (juvenile) | 2 |
| <i>Cymatium trilineatum</i> | 4 | <i>Xenophora</i> sp. | 1 |
| <i>Diala semistriata</i> | 12 | <i>Zafra</i> sp. | 16 |

Appendix 4: CLUSTER INTERMEDIATE

| <u>BIUV 40top</u> | <u>No. individuals</u> | | |
|--|------------------------|------------------------------------|-----|
| <i>Amygdalum peasei</i> | 3 | <i>Notocochlis gualtieriana</i> | 3 |
| <i>Anodontia</i> | 8 | <i>Odostomia</i> | 2 |
| <i>Arca navicularis</i> | 15 | <i>Pagodatrochus variabilis</i> | 2 |
| <i>Arcopella isseli</i> | 1 | <i>Perrinia stellata</i> | 1 |
| <i>Barbatia foliata</i> | 1 | <i>Philine vaillanti</i> | 1 |
| Bivalve 1 | 2 | <i>Plesiotrochus souverbianus</i> | 3 |
| Cardiid sp. BIUV40top | 6 | <i>Pupa affinis</i> | 7 |
| <i>Corbula</i> | 95 | <i>Cylichnia</i> sp.1 | 5 |
| <i>Cryptopecten nux</i> | 2 | <i>Rhinoclavis sordidula</i> | 17 |
| <i>Ctena divergens</i> | 71 | <i>Ringicula minuta</i> | 1 |
| <i>Cyrella diabolica</i> | 1 | <i>Rubritrochus declivis</i> | 1 |
| <i>Frigidocardium</i> | 2 | <i>Smaragidia purpureomaculata</i> | 2 |
| Galeommatidae sp. | 1 | <i>Spirolaxis</i> sp. | 1 |
| <i>Limea pectinata</i> | 2 | <i>Syrnola</i> sp.2 | 2 |
| <i>Lioconcha philippinarum</i> | 7 | <i>Turbonilla nitidissima</i> | 2 |
| <i>Lioconcha</i> sp.1 | 106 | Turridae sp.1 BIUV40top | 2 |
| <i>Lioconcha</i> sp.2 | 13 | Turridae sp.2 BIUV40top | 2 |
| Lucinid sp. BIUV40top | 1 | Turridae sp.3 BIUV40top | 1 |
| <i>Microcirce</i> "smooth" | 6 | Turridae sp.4 BIUV40top | 1 |
| <i>Moerella lactea</i> | 4 | <i>Turritella cochlea</i> | 11 |
| <i>Pharaonella perna</i> | 5 | <i>Vacerrena nana</i> | 2 |
| <i>Pictada radiata</i> | 105 | <i>Varicopeza pauxilla</i> | 232 |
| <i>Pinguitellina pinguis</i> | 23 | <i>Zafra savignyi</i> | 5 |
| Pinnidae | 3 | | |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 9 | | |
| ? <i>Semele</i> BIUV40top | 1 | | |
| <i>Semele fragillima</i> | 6 | | |
| <i>Septifer forskli</i> | 7 | | |
| <i>Solemya</i> sp. | 1 | | |
| telinid sp. BIUV40top | 1 | | |
| Tellinelidae BIUV40top | 1 | | |
| unidentified 1 BIUV 40top | 1 | | |
| unidentified 2 BIUV 40top | 1 | | |
| <i>Atys</i> | 1 | | |
| <i>Bothropoma isseli</i> | 6 | | |
| <i>Cerithidium</i> sp. BIUV40top | 2 | | |
| <i>Costellaria</i> sp.1 | 4 | | |
| <i>Diala semistriata</i> | 22 | | |
| <i>Domiporta</i> | 2 | | |
| <i>Ethalia bellardii</i> | 7 | | |
| <i>Ethminolia hemprichi</i> | 1 | | |
| <i>Eulimidae</i> sp. BIUV40top | 1 | | |
| Hipponicidae | 1 | | |
| <i>Leucorhynchia crossei</i> | 12 | | |
| <i>Lodderia novemcarinata</i> | 4 | | |
| <i>Mitrella</i> sp.1 | 4 | | |
| <i>Nassarius sinusigerus</i> | 29 | | |
| <i>Nassarius</i> sp.2 | 1 | | |
| <i>Neocancilla circula</i> | 2 | | |

| <u>BIUV 40bottom</u> | <u>No. individuals</u> | | |
|--|------------------------|------------------------------------|-----|
| <i>Anodontia</i> | 4 | Muricidae BIUV40bottom | 1 |
| <i>Arca navicularis</i> | 11 | <i>Nassarius sinusigerus</i> | 33 |
| <i>Barbatia foliata</i> | 3 | <i>Nassarius</i> sp.2 BIUV40bottom | 5 |
| Bivalve 1 | 5 | Naticidae 1 (operculum) | 1 |
| <i>Corbula</i> | 54 | Naticidae 2 (operculum) | 1 |
| <i>Crenella striatissima</i> | 1 | <i>Neocancilla circula</i> | 11 |
| <i>Ctena divergens</i> | 92 | <i>Notocochlis gualtieriana</i> | 12 |
| <i>Cyrella diabolica</i> | 2 | <i>Odostomia</i> | 4 |
| <i>Dorsica nana</i> | 8 | <i>Pagodatrochus variabilis</i> | 5 |
| <i>Exotica radiata</i> | 3 | <i>Plesiotrochus souverbianus</i> | 5 |
| <i>Frigidocardium</i> | 6 | <i>Pupa affinis</i> | 2 |
| Galeommatidae sp.BIUV40bottom | 1 | <i>Retusa desgenettii</i> | 5 |
| <i>Limatulella</i> | 1 | <i>Rhinoclavis sordidula</i> | 27 |
| <i>Limea pectinata</i> | 5 | <i>Ringicula minuta</i> | 2 |
| <i>Lioconcha philippinarum</i> | 3 | <i>Smaragidia purpureomaculata</i> | 13 |
| <i>Lioconcha</i> sp.1 | 114 | Triphoridae sp.1 | 1 |
| <i>Lioconcha</i> sp.2 (wide) | 7 | <i>Turbonilla nitidissima</i> | 4 |
| <i>Loxoglypta subpallida</i> | 1 | Turridae sp.1 BIUV40bottom | 1 |
| <i>Microcirce</i> (ribbed) | 11 | Turridae sp.2(spines) BIUV40bottom | 1 |
| <i>Moerella</i> | 5 | Turridae sp.3 BIUV40bottom | 2 |
| <i>Nucula inconspicua</i> | 2 | Turridae sp.4 BIUV40bottom | 2 |
| Oystreid BIUV40bottom | 1 | Turridae sp.5 BIUV40bottom | 1 |
| <i>Pictada radiata</i> | 25 | Turridae sp.6 BIUV40bottom | 1 |
| <i>Pinguitellia pinguis</i> | 31 | <i>Turritella cochlea</i> | 25 |
| Pinnidae | 1 | unidentified G BIUV40bottom | 1 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 9 | <i>Varicopeza pauxilla</i> | 206 |
| <i>Semele fragillima</i> | 3 | <i>Xenophora</i> | 1 |
| <i>Semele</i> sp.BIUV40bottom | 1 | <i>Zafra</i> | 12 |
| <i>Septifer forskli</i> | 5 | | |
| tellinid sp. BIUV40bottom | 1 | | |
| Tellinoidae BIUV40bottom | 2 | | |
| unidentified 1 BIUV40bottom | 1 | | |
| <i>Alys</i> | 1 | | |
| <i>Bittium</i> sp. | 1 | | |
| <i>Bothropoma isseli</i> | 3 | | |
| <i>Cerithidium perpavulum</i> | 2 | | |
| <i>Chrysallida</i> sp.2 BIUV40bottom | 1 | | |
| <i>Costellaria</i> BIUV40bottom | 1 | | |
| <i>Costellaria</i> sp.1 | 4 | | |
| <i>Cylichnia</i> sp.3 | 1 | | |
| <i>Cylichnia</i> sp.4 | 1 | | |
| <i>Cylichnia</i> sp.2 | 1 | | |
| <i>Cylichnia</i> sp.1 | 2 | | |
| <i>Diala semistriata</i> | 41 | | |
| <i>Domiporta</i> | 2 | | |
| <i>Ethalia bellardii</i> | 3 | | |
| Eulimidae BIUV40bottom | 2 | | |
| Hipponicidae | 1 | | |
| <i>Hytissa numisma</i> | 1 | | |
| <i>Leucorhynchia crossei</i> | 26 | | |
| <i>Lodderia novemcarinata</i> | 15 | | |
| <i>Mitrella</i> sp.1 BIUV40bottom | 8 | | |

| <u>FF 50top</u> | <u>No. individuals</u> | | |
|---|------------------------|---------------------------------|-----|
| <i>Arcopella isseli</i> | 1 | <i>Neocancilla</i> sp. | 1 |
| <i>Amygdalum peasei</i> | 2 | <i>Notocochlis gualtieriana</i> | 5 |
| <i>Anodontia</i> sp. | 6 | <i>Pseudominolia</i> sp.? | 2 |
| <i>Arca accumunata</i> | 2 | <i>Pupa affinis</i> | 1 |
| <i>Arca navicularis</i> | 15 | Pyramidellidae sp.1FF50B top | 1 |
| <i>Barbatia foliata</i> | 14 | Pyramidellidae sp.2FF50B top | 1 |
| Cardiid | 1 | <i>Retusa desgenettii</i> | 4 |
| <i>Corbula erythraeensis</i> | 69 | <i>Rhinoclavis sordidula</i> | 3 |
| <i>Cryptopecten nux</i> | 1 | <i>Rhizorus</i> sp. | 1 |
| <i>Ctena divergens</i> | 11 | <i>Ringicula minuta</i> | 1 |
| <i>Frigidocardium torresi</i> | 4 | Rissoidea sp. (?Cetia) | 1 |
| <i>Fulvia australis</i> | 1 | <i>Turbonilla nitidissima?</i> | 1 |
| <i>Lioconcha</i> sp.1 | 37 | <i>Turbonilla</i> sp.4-FF50Btop | 2 |
| <i>Limea pectinata</i> | 2 | Turridae sp.1-FF50B top | 1 |
| <i>Mactrotoma ovalina</i> | 1 | Turridae sp.2-FF50B top | 1 |
| Mytilid sp. | 1 | Turridae sp.3-FF50B top | 4 |
| <i>Nucula inconspicua</i> | 1 | Turridae sp.4-FF50B top | 1 |
| <i>Pictada radiata</i> | 264 | Turridae sp.5-FF50B top | 1 |
| <i>Pinguitellia pinguis</i> | 19 | Turridae sp.6-FF50Btop | 2 |
| Pinnidae | 7 | <i>Varicopeza pauxilla</i> | 159 |
| <i>Rochefurina</i> cf. <i>sandwichensis</i> | 16 | <i>xenophora solaroides</i> | 1 |
| <i>Semele fragillima</i> | 2 | <i>Zafra</i> spp. | 2 |
| Semeleidae sp. | 1 | | |
| <i>Septifer forskali</i> | 3 | | |
| Tellinid sp. | 3 | | |
| unknown bivalve | 1 | | |
| Venerid unknown | 1 | | |
| <i>Archimediella maculata</i> | 1 | | |
| <i>Atys angustatus</i> | 7 | | |
| <i>Bothropoma isseli</i> | 4 | | |
| <i>Cerithidium perpavulum</i> | 3 | | |
| Cerithidae sp. FF50Btop | 1 | | |
| Ceritiid sp. | 6 | | |
| Colombilidae sp. | 1 | | |
| <i>Costellaria</i> sp.1 | 2 | | |
| <i>Costellaria</i> sp.2 | 2 | | |
| <i>Costellaria</i> sp.3 | 1 | | |
| Cyclostrematidae | 1 | | |
| <i>Diala semistriata</i> | 12 | | |
| <i>Epitonium</i> sp.1 FF50Btop | 1 | | |
| <i>Epitonium</i> sp.2 FF50Btop | 1 | | |
| <i>Ethalia bellardii</i> | 13 | | |
| <i>Ethiminolia hemprichii</i> | 1 | | |
| <i>Eulima</i> sp. | 4 | | |
| <i>Favartia</i> sp. | 4 | | |
| <i>Gazameda alba</i> | 2 | | |
| <i>Loddaria novemcarinata</i> | 6 | | |
| <i>Mitrella</i> sp. 2 | 3 | | |
| <i>Mitrella</i> sp.1 | 8 | | |
| <i>Nassarius sinusigerus</i> | 23 | | |
| <i>Nassarius</i> sp.FF50Btop | 2 | | |
| Naticid sp. | 2 | | |

| <u>FF 50bottom</u> | <u>No. individuals</u> | | |
|---|------------------------|---------------------------------------|-----|
| <i>Amygdalum peasei</i> | 3 | <i>Heliacus implexus</i> | 3 |
| <i>Anodontia</i> sp. | 9 | <i>Latirus</i> sp. | 1 |
| <i>Anomia</i> sp. | 3 | <i>Leocorhynchia crossei</i> | 9 |
| <i>Arca accumulata</i> | 14 | <i>Loddaria novemcarinata</i> | 2 |
| <i>Arca navicularis</i> | 26 | <i>Mitrella</i> sp. 2FF50Btop | 12 |
| <i>Arcopella isseli</i> | 1 | <i>Mitrella</i> sp.4-FF50Bbot | 2 |
| <i>Barbatia foliata</i> | 22 | <i>Nassarius sinusigerus</i> | 23 |
| <i>Corbula erythraeensis</i> | 117 | <i>Nassarius</i> sp.2 | 2 |
| <i>Crenella striatissima</i> | 2 | <i>Nassarius</i> sp.1 FF50bot | 1 |
| <i>Ctena divergens</i> | 26 | <i>Neocancilla circula?</i> | 1 |
| <i>Dosinia</i> | 1 | <i>Notocochlis gualtieriana</i> | 19 |
| <i>Exotica triradiata</i> | 6 | <i>Odostomia</i> sp. | 2 |
| <i>Frigidocardium torresi</i> | 10 | <i>Pagodatrochus variabilis</i> | 1 |
| Galeommatidae sp. | 4 | <i>Pelycidion</i> cf. <i>xanthias</i> | 1 |
| <i>Huxleyia diabolica</i> | 1 | <i>Philine vaillanti</i> | 1 |
| <i>Limatulella</i> sp. | 1 | <i>Plesiotrochus souverbianus</i> | 5 |
| <i>Lioconcha</i> sp.1 | 99 | <i>Pupa affinis</i> | 2 |
| <i>Nucula inconspicua</i> | 3 | Pyramidellidae sp.3FF50B bot | 1 |
| <i>Pictada radiata</i> | 622 | <i>Recluzia jehennei</i> | 1 |
| <i>Pinguitellia pinguis</i> | 58 | <i>Retusa desgenettii</i> | 10 |
| Pinnidae | 15 | <i>Rhinoclavis sordidula</i> | 11 |
| <i>Pteria</i> sp.FF-50Bbottom | 1 | <i>Ringicula minuta</i> | 3 |
| <i>Rocheffurtina</i> cf. <i>sandwichensis</i> | 37 | Rissoidea sp. | 1 |
| <i>Seleme</i> sp. | 3 | <i>Rissoina pachystoma?</i> | 1 |
| <i>Septifer forskali</i> | 13 | <i>Scaliola elata</i> | 2 |
| <i>Tellinia</i> unknown sp. FF50Bbottom | 1 | <i>Syrnola</i> sp. | 3 |
| <i>Tellinid</i> sp.(smooth)FF50B bottom | 4 | Trichotropidae sp. | 1 |
| <i>Timoclea djiboutiensis</i> | 2 | Triphoridae sp.2-FF50B bot | 1 |
| <i>Acteocina inconspicua</i> | 1 | <i>Turbonilla</i> sp.1- | 1 |
| <i>Archimediella maculata</i> | 10 | Turridae sp.(cf.2 FF90bot) | 8 |
| <i>Bothropoma isseli</i> | 20 | Turridae sp.10-FF50B bot | 1 |
| <i>Calyostoma</i> | 1 | Turridae sp.1-FF50B bot | 1 |
| <i>Cerithidium perpavulum</i> | 10 | Turridae sp.3-FF50B bot | 1 |
| Cerithidae sp. FF50Bbot | 2 | Turridae sp.4-FF50B bot | 1 |
| <i>Costellaria</i> sp.1 | 5 | Turritilidae sp. | 1 |
| <i>Costellaria</i> sp.2 | 3 | Unidentified sp.1 FF50Bbot | 1 |
| Costelloridae sp.3 | 1 | <i>Varicopeza pauxilla</i> | 268 |
| " <i>Cyclostrema</i> " sp.10 | 1 | <i>Weinkauffia</i> | 1 |
| " <i>Cyclostrema</i> " sp.11 | 1 | <i>Xenophora</i> sp. | 1 |
| <i>Diala semistriata</i> | 11 | <i>Zafra</i> sp. | 13 |
| <i>Domiporta</i> sp. | 1 | | |
| <i>Eocylichna villersii</i> | 7 | | |
| <i>Epitonium</i> sp.1 FF50Bbot | 1 | | |
| <i>Ergalatax contracta</i> | 5 | | |
| <i>Ethalia bellardii</i> | 27 | | |
| <i>Eulima</i> sp.1 | 6 | | |
| <i>Eulima</i> sp.2 | 2 | | |
| <i>Pelseneeria</i> | 1 | | |
| Fasciolaridae sp.1 | 1 | | |
| Fasciolaridae sp.2 | 3 | | |
| Fasciolaridae sp.3 | 1 | | |
| <i>Finella pupoides</i> | 1 | | |

| <u>MAR 50top</u> | <u>No. individuals</u> | | |
|--|------------------------|------------------------------------|-----|
| <i>Amygdalum peasei</i> | 5 | <i>Ethiminolia hemprichii</i> | 1 |
| <i>Anodontia</i> sp. | 3 | <i>Eulima</i> sp. | 4 |
| <i>Anomia</i> sp. | 1 | <i>Fusinus</i> sp.1- MAR50top | 2 |
| <i>Arca navicularis</i> | 13 | <i>Fusinus</i> sp.2- MAR50top | 2 |
| <i>Barbatia foliata</i> | 6 | <i>Fusinus</i> sp.3- MAR50top | 1 |
| Cardiid MAR50top | 1 | <i>Leucorhynchia crossei</i> | 6 |
| <i>Corbula erythraeensis</i> | 169 | <i>Lodderena</i> sp. | 1 |
| <i>Cryptopecten nux</i> | 2 | <i>Lodderia novemcarinata</i> | 1 |
| <i>Ctena divengens</i> | 15 | <i>Mitrella</i> sp. | 1 |
| <i>Exotica triradiata</i> | 10 | <i>Mitrella</i> sp.1 MAR50top | 8 |
| <i>Frigidocardium torresi</i> | 12 | Muricidae sp.1 MAR50top | 1 |
| Galeommatidae sp. MAR50top | 4 | Muricoidae? MAR50top | 1 |
| <i>Leptomya</i> sp. | 1 | <i>Nassarius sinusigerus</i> | 18 |
| <i>Limea pectinata</i> | 3 | <i>Nassarius splendidulus</i> | 2 |
| <i>Lioconcha philippinarum</i> | 2 | <i>Neocancilla circula</i> | 5 |
| <i>Lioconcha</i> sp.1 | 107 | <i>Notocochlis gualtieriana</i> | 16 |
| <i>Microcirce constenans?</i> | 13 | <i>Odostomia</i> sp. | 2 |
| Mytilid | 1 | <i>Pagodatrochus variabilis</i> | 2 |
| <i>Nucula inconspicua</i> | 2 | <i>Plesiotrochus souverbianus</i> | 2 |
| <i>Parvamussium thyrideum</i> | 1 | <i>Retusa desgenettii</i> | 8 |
| <i>Pictada radiata</i> | 277 | <i>Cylichnia</i> sp.1 | 10 |
| <i>Pinguitellia pinguis</i> | 75 | <i>Rhinoclavis sordidula</i> | 25 |
| Pinnidae | 12 | <i>Ringicula minuta</i> | 6 |
| Pteria MAR50top | 1 | <i>Scaliola elata</i> | 2 |
| Pteriidae MAR50top | 1 | <i>Smaragidia purpureomaculata</i> | 2 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 21 | <i>Syrnola</i> sp. | 1 |
| <i>Semele fragillima</i> | 4 | Triphoridae sp.1 | 1 |
| <i>Semele</i> sp. MAR50top | 4 | <i>Turbonilla</i> sp.4 MAR50top | 1 |
| <i>Septifer forskali</i> | 4 | Turridae sp.10-MAR50top | 1 |
| <i>Similipecten eous</i> | 1 | Turridae sp.1-MAR50top | 2 |
| strong ribs unidentified MAR50top | 1 | Turridae sp.6 | 1 |
| unidentified 1 MAR50top | 1 | Turridae sp.3-MAR50top | 1 |
| unidentified 2 MAR50top | 1 | Turridae sp.4-MAR50top | 3 |
| Veneridae? MAR50top | 1 | Turridae sp.5-MAR50top | 1 |
| <i>Archimediella maculata</i> | 5 | Turridae sp.6-MAR50top | 2 |
| <i>Argyropeza divina</i> | 1 | Turridae sp.7-MAR50top | 1 |
| <i>Atys</i> | 1 | Turridae sp.8-MAR50top | 3 |
| <i>Bothropoma isseli</i> | 7 | Turridae sp.9-MAR50top | 1 |
| <i>Cerithidium perpavulum</i> | 10 | unidentified sp.10 MAR50top | 1 |
| <i>Conus acutangulus</i> | 1 | unidentified sp.11 MAR50top | 1 |
| <i>Costellaria large</i> MAR50top | 1 | unidentified sp.12 MAR50top | 1 |
| <i>Costellaria</i> sp.1 | 11 | <i>Vacerrena nana</i> | 4 |
| <i>Costellaria</i> sp.4 MAR50top | 1 | <i>Varicopeza pauxilla</i> | 401 |
| Costellaridae/Mytridae? | 1 | <i>Viriola?</i> | 1 |
| " <i>Cyclostrema</i> " <i>quinquecarinatum</i> | 1 | <i>Xenophora</i> sp. | 1 |
| <i>Diala semistriata</i> | 7 | <i>Zafra</i> | 1 |
| <i>Diala</i> sp. | 2 | | |
| <i>Domiporta</i> sp. | 3 | | |
| <i>Cycloscala hyalina</i> | 1 | | |
| <i>Epitonium replicatum</i> | 1 | | |
| <i>Ergalatax contracta</i> | 1 | | |
| <i>Ethalia bellardii</i> | 16 | | |

| <u>MAR 50bottom</u> | <u>No. individuals</u> | | |
|---|------------------------|--------------------------------------|-----|
| <i>Amygdalum peasei</i> | 4 | <i>Nassarius conoidalis labordei</i> | 1 |
| <i>Anadara</i> | 1 | <i>Nassarius sinusigerus</i> | 18 |
| <i>Anodontia</i> | 5 | <i>Neocancilla circula</i> | 5 |
| <i>Arca navicularis</i> | 19 | <i>Notocochlis gualtieriana</i> | 15 |
| <i>Barbatia foliata</i> | 9 | <i>Odostomia</i> | 7 |
| <i>Corbula</i> | 158 | <i>Pagodatrochus variabilis</i> | 4 |
| <i>Crenella striatissima</i> | 1 | <i>Plesiotrochus souverbianus</i> | 1 |
| <i>Cryptopecten nux</i> | 1 | <i>Pupa affinis</i> | 2 |
| <i>Ctena divergens</i> | 18 | <i>Retusa desgenettii</i> | 8 |
| <i>Exotica triradiata</i> | 7 | <i>Rhinoclavis sordidula</i> | 22 |
| <i>Frigidocadium torressi</i> | 6 | <i>Ringicula minuta</i> | 1 |
| <i>Fulvia</i> | 1 | <i>Rissoina pachystoma?</i> | 1 |
| Galeommatidae (MAR50bottom) | 2 | <i>Smaragidia purpureomaculata</i> | 1 |
| <i>Limatullela</i> | 1 | <i>Tritonoharpa antiquata</i> | 1 |
| <i>Limea pectinata</i> | 3 | <i>Turbonilla nitidissima</i> | 3 |
| <i>Lioconcha</i> sp.1 | 113 | Turridae MAR50bot1 | 1 |
| <i>Lioconcha</i> sp.2 | 3 | Turridae sp.8 | 4 |
| <i>Microcirce dilecta</i> | 10 | Turridae sp.2 MAR50bot | 1 |
| Mytilid MAR50bot | 1 | <i>Turritella cochlea</i> | 6 |
| <i>Nucula inconspicua</i> | 4 | <i>Vacerrina nana</i> | 1 |
| <i>Pictada radiata</i> | 273 | <i>Varicopeza pauxilla</i> | 549 |
| <i>Pinguitellina pinguis</i> | 47 | <i>Ventomnestia girardi</i> | 7 |
| Pinnidae | 13 | <i>Xenophora</i> sp. | 1 |
| <i>Rochefurtina</i> cf. <i>sandwichensi</i> | 21 | <i>Zafra</i> sp. | 1 |
| <i>Semele fragillima</i> | 6 | | |
| <i>Semele</i> sp.MAR50bottom | 11 | | |
| <i>Septifer forskali</i> | 10 | | |
| unidentified (venridae?)MAR50bot | 1 | | |
| <i>Aclis</i> | 1 | | |
| <i>Atys</i> | 5 | | |
| <i>Bothropoma isseli</i> | 15 | | |
| <i>Cerithidum perpavulum</i> | 11 | | |
| Ceritiid ? MAR50top | 1 | | |
| <i>Chrysallida</i> sp. 1 | 4 | | |
| <i>Costellaria</i> sp.1 | 11 | | |
| <i>Costellaria</i> sp.2 | 5 | | |
| Cymatidae sp.1 | 1 | | |
| <i>Diala semistriata</i> | 6 | | |
| <i>Domiporta</i> sp. | 4 | | |
| <i>Ergalatax contracta</i> | 2 | | |
| <i>Erosaria macandrewi</i> | 1 | | |
| <i>Ethalia bellardii</i> | 17 | | |
| Eulimidae sp.1 MAR50bot | 1 | | |
| Fascioladae/Turridae? | 3 | | |
| <i>Finella pupoides</i> | 1 | | |
| <i>Leucorhynchia crossei</i> | 7 | | |
| <i>Lodderia novemcarinata</i> | 4 | | |
| <i>Miralda noduslosa</i> | 1 | | |
| <i>Mitrella</i> sp.1 | 5 | | |
| <i>Mitrella</i> sp.2 | 1 | | |
| Muricidae sp.1 MAR50bot | 1 | | |
| Muricidae sp.2 MAR50 bot | 1 | | |

| <u>MAR 70top</u> | <u>No. individuals</u> | | |
|---|------------------------|-----------------------------------|-----|
| <i>Amygdalum peasei</i> | 10 | <i>Nassarius</i> sp.1 MAR70top | 4 |
| <i>Anodontia</i> sp. | 5 | <i>Nassarius</i> sp.10 MAR70top | 1 |
| <i>Anomia</i> sp. | 1 | Naticid MAR70top | 1 |
| <i>Arca accumulata</i> | 8 | <i>Notocochlis gualtieriana</i> | 15 |
| <i>Arca navicularis</i> | 7 | <i>Odostomia</i> sp. | 1 |
| <i>Barbatia foliata</i> | 20 | <i>Pagodatrochus variabilis</i> | 2 |
| Cardiid MAR70top | 1 | <i>Pseudominolia nedyma</i> | 1 |
| <i>Cardiomya singaporensis</i> | 1 | Pyramidellidae sp. MAR70top | 1 |
| <i>Corbula erythraeensis</i> | 182 | Ranellidae MAR70top | 1 |
| <i>Crenella striatissima</i> | 2 | Ranellidae?sp. MAR70top | 1 |
| <i>Ctena divengens</i> | 3 | <i>Retusa desgenettii</i> | 5 |
| <i>Exotica triradiata</i> | 3 | <i>Cylichnia</i> sp.1 | 5 |
| <i>Frigidocardium torresi</i> | 18 | <i>Rhinoclavis sordidula</i> | 3 |
| <i>Linea pectinata</i> | 3 | <i>Ringicula acuta</i> | 5 |
| <i>Lioconcha</i> sp.1 | 57 | <i>Ringicula minuta</i> | 1 |
| <i>Lioconcha</i> sp.2 | 8 | Triphoridae sp.1 | 2 |
| <i>Loripes</i> | 1 | <i>Turbonilla</i> sp. 3 | 1 |
| Mytilid | 1 | Turridae MAR70top(cf. 9NAVY50top) | 3 |
| <i>Nucula inconspicua</i> | 7 | Turridae sp.2 MAR70top | 4 |
| <i>Parvamussium formosum</i> | 3 | Turridae sp.3 MAR70top | 2 |
| <i>Pictada radiata</i> | 922 | Turridae sp.4 MAR70top | 1 |
| <i>Pinguitellia pinguis</i> | 25 | Turridae sp.5 MAR70top | 1 |
| Pinnidae | 21 | Turridae sp.6 MAR70top | 1 |
| <i>Rocheffurtina</i> cf. <i>sandwichensis</i> | 23 | Turridae1 MAR70top | 1 |
| <i>Septifer forskali</i> | 1 | Turridae MAR70top(4NAVY50top) | 1 |
| <i>Similipecten eous</i> | 4 | Turridae sp. 10 | 1 |
| Tellinidea 1MAR70top | 1 | <i>Vacerrina nana</i> | 3 |
| Tellinidea 2MAR70top | 1 | <i>Varicopeza pauxilla</i> | 178 |
| <i>Atys angustatus</i> | 2 | <i>Xenophora</i> sp. | 3 |
| <i>Bothropoma isseli</i> | 7 | <i>Zafra</i> sp 1 | 11 |
| <i>Cerithidium perpavulum</i> | 1 | | |
| Cerithidae sp. MAR70top | 2 | | |
| Collumbillidae MAR70top | 2 | | |
| <i>Costellaria</i> sp.1 | 6 | | |
| <i>Costellaria</i> sp.2 | 7 | | |
| <i>Diala semistriata</i> | 1 | | |
| <i>Domiporta</i> sp. | 2 | | |
| <i>Epitonium</i> sp.1 MAR70top | 1 | | |
| <i>Ergalatax contracta</i> | 1 | | |
| <i>Ethalia bellardii</i> | 10 | | |
| <i>Eulima</i> sp.1 MAR70top | 1 | | |
| <i>Eulima</i> sp.2 MAR70top | 1 | | |
| Fasciolaridae sp?MAR70top | 5 | | |
| <i>Gazameda alba</i> | 1 | | |
| Lamellariidae | 1 | | |
| <i>Leucorhynchia crossei</i> | 1 | | |
| <i>Lodderia novemcarinata</i> | 5 | | |
| <i>Miralda noduslosa</i> | 1 | | |
| <i>Mitrella</i> sp.1 | 2 | | |
| <i>Mitrella</i> sp.MAR70top | 1 | | |
| <i>Nassarius sinusigerus</i> | 9 | | |

| <u>NAVY 50top</u> | <u>No. individuals</u> | | |
|--|------------------------|------------------------------------|-----|
| <i>Amygdalum peasei</i> | 40 | Fusinidae sp.3 NAVY50top | 1 |
| <i>Anodontia</i> sp. | 4 | Hipponicidae | 1 |
| <i>Anomia</i> sp. | 1 | <i>Leucorhynchia crossei</i> | 19 |
| <i>Arca navicularis</i> | 25 | <i>Lodderia novemcarinata</i> | 1 |
| <i>Arca</i> sp. NAVY50top | 2 | <i>Mitrella</i> sp.1 NAVY50top | 7 |
| <i>Barbatia foliata</i> | 9 | <i>Nassarius sinusigerus</i> | 8 |
| <i>Cardiolucina semperiana</i> | 1 | <i>Nassarius</i> sp.1 NAVY50top | 9 |
| <i>Corbula erythraeensis</i> | 71 | <i>Nassarius</i> sp.2 NAVY50top | 6 |
| <i>Ctena divergens</i> | 11 | <i>Neocancilla circula</i> | 2 |
| <i>Cyrella diabolica</i> | 2 | <i>Notocochlis gualtieriana</i> | 12 |
| <i>Crenella striatissima</i> | 2 | <i>Odostomia</i> sp. | 2 |
| <i>Dorisca nana</i> | 1 | <i>Pagodatrochus variabilis</i> | 5 |
| <i>Exotica triradiata</i> | 6 | <i>Phasianella solida</i> | 2 |
| <i>Frigidocardium torresi</i> | 10 | <i>Planaxis savignyi</i> | 1 |
| Galeommatidae sp. NAVY50top | 7 | <i>Plesiotrochus souverbianus</i> | 1 |
| <i>Glycymeris livida</i> | 2 | <i>Pupa affinis</i> | 5 |
| <i>Juxtamusium maldivense</i> | 1 | <i>Retusa desgenettii</i> | 20 |
| <i>Lioconcha philippinarum</i> | 72 | <i>Cylichnia</i> sp.1 | 2 |
| <i>Lioconcha</i> sp.2 | 2 | <i>Retusa tarutana</i> | 1 |
| <i>Limea pectinata</i> | 10 | <i>Rhinoclavis sordidula</i> | 7 |
| <i>Limatulella</i> sp. | 1 | <i>Ringicula acuta</i> | 4 |
| <i>Microcirce dilecta</i> | 1 | <i>Ringicula minuta</i> | 3 |
| <i>Nucula inconspicua</i> | 8 | <i>Scaliola elata</i> | 4 |
| <i>Parvamussium formosum</i> | 1 | <i>Smaragidia purpureomaculata</i> | 3 |
| <i>Pictada radiata</i> | 436 | <i>Terebra</i> NAVY50top | 1 |
| <i>Pinguitellia pinguis</i> | 37 | Triphoridae sp.1 | 1 |
| Pinnidae | 9 | Triphoridae sp.2(cf. FF50bot) | 1 |
| ?Pteriid | 1 | <i>Turbonilla</i> sp.3 | 2 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 38 | Turridae sp.1 NAVY50top | 2 |
| <i>Semelangulus mesodesmoides</i> | 2 | Turridae sp.6 | 1 |
| <i>Semele fragillima</i> | 3 | Turridae sp.3 NAVY50top | 2 |
| <i>Septifer forskali</i> | 4 | Turridae sp.4 NAVY50top | 2 |
| <i>Timoclea roemeriana</i> | 5 | Turridae sp.5 NAVY50top | 1 |
| unidentified bivalve1 NAVY50top | 1 | Turridae sp.7 NAVY50top | 1 |
| unidentified bivalve2 NAVY50top | 1 | Turridae sp.8 NAVY50top | 1 |
| <i>Ancilla</i> | 1 | Turridae sp.9 NAVY50top | 1 |
| <i>Atys angustatus</i> | 6 | Turridae/Fusinidae? | 2 |
| <i>Borthopoma isseli</i> | 26 | <i>Turritella cochlea</i> | 3 |
| Buccinidae NAVY50top | 1 | unidentified 1 NAVY50top | 1 |
| Cerithicea NAVY50top | 1 | unidentified 2 NAVY50top | 1 |
| <i>Cerithidium perpavulum</i> | 21 | unidentified 3 NAVY50 | 1 |
| Cerithidae 1 (cf. FF90bot)NAVY50top | 5 | unidentified 4 NAVY50top | 1 |
| <i>Chrysallida</i> 1 (cf. bot)NAVY50top | 6 | unidentified 5 NAVY50top | 1 |
| <i>Costellaria</i> sp.1 | 17 | <i>Vacerrena nana</i> | 7 |
| <i>Costellaria</i> sp.2 | 5 | <i>Varicopeza pauxilla</i> | 251 |
| <i>Diala semistriata</i> | 21 | <i>Xenophora</i> sp. | 3 |
| <i>Epitonium</i> 1 NAVY50top | 1 | <i>Zafra</i> sp. | 1 |
| <i>Epitonium</i> cf. <i>laidlawi</i> | 1 | | |
| <i>Ethalia bellardii</i> | 21 | | |
| <i>Eulima</i> sp.1 NAVY50top | 3 | | |
| Fusinidae sp.1 NAVY50top | 1 | | |
| Fusinidae sp.2 NAVY50top | 2 | | |

| <u>NAVY 50bottom</u> | <u>No. individuals</u> | | |
|--|------------------------|--|----|
| <i>Acrosterigma maculosum</i> | 1 | Collumbillidae NAVY50bottom | 1 |
| <i>Acrosterigma</i> sp. | 1 | <i>Costellaria</i> cf. <i>malcolmensis</i> | 2 |
| <i>Amygdalum peasei</i> | 23 | <i>Costellaria</i> sp.1 | 27 |
| <i>Anodontia</i> sp. | 4 | <i>Costellaria</i> sp.2 | 2 |
| <i>Arca navicularis</i> | 31 | ? <i>Ventomnestia girardi</i> | 1 |
| <i>Barbatia foliata</i> | 3 | <i>Diala semistriata</i> | 27 |
| <i>Barbatia</i> cf. <i>sulcata</i> | 2 | <i>Epitonium</i> NAVY50bottom | 1 |
| Cardiid sp. (39 ribs) | 1 | <i>Ethalia bellardii</i> | 24 |
| Cardioidea sp. NAVY50bottom | 2 | <i>Eulima</i> sp. | 3 |
| <i>Cardiolucina semperiana</i> | 1 | Fasciolaridae NAVY50bottom | 1 |
| <i>Cardites akabana</i> | 1 | <i>Fusinus</i> NAVY50bottom | 1 |
| <i>Cardites rufa</i> | 2 | <i>Leucorhynchia crossei</i> | 8 |
| <i>Corbula erythraeensis</i> | 94 | ? <i>Leucorhynchia crossei</i> (juvenile?) | 19 |
| <i>Cryptopecten nux</i> | 1 | <i>Lodderia novemcarinata</i> | 1 |
| <i>Ctena divergens</i> | 7 | <i>Mitrella nympa</i> | 1 |
| <i>Cyrella diabolica</i> | 1 | <i>Mitrella</i> sp.1 NAVY50bottom | 6 |
| <i>Crenella striatissima</i> | 2 | Muricoidae sp. 1 NAVY50bottom | 1 |
| <i>Dosinia erythrea</i> | 1 | Muricoidae sp. 2 NAVY50bottom | 1 |
| <i>Exotica triradiata</i> | 5 | Muricoidae sp. 3 NAVY50bottom | 1 |
| <i>Frigidocardium torresi</i> | 13 | Muricoidae sp. 4 NAVY50bottom | 3 |
| <i>Fulvia fragilis</i> | 1 | Muricoidae sp. 5 NAVY50bottom | 1 |
| Galeommatidae sp. | 3 | Muricoidae sp. 6 NAVY50bottom | 1 |
| <i>Glycymeris livida</i> | 2 | Muricoidae sp. 7 NAVY50bottom | 2 |
| <i>Lioconcha philippinarum</i> | 92 | <i>Nassarius</i> sp.1 | 6 |
| <i>Lioconcha</i> sp.2 | 3 | <i>Nassarius sinusigerus</i> | 14 |
| <i>Lioconcha</i> sp.3 | 1 | Naticid | 2 |
| <i>Limea pectinata</i> | 8 | <i>Neocancilla circula</i> | 2 |
| <i>Limatulella</i> sp. | 2 | <i>Notocochlis gualtieriana</i> | 18 |
| Lucinoidea sp. | 1 | <i>Odostomia</i> sp. | 4 |
| <i>Nucula inconspicua</i> | 14 | <i>Pagodatrochus variabilis</i> | 5 |
| <i>Pharaonella perna</i> | 2 | <i>Perrinia stellata</i> | 2 |
| <i>Pictada radiata</i> | 459 | <i>Philine vaillanti</i> | 1 |
| <i>Pinguitellia pinguis</i> | 30 | <i>Plesiotrochus souverbianus</i> | 5 |
| Pinnidae | 9 | <i>Pseudoliotia henjamense</i> | 1 |
| <i>Rochefurtina</i> cf. <i>sandwichensis</i> | 42 | <i>Pupa affinis</i> | 3 |
| <i>Saccostrea</i> ? | 1 | Pyramidellidae NAVY50bottom | 1 |
| <i>Semele fragillima</i> | 6 | <i>Retusa desgenettii</i> | 17 |
| <i>Septifer forskali</i> | 5 | <i>Retusa tarutana</i> | 3 |
| <i>Similipecten eous</i> | 3 | <i>Rhinoclavis sordidula</i> | 3 |
| Tellinid sp. NAVY50bottom | 1 | <i>Rhizorus</i> sp. | 2 |
| <i>Timoclea roemeriana</i> | 1 | <i>Ringicula acuta</i> | 4 |
| unidentified sp.1 NAVY50bottom | 1 | <i>Rubritrochus declivis</i> | 1 |
| <i>Issina issina</i> | 1 | <i>Scaliola elata</i> | 3 |
| unidentified sp.3 NAVY50bottom | 1 | <i>Smaragidia purpleomaculata</i> | 5 |
| unidentified sp.4 NAVY50bottom | 1 | <i>Syrnola</i> | 1 |
| <i>Atys angustatus</i> | 6 | Triphoridae sp.2 | 1 |
| <i>Bothropoma isseli</i> | 28 | <i>Turbonilla nitidissima</i> | 1 |
| <i>Cerithidium</i> NAVY50bottom | 4 | Turridae sp.1 NAVY50bottom | 6 |
| <i>Cerithidium perpavulum</i> | 21 | Turridae sp.2 NAVY50bottom | 1 |
| Cerithiopsidae sp. | 1 | Turridae sp.3 NAVY50bottom | 5 |
| <i>Chrysallida</i> sp. 1 NAVY50bottom | 8 | Turridae sp.4 NAVY50bottom | 1 |
| <i>Chrysallida</i> sp. 2 NAVY50bottom | 1 | Turridae sp.8 | 1 |

| | |
|----------------------------|-----|
| Turritilidae NAVY50bottom | 1 |
| unidentified NAVY50 | 1 |
| <i>Vacerrera nana</i> | 4 |
| <i>Varicopeza pauxilla</i> | 305 |
| <i>Xenophora</i> sp. | 6 |
| <i>Zafra savignyi</i> | 2 |
| <i>Zafra</i> sp. | 3 |

PLATES
BIVALVES 1-13

PLATE 1

Protobranchia

1. *Solemya* sp. [5 mm]
2. *Cyrella diabolica* (Jousseume, 1897) [2.5 mm]
3. *Nucula inconspicua* H. Adams, 1871 [3 mm]

Arcoidea

4. *Arca accumunata* Oliver & Chesney, 1994 [6 mm]
5. *Arca navicularis* Bruguiere, 1789 [7 mm]
6. *Barbatia* cf. *sulcata* (Lamarck, 1819) [3.5 mm]
7. *Barbatia foliata* (Forsskal, 1775) [5.5 mm]
8. *Barbatia trapezina* (Lamarck, 1819) [4.5 mm]
9. *Anadara* [4 mm]



PLATE 2

Limopsoidea

10. *Limopsis elachista* Sturany, 1899 [1.5 mm]
11. *Glycymeris livida* (Reeve, 1843) [2.5 mm]

Mytiloidea

12. *Septifer forskali* (Dunker, 1855) [4 mm]
13. *Amygdalum peasei* (Newcomb, 1870) [4 mm]
14. *Musculus viridulus* (H. Adams, 1871) [3.5 mm]
15. *Crenella striatissima* Sowerby, 1904 [3 mm]
16. Mytilid [0.35 mm]

Pinnoidea

17. Pinnidae sp. [3 mm]

10a



10b



11a



11b



12a



12b



13a



13b



14a



14b



15a



15b



16a



16b



17a



17b



PLATE 3

Pterioidea

18. *Pteria* sp. [8.5 mm]
19. *Pteria* sp. FF50B bottom [4 mm]
20. *Pteria* MAR50top [4 mm]
21. Pteriidae MAR50top [4 mm]
22. ?Pteriid [3.5 mm]
23. *Pictada radiata* (Leach, 1814) [6 mm]

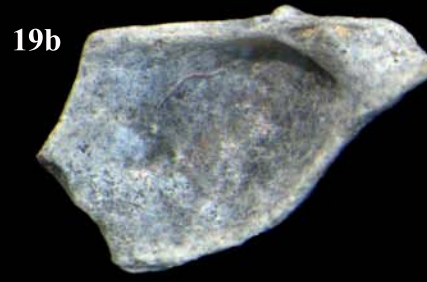
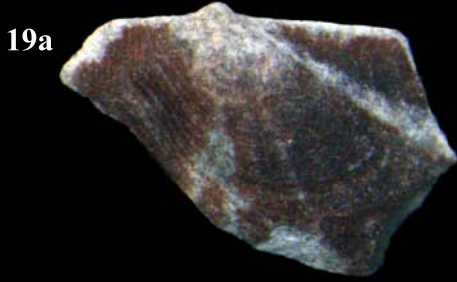


PLATE 4

Pectinoidea

24. Pectinidae sp. [7 mm]
25. *Parvamussium thyrideum* (Melvill in Melvill & Standen, 1907) [8 mm]
26. *Parvamussium formosum* (Melvill in Melvill & Standen, 1907) [4 mm]
27. *Similipecten eous* (Melvill & Standen, 1907) [3.5 mm]
28. *Juxtamusium maldivense* (Smith, 1903) [12 mm]
29. *Cryptopecten nux* (Reeve, 1853) [3.5 mm]

Limoidea

30. *Limatulella* sp. [3 mm]
31. *Limea pectinata* H. Adams, 1870 [2 mm]

24



25a



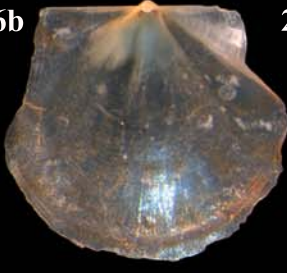
25b



26a



26b



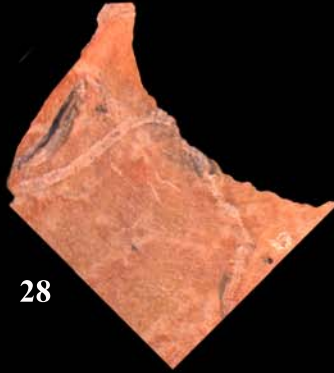
27a



27b



28



29a



29b



29c



30a



30b



31a



31b



PLATE 5

Ostreioidea

- 32. Ostreidae
- 33. Oystreid
- 34. Oystreid BIUV40bottom
- 35. *Saccostrea?*
- 36. *Parahyotissa numisma* (Lamarck, 1819)

Anomioidea

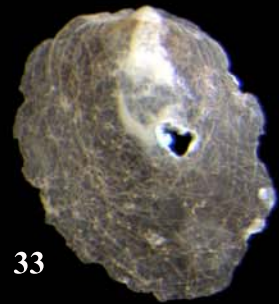
- 37. *Anomia* sp.



32a



32b



33



34a



34b



35a



35b



36a



36b



37a



37b



37c

PLATE 6

Lucinoidea

- 38. *Anodontia* sp. [3.5 mm]
- 39. *Cardiolucina semperiana* (Issel, 1869) [3 mm]
- 40. *Ctena divergens* (Philippi, 1850) [3 mm]
- 41. lucinid sp. BIUV40top [2.5 mm]
- 42. Lucinoidea sp. [2.5 mm]
- 43. *Loripes* sp. [2 mm]

Galeommatoidea

- 44. Galeommatidae sp. [3 mm]

Chamoidea

- 45. *Chama* sp.1 [4 mm]
- 46. *Chama* sp.2 [4.5 mm]



38a



38b



39a



39b



40a



40b



41a



41b



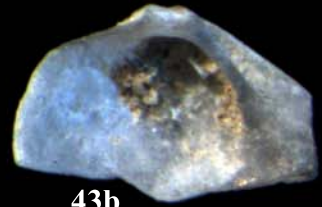
42a



42b



43a



43b



44a



44b



45a



45b



46

PLATE 7

Carditoidea

- 47. *Cardites akabana* (Sturany, 1899) [2.5 mm]
- 48. *Cardites rufa* (Labordes & Deshayes, 1834) [2.5 mm]

Cardioidea

- 49. *Parvicardium sueziensis* (Issel, 1869) [6 mm]
- 50. *Afrocardium richardi* (Audouin, 1826) [2.5 mm]
- 51. *Fulvia fragilis* (Forsskal, 1775) [7.5 mm]
- 52. *Fulvia australis* (Sowerby, 1834) [3 mm]
- 53. *Acrosterigma maculosum* (Wood, 1815) [4 mm]
- 54. *Frigidocardium torresi* [6 mm]
- 55. Cardiid sp. (39 ribs) [7 mm]
- 56. Cardiid sp. BUIV40top [3 mm]
- 57. *Cardiodea* sp. NAVY50bottom [3 mm]

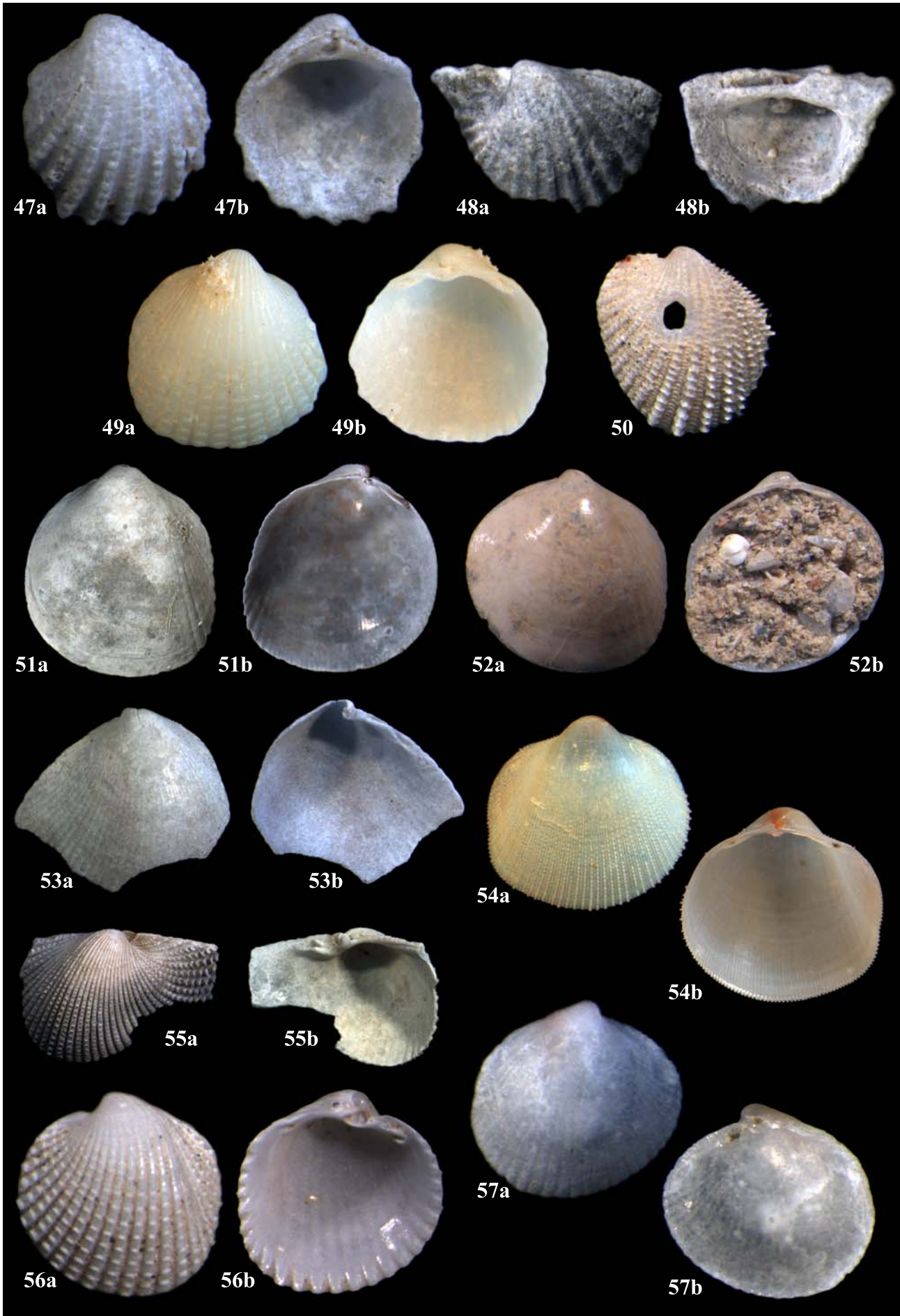


PLATE 8

Mactroidea

58. *Mactrotoma ovalina* Lamarck, 1818 [15 mm]

Tellinoidea

59. *Exotica triradiata* H. Adams, 1871 [5 mm]

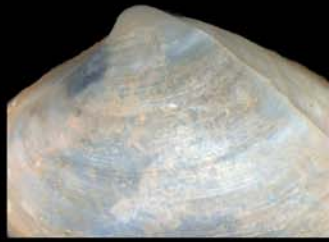
60. *Moerella lactea* (H. Adams, 1871) [4 mm]

61. *Semelangulus mesodesmoides* Oliver & Zuschin, 2000 [2.5 mm]

62. *Pharaonella perna* (Spengler, 1797) [5 mm]

63. *Arcopella isseli* (H. Adams, 1871) [8 mm]

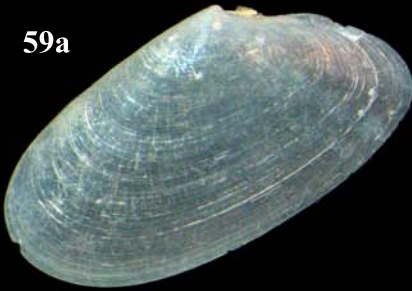
64. *Pinguitellia pinguis* (Hanley, 1844) [3 mm]



58a



58b



59a



59b



60c



60a



60b



61a



62a



62b



61b



62c



63a



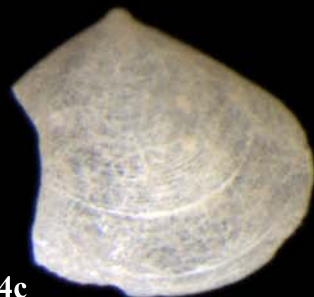
63b



64a



64b



64c

PLATE 9

Tellinoidea

65. "Tellina" sp.-FF90bottom [3.5 mm]
66. tellinid sp. NAVY50bottom [2 mm]
67. tellinid sp. (smooth) FF50Bbottom [5 mm]
68. tellinid unknown sp. FF50Bbottom [4 mm]
69. tellinid [4 mm]
70. tellinid sp. BIUV40top [5 mm]
71. Tellinellidae BIUV40top [4 mm]
72. Tellinidea 1MAR70top [3 mm]
73. Tellinidea 2MAR70top [4 mm]
74. Tellinidae BIUV20B bottom [5 mm]



PLATE 10

Tellinoidea

75. Tellinoidea BIUV40bottom [5 mm]
76. tellinid BIUV40bottom [4.5 mm]
77. *Loxoglypta clathrata* (Deshayes, 1835) [4 mm]
78. *Loxoglypta subpallida* (Smith, 1891) [3 mm]
79. *Semele fragillima* (Issel, 1869) [3 mm]
80. *Rochefurtina* cf. *Sandwichensis* (Smith, 1885) [4 mm]
81. *Semele* sp.1 [4.5 mm]
82. *Leptomya* sp. [3 mm]

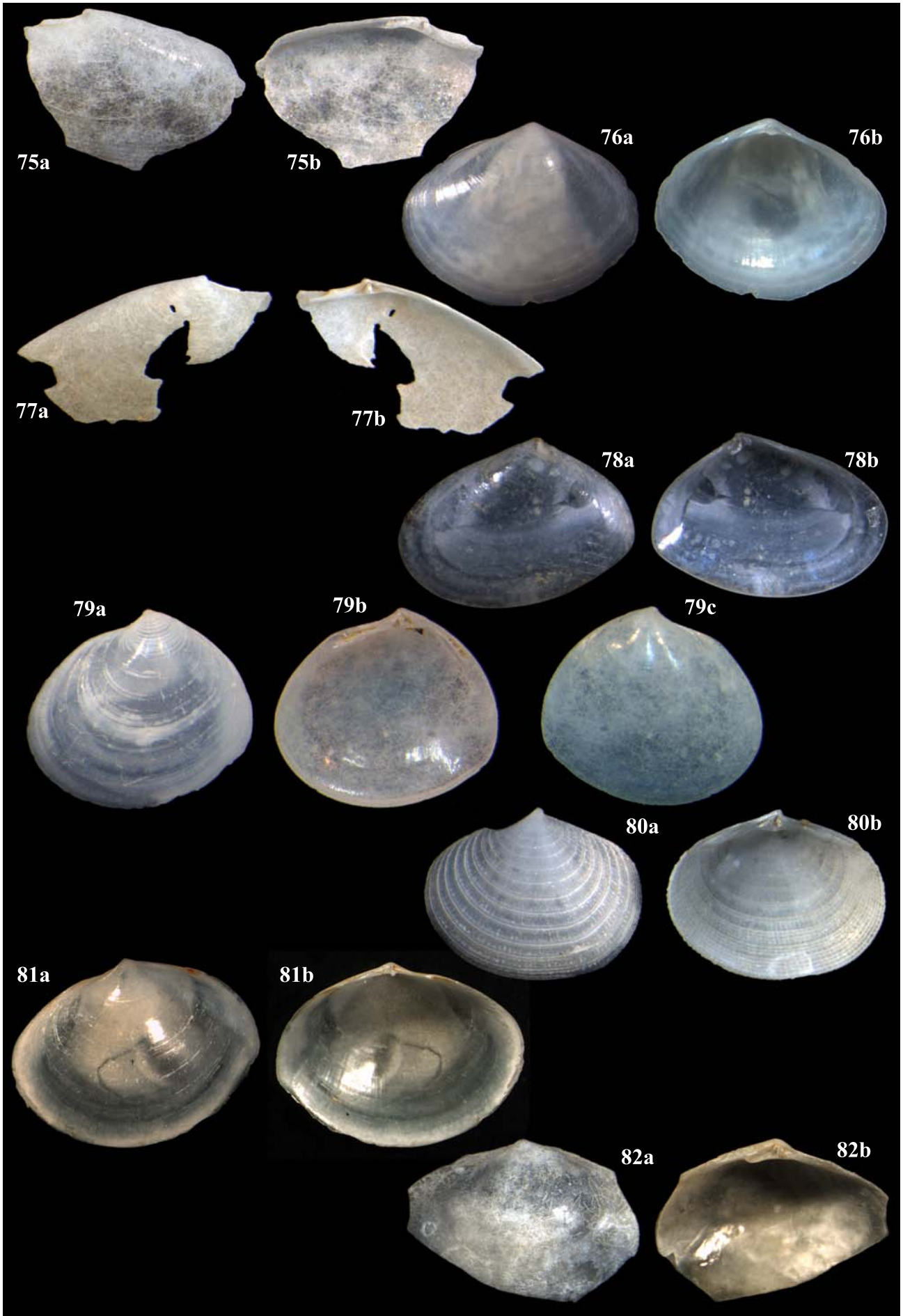


PLATE 11

Veneroidea

83. *Dorisca nana* (Melvill, 1898) [4 mm]
84. *Microcirce dilecta* (Gould, 1861) [3.5 mm]
85. *Microcirce constenans?* Oliver & Zuschin, 2001 [3 mm]
86. *Lioconcha philippinarum* (Hanley, 1844) [86 a-b = 4 mm; 86c = 8.5 mm]
87. *Lioconcha* sp.1 [3.5 mm]
88. *Lioconcha* sp.2 [4.5 mm]
89. *Lioconcha* sp.3 [3 mm]
90. *Pitar yerburyi* (Smith, 1891) [3.5 mm]
91. *Clementia papyracea* (Gray, 1825) [11 mm]
92. *Dosinia erythrea* Romer, 1860 [3 mm]
93. *Timoclea roemeriana* (Issel, 1869) [4 mm]

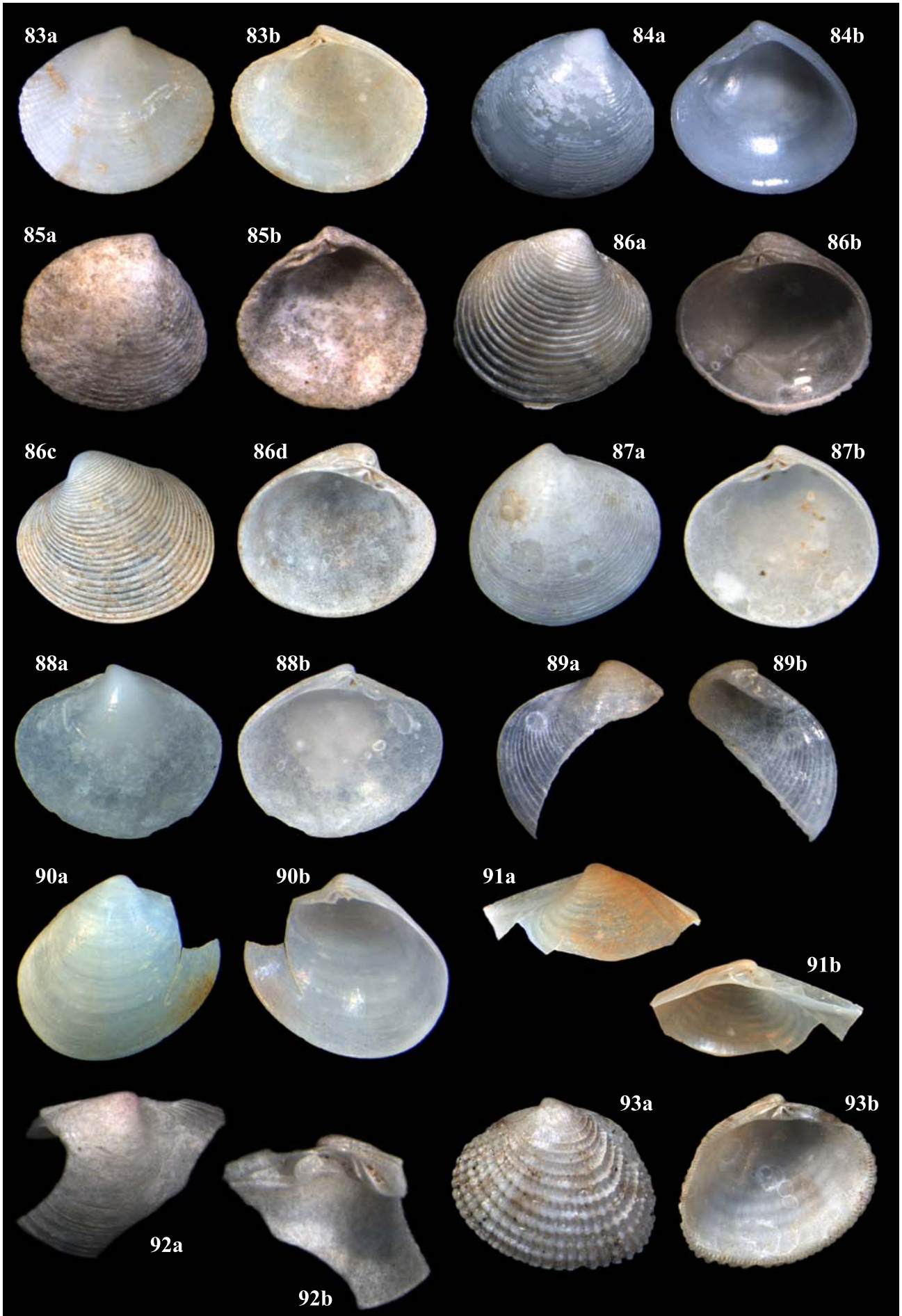


PLATE 12

Veneroidea

- 94. *Timoclea djiboutiensis* (Jousseaume, 1894) [4.5 mm]
- 95. Venerid unknown [3.5 mm]
- 96. Venerid cf. *Timoclea*? [4 mm]
- 97. *Issina issina* Jousseaume, 1898 [2.5 mm]

Myoidea

- 98. *Corbula erythraeensis* H. Adams, 1871 [5 mm]

Pandoroidea

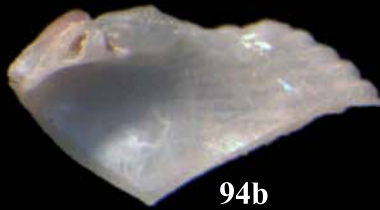
- 99. *Cardiomya singaporensis* (Hinds, 1843) [4 mm]

Unidentified

- 100. unidentified (venridae?)MAR50bot [5 mm]
- 101. unidentified sp.1 NAVY50top [3 mm]
- 102. unidentified sp.1 NAVY50bottom [3 mm]
- 103. unidentified sp.3 NAVY50bottom [3 mm]



94a



94b



95a



95b



96a



96b



97a



97b

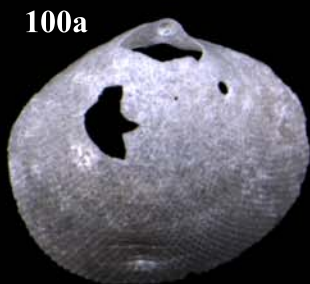


98a

98b



99



100a



100b



101a



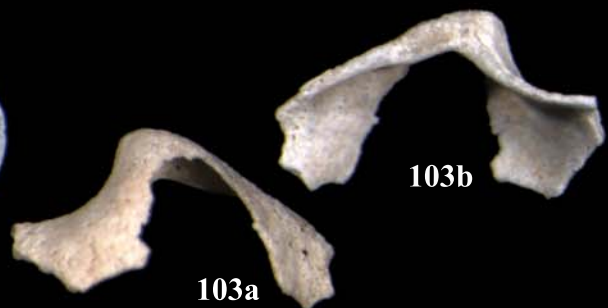
101b



102a



102b



103a

103b

PLATE 13

Unidentified

- 104. unidentified sp.4 NAVY50bottom [3 mm]
- 105. unidentified 2 MAR50top [4 mm]
- 106. unidentified 1 BIUV40top [4 mm]
- 107. unidentified 2 BIUV40top [4 mm]
- 108. unidentified 1 BIUV40bottom [3.5 mm]
- 109. unidentified strong ribs MAR50top [8 mm]

104a



104b



105a



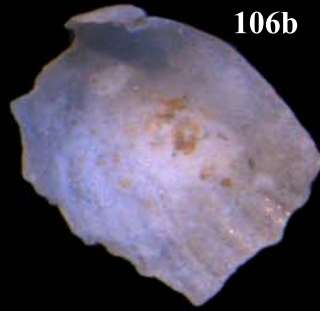
105b



106a



106b



107a



107b



108a



108b



109



PLATES
GASTROPODS 1-21

PLATE 1

Pleurotomarioidea

1. ?*Scissurella aetheria* (Melvill and Standen, 1903) [2 mm]

Neritoidea

2. *Smaragdia purpureomaculata* Dekker, 2000 [2 mm]

Fissurelloidea

3. *Vacerrina nana* (H. Adams 1872) [2 mm]

Trochoidea

4. *Perrinia stellata* (A. Adams, 1864) [4.5 mm]
5. *Rubritrochus declivis* (Forsskal, 1775) [7 mm]
6. *Ethalia bellardii* (Issel, 1869) [2 mm]
7. *Ethiminolia hemprichii* (Issel, 1869) [2.5 mm]



PLATE 2

Trochoidea

8. *Pagodatrochus variabilis* (H. Adams, 1873) [3 mm]
9. *Pseudominolia biangulosa* (A. Adams, 1864) [2 mm]
10. *Pseudominolia gradata* (Sowerby, 1895) [3 mm]
11. *Pseudominolia nedyma* (Melvill, 1897) [3 mm]
12. *Lodderena* sp. (in Oliver, 1995) [2 mm]
13. *Leucorhynchia crossei* Tryon, 1888 [2 mm]
14. *Lodderia novemcarinata* (Melvill, 1906) [1.5 mm]
15. "*Cyclostrema*" *quinquecarinatum* Melvill, 1906 [1.5 mm]



8a



8b



9a



9b



10a



10b



11a



11b



12a



12b



13a



13b



14a



14b



15a



15b



15c

PLATE 3

Trochoidea

16. "*Cyclostrema*" sp.10 [1 mm]
17. "*Cyclostrema*" sp.11 [0.5 mm]
18. ?*Cyclostrematidae* [2 mm]
19. *Bothropoma isseli* (Thiele, 1921) [2.5 mm]
20. *Phasianella solida* (Born, 1778) [2 mm]
21. *Calyostoma* sp. [1.5 mm]

Cerithioidea

22. *Bittium* sp. [3 mm]
23. *Cerithicea* NAVY50top [2 mm]
24. *Cerithidium diplax* (Watson, 1886) [1.5 mm]
25. *Cerithidium perpavulum* (Watson, 1886) [1.5 mm]
26. *Cerithidium* NAVY50bottom [1.5 mm]
27. *Cerithidium* sp. BIUV40top [2 mm]
28. *Cerithium scabridum* Philippi, 1848 [7 mm]
29. *Cerithium* sp. 1-FF90bottom [3 mm]



16



17



18a



18b



19a



19b



20a



20b



21



22a



22b



23a



23b



24a



24b



25a



25b



26a



26b



27a



27b



28a



28b



29

PLATE 4

Cerithioidea

30. *Cerithium* sp. 2-FF90bottom [2.5 mm]
31. Ceritidae sp. FF50Btop [3 mm]
32. Ceritidae sp. FF50Bbot [2 mm]
33. Ceritidae sp. FF70-top [2 mm]
34. Ceritidae sp. MAR70top (encrusted) [1 mm]
35. Ceritidae sp.1-FF90bottom (sp.1 NAVY50top) [2 mm]
36. Ceritiid sp. [1.5 mm]
37. Ceritiid ? MAR50top [2 mm]
38. *Varicopeza pauxilla* (A. Adams, 1855) [3 mm]
39. *Argyropeza divina* Melvill & Standen. 1901 [1.5 mm]
40. *Plesiotrochus souverbianus* Fischer, 1878 [3 mm]
41. *Rhinoclavis sordidula* (Gould, 1849) [4 mm]
42. *Diala semistriata* (Philippi, 1849) [2.5 mm]
43. *Planaxis savignyi* Deshayes, 1844 [1.5 mm]
44. *Scaliola elata* Issel, 1869 [2 mm]

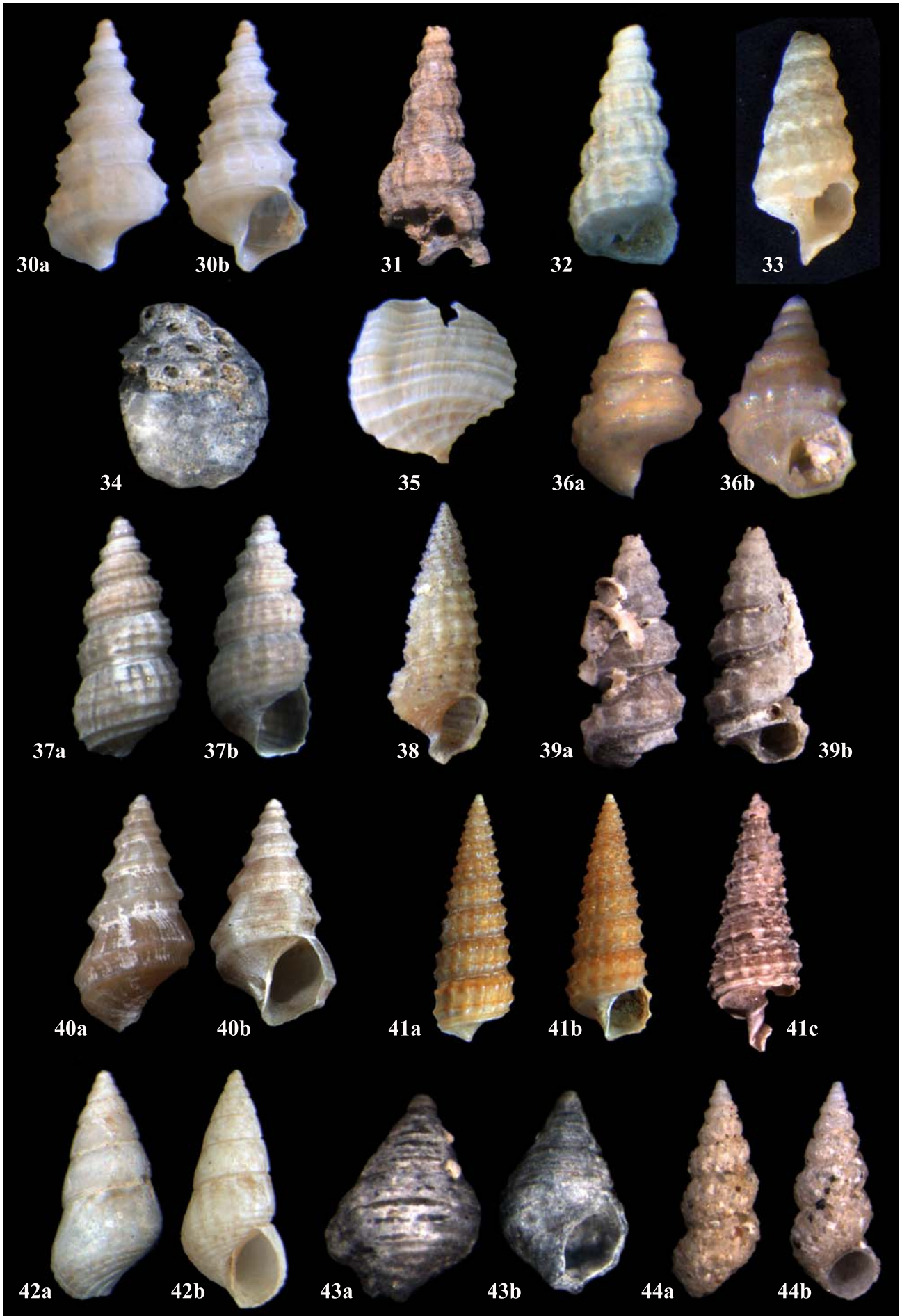


PLATE 5

Cerithioidea

- 45. *Finella pupoides* Adams A., 1860 [3 mm]
- 46. *Turritella cochlea* Reeve, 1849 [12 mm]
- 47. *Archimediella maculate* (Reeve, 1849) [2 mm]
- 48. *Gazameda alba* (H. Adams, 1872) [1.5 mm]

Rissooidea

- 49. *Rissoidea* sp. [2 mm]
- 50. *Rissoidea* sp. (?*Setia*) [2 mm]
- 51. *Rissoina pachystoma?* Melvill, 1896 [3.5 mm]
- 52. *Pelycidion* cf. *xanthias* (Watson, 1888) [1 mm]
- 53. *Pseudoliotia henjamense* (Melvill & Standen, 1903) [2 mm]

Hipponicoidea

- 54. *Hipponicidae* sp. [2.5 mm]

Crepiduloidea

- 55. *Trichotropidae* sp. [2 mm]

Xenophoroidea

- 56. *Xenophora solaroides* (Reeve, 1845) [2 mm]

Cypraeoidea

- 57. *Erosaria macandrewi* (Sowerby, 1870) [10 mm]

Velutinoidea

- 58. *Lamellariidae* Orbigny, 1841 [2 mm]

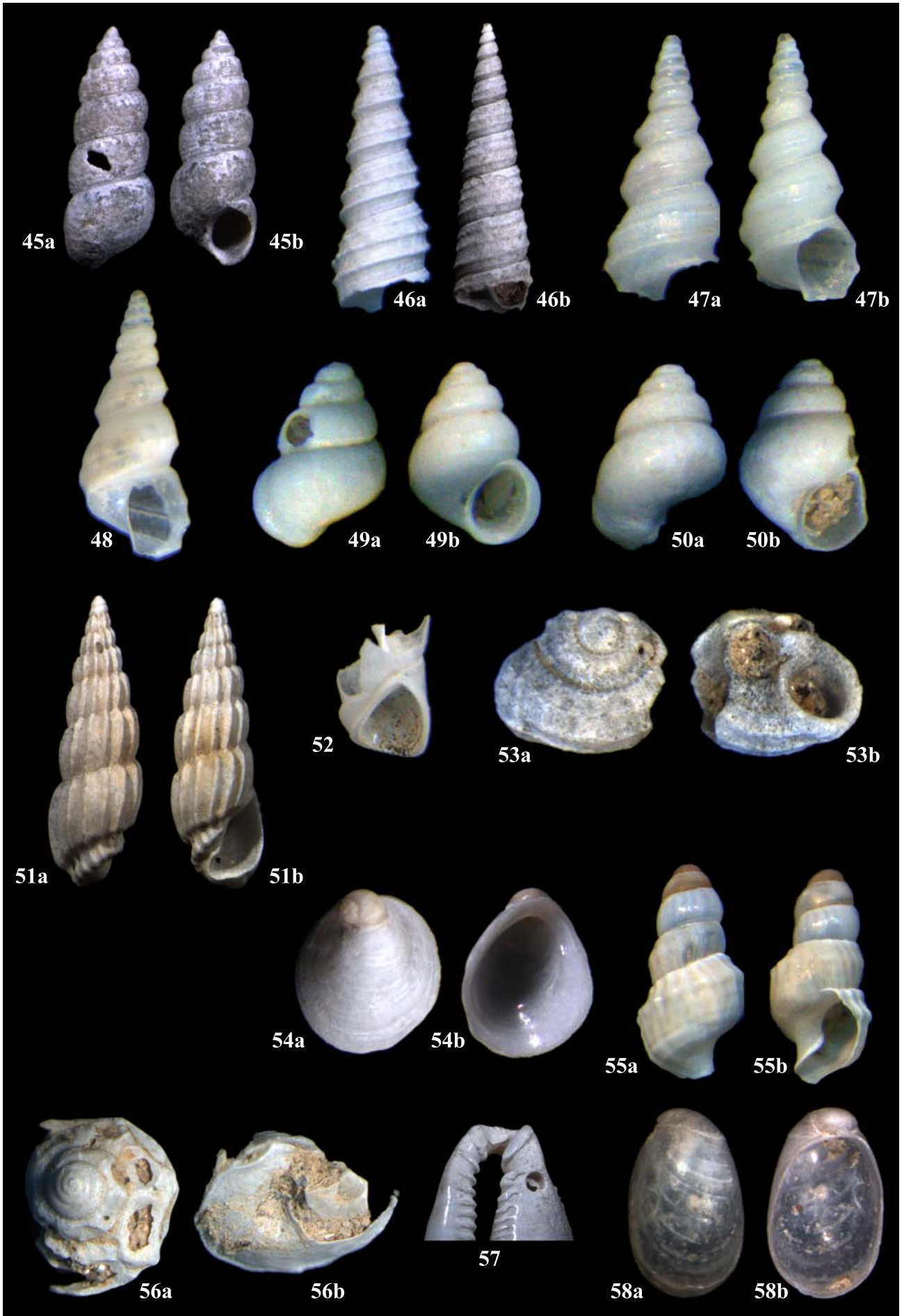


PLATE 6

Naticoidea

- 59. Naticid sp. [2.5 mm]
- 60. Naticidae [2.5 mm]
- 61. Naticidae 1 (operculum) [2.5 mm]
- 62. Naticidae 2 (operculum) [3 mm]
- 63. Naticoidea?BIUV20Bbot [4 mm]
- 64. *Notocochlis gualtieriana* (Récluz, 1844) [2.5 mm]

Tonnoidea

- 65. Ranellidae MAR70top [1 mm]
- 66. Ranellidae?sp. MAR70top [1 mm]
- 67. Cymatidae sp.1 [3 mm]
- 68. *Cymatium* sp. [1.5 mm]
- 69. *Cymatium trilineatum* (Reeve, 1844) [11 mm]
- 70. *Cymatium aquatile* (Reeve, 1846) [20 mm]

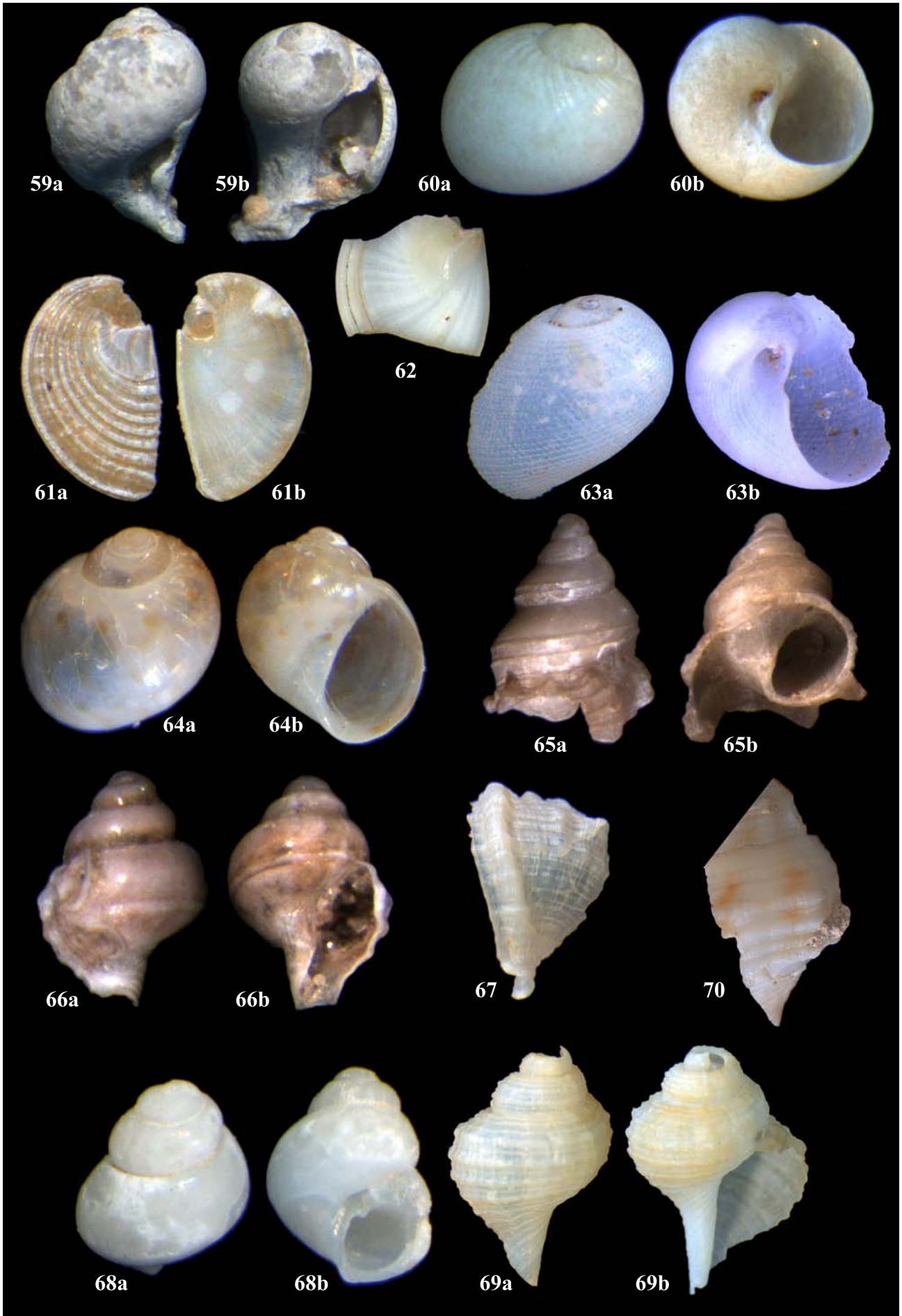


PLATE 7

Cerithiopsoida

71. Cerithiopsidae sp. [1 mm]

Triphoroidea

72. Triphoridae sp.1 [3 mm]
73. Triphoridae sp.2 [3.5 mm]
74. *Viriola?* [2 mm]

Epitonioida

75. *Cycloscala hyaline* (Sowerby, 1844) [1.5 mm]
76. *Epitonium* cf. *laidlawi* (Melvill & Standen, 1903) [2.5 mm]
77. *Epitonium* sp.1 FF50Btop [2 mm]
78. *Epitonium* sp.1 FF50Bbot [2 mm]
79. *Epitonium* NAVY50bottom [1 mm]
80. *Grxqpkw* FF90bot [1.5 mm]
81. *Epitonium* 1 NAVY50top [2 mm]
82. *Epitonium replicatum* (Sowerby, 1844) [1 mm]
83. *Recluzia jehennei* (Petit, 1853) [1 mm]

Eulimoidea

84. *Aclis* Lovén, 1846 [2 mm]
85. *Eulima* sp.2 FF50Bbot [1.5 mm]
86. *Eulima* sp.1 NAVY50top [2 mm]

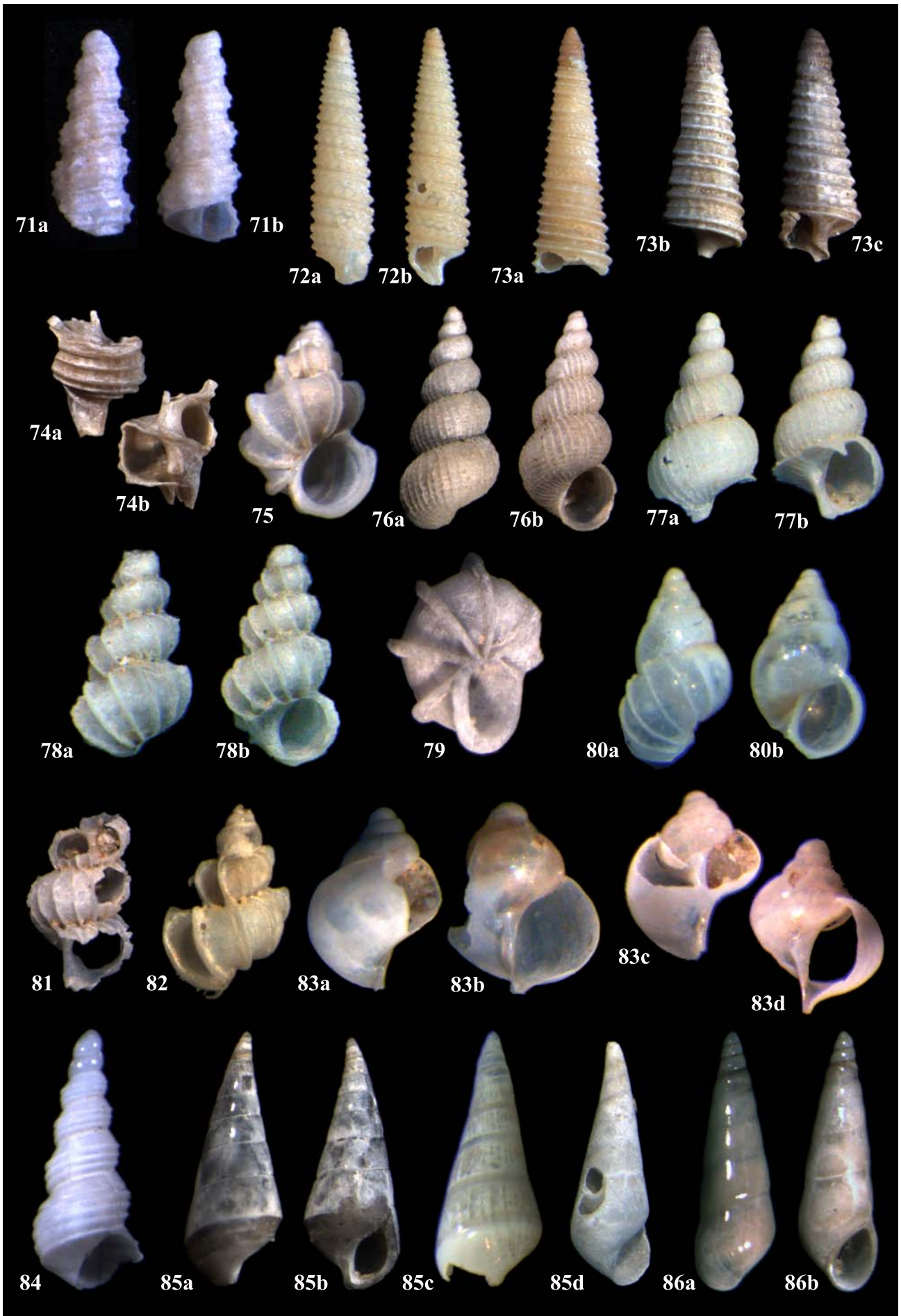


PLATE 8

Eulimoidea

87. Eulimidae sp.1 MAR50bot [1.5 mm]
88. Eulimidae sp.BIUV40top [2 mm]
89. Eulimidae BIUV40bottom [2.5 mm]
90. *Pelseneeria* Kohler and Vaney, 1908 [2 mm]

Muricoidea

91. Muricid [3 mm]
92. Muricidae sp.1 MAR50top [2.5 mm]
93. Muricoidae? MAR50top [3.5 mm]
94. Muricoidae sp. 1 NAVY50bottom [2.5 mm]
95. Muricoidae sp. 2 NAVY50bottom [2 mm]
96. Muricoidae sp. 3 NAVY50bottom [2.5 mm]
97. Muricoidae sp. 4 NAVY50bottom [2.5 mm]
98. Muricoidae sp. 5 NAVY50bottom [2 mm]
99. Muricoidae sp. 6 NAVY50bottom [2.5 mm]
100. Muricoidae sp. 7 NAVY50bottom [2.5 mm]



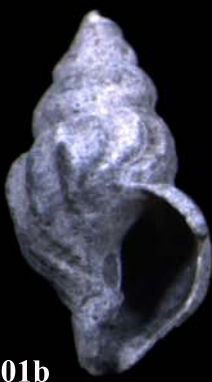
PLATE 9

Muricoidea

101. Muricidae sp.1 MAR50bot [3 mm]
102. Muricidae sp.2 MAR50 bot [3 mm]
103. Muricidae BIUV40bottom [2 mm]
104. *Favartia* sp. [2.5 mm]
105. *Ergalatax contracta* (Reeve, 1846) [9 mm]
106. Buccinidae NAVY50top [2.5 mm]
107. Collumbillidae NAVY50bottom [1 mm]
108. Collumbillidae MAR70top [1.5 mm]
109. Colombilidae sp. [2.5 mm]



101a



101b



102a



102b



103a



103b



104a



104b



105a



105b



105c



106a



106b



107a



107b



108



109a



109b

PLATE 10

Muricoidea

110. *Mitrella nympha* (Kiener, 1841) [3.5 mm]
111. *Mitrella* sp. 1 [2.5 mm]
112. *Mitrella* sp. 2-FF50Btop [2 mm]
113. *Mitrella* sp. 4-FF50Bbot [2 mm]
114. *Mitrella* sp.1-FF90bottom [2 mm]
115. *Mitrella* sp.2-FF90bottom [9 mm]
116. *Mitrella* sp.2 [2.5 mm]
117. *Mitrella* sp.MAR70top [2 mm]
118. *Mitrella* sp.2 MAR50bot [3 mm]
119. *Zafra savignyi* (Moazzo, 1939) [4 mm]
120. *Zafra* sp. 1 [3 mm]

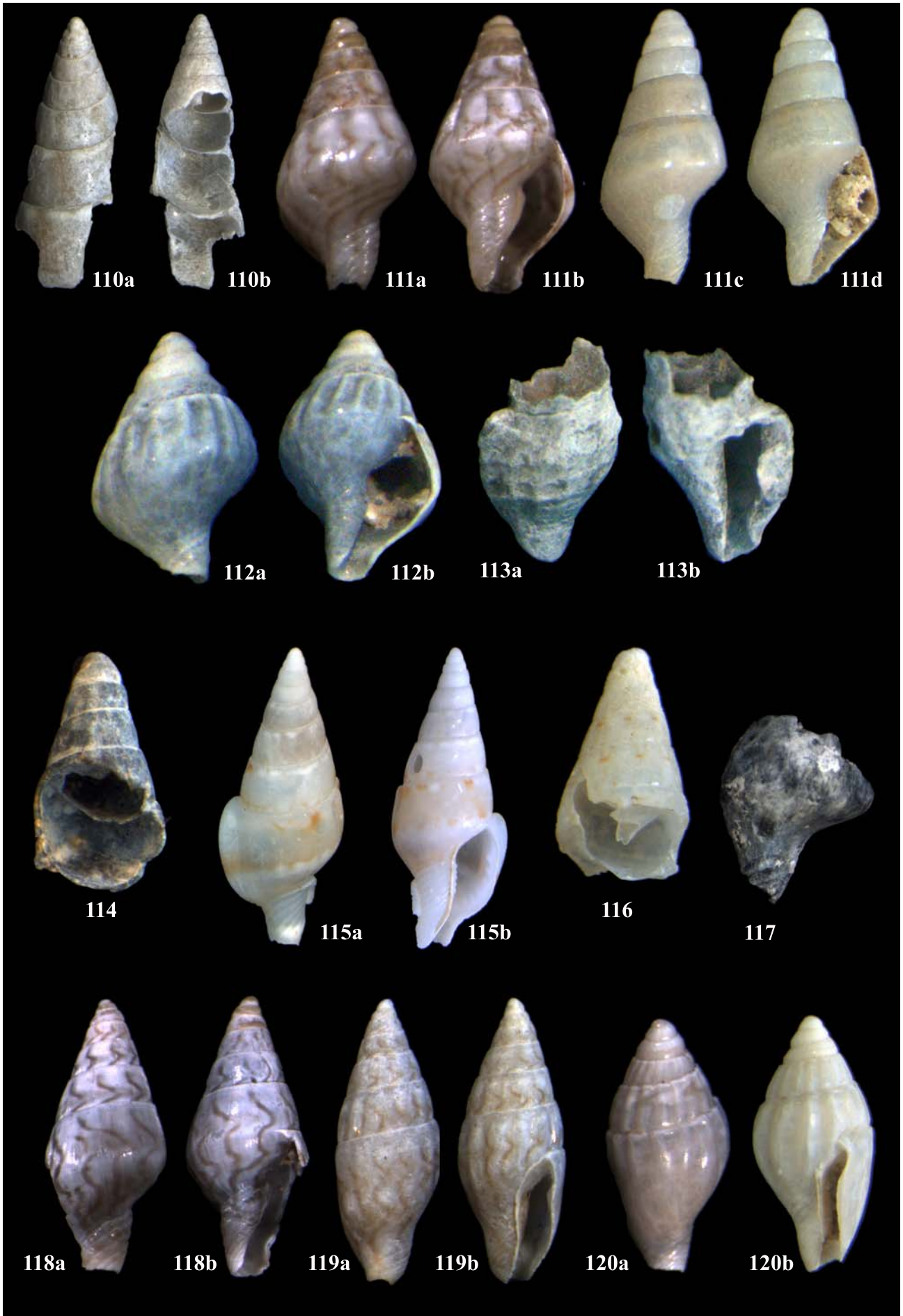


PLATE 11

Muricoidea

121. *Nassarius conoidalis labordei* Mari, 1929 [6 mm]
122. *Nassarius sinusigerus* (A. Adams, 1852) [4 mm]
123. *Nassarius splendidulus* (Dunker, 1846) [2.5 mm]
124. *Nassarius* sp.1 [2 mm]
125. *Nassarius* sp.2 [2 mm]
126. *Nassarius* sp.3 MAR70top [2 mm]
127. Fasciolaridae sp. 1FF50Bbot [6 mm]
128. Fasciolaridae sp. 2 FF50Bbot [2 mm]
129. Fasciolaridae sp. 3 FF50Bbot [4 mm]
130. Fasciolaridae NAVY50bottom [2.5 mm]
131. Fasciolaridae spp?MAR70top [7 mm]

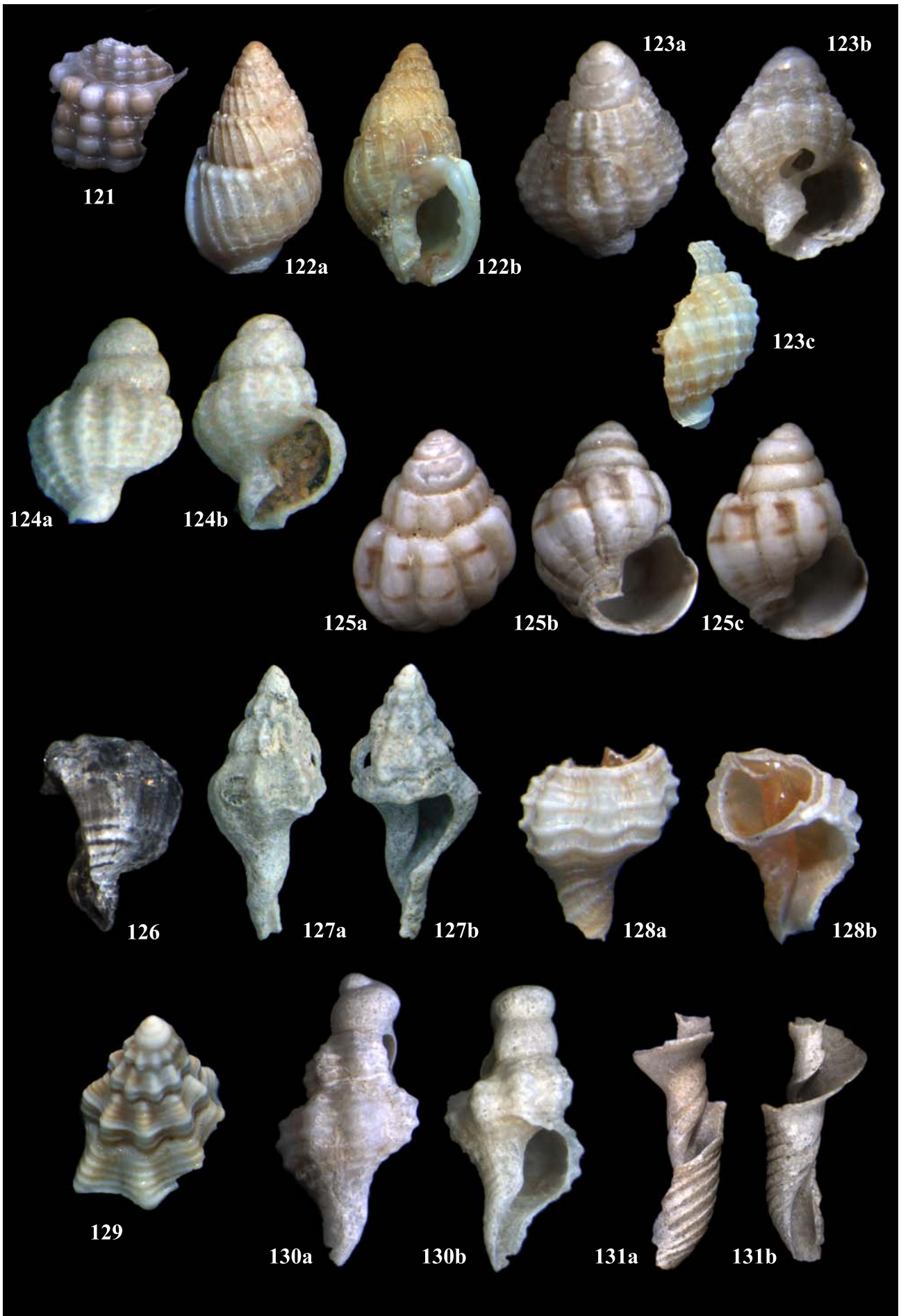


PLATE 12

Muricoidea

132. Fusinidae sp.1 NAVY50top [1.5 mm]
133. Fusinidae sp.2 NAVY50top [2 mm]
134. Fusinidae sp.3 NAVY50top [2 mm]
135. *Fusinus* NAVY50bottom [2.5 mm]
136. *Fusinus* sp.1-FF90bottom [2.5 mm]
137. *Fusinus* sp.2-FF90bottom [3 mm]
138. *Fusinus* sp.3-FF90bottom [13 mm]
139. *Fusinus* sp.4-FF90bottom [2.5 mm]
140. *Fusinus* sp.3- MAR50top [8 mm]
141. *Latirus* sp. [2.5 mm]
142. *Ancilla* sp. [2 mm]
143. *Granulina* sp. [2 mm]
144. *Mitra* sp. [2 mm]

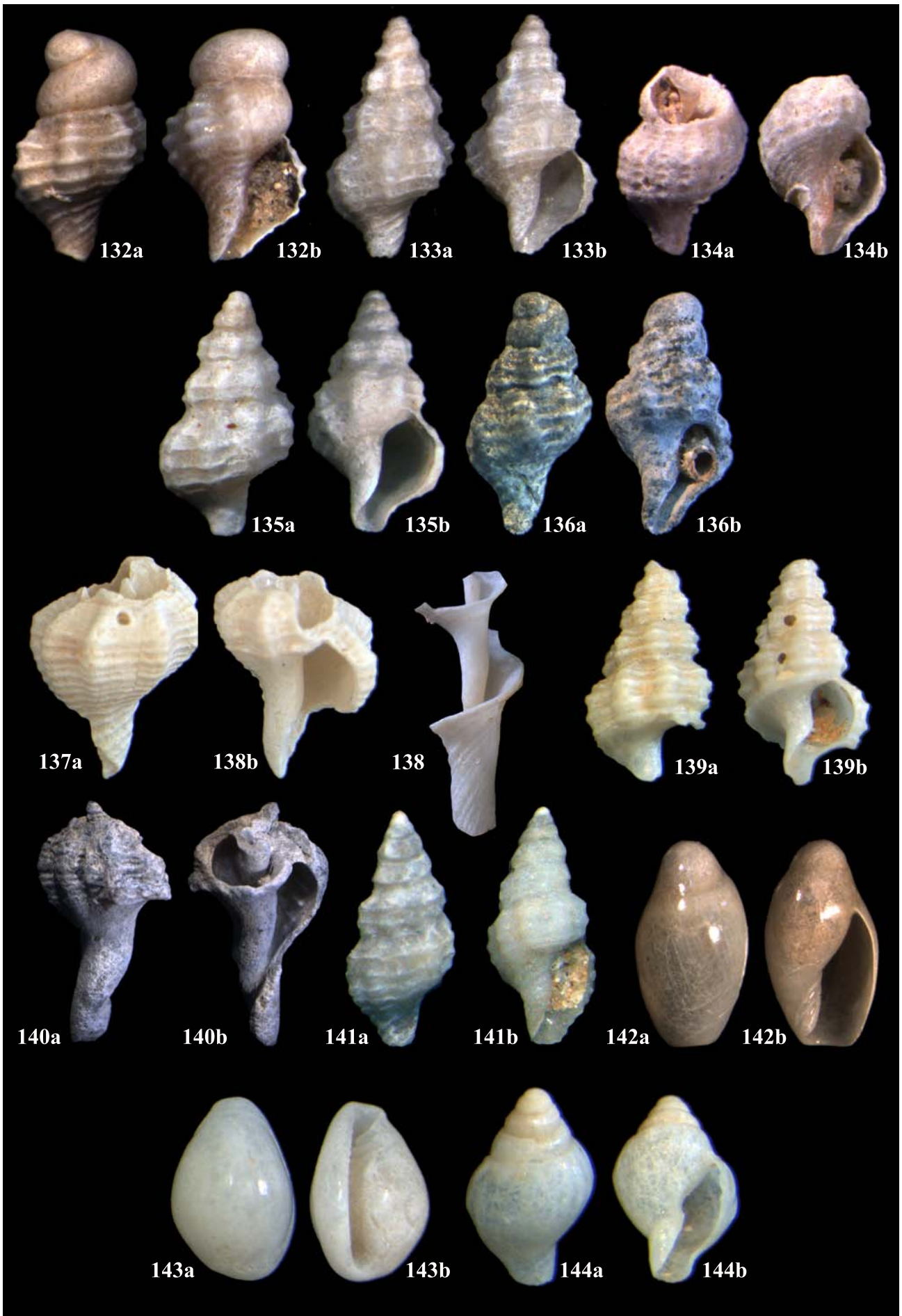


PLATE 13

Muricoidea

145. *Domiporta* sp. [2.5 mm]
146. *Neocancilla circula* (Kiener, 1838) [3 mm]
147. *Costellaria* cf. *malcolmensis* (Melvill & Standen, 1901) [5 mm]
148. *Costellaria* sp.1 [3.5 mm]
149. *Costellaria* sp.2 [4 mm]
150. *Costellaria* sp.3 [3 mm]
151. *Costellaria* large MAR50top [8 mm]
152. *Costellaria* sp.4 MAR50top [4 mm]
153. *Costellaria* BIUV40bottom [6.5 mm]
154. Costelloridae sp.3 [2 mm]

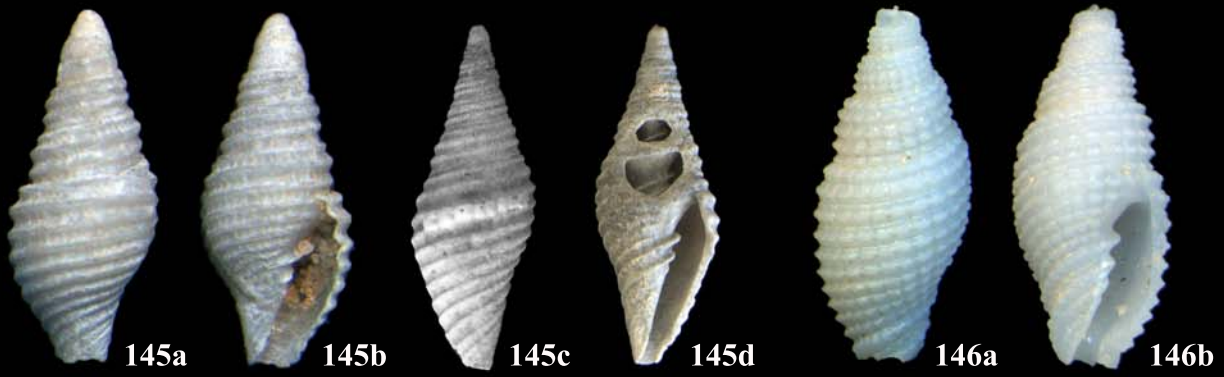


PLATE 14

Muricoidea

- 155. Costellaridae/Mytridae? MAR50top [5.5 mm]
- 156. *Vexillum* sp.1 [2.5 mm]
- 157. *Vexillum* sp.3 [4 mm]

Cancellarioidea

- 158. *Tritonoharpa antiquate* (Reeve, 1844) [2.5 mm]

Conoidea

- 159. *Conus* sp. [4 mm]
- 160. *Conus acutangulus* Lamarck, 1810 [3 mm]
- 161. Turridae sp.6-FF50Btop [3 mm]
- 162. Turridae sp.1-FF50Btop [3 mm]
- 163. Turridae sp.3-FF50Btop [2.5 mm]
- 164. Turridae sp. (cf. 2 FF90bot) [2 mm]
- 165. Turridae sp.10-FF50Bbot [4 mm]
- 166. Turridae sp.1-FF50Bbot [3 mm]
- 167. Turridae sp.3-FF50Bbot [2 mm]
- 168. Turridae sp. 3 FF90top [2.5 mm]
- 169. Turridae sp.1-FF90bottom [3.5 mm]
- 170. Turridae sp.3-FF90bottom [5 mm]
- 171. Turridae sp.22 [4 mm]



PLATE 15

Conoidea

172. Turridae sp.5-FF90bottom [3.5 mm]
173. Turridae sp.6-FF90bottom [3 mm]
174. Turridae sp.8-FF90bottom [2.5 mm]
175. Turridae sp.1 NAVY50top [3 mm]
176. Turridae sp. 6 [3 mm]
177. Turridae sp.3 NAVY50top [2 mm]
178. Turridae sp.5 NAVY50top [2.5 mm]
179. Turridae sp.7 NAVY50top [3 mm]
180. Turridae sp.8 NAVY50top [2 mm]
181. Turridae sp.1 NAVY50bottom [3 mm]
182. Turridae sp.2 NAVY50bottom [2.5 mm]
183. Turridae sp.3 NAVY50bottom [3 mm]
184. Turridae sp. 8 [2 mm]
185. Turridae sp.1-MAR50top [3 mm]
186. Turridae sp.3MAR50top(2mm) [2 mm]

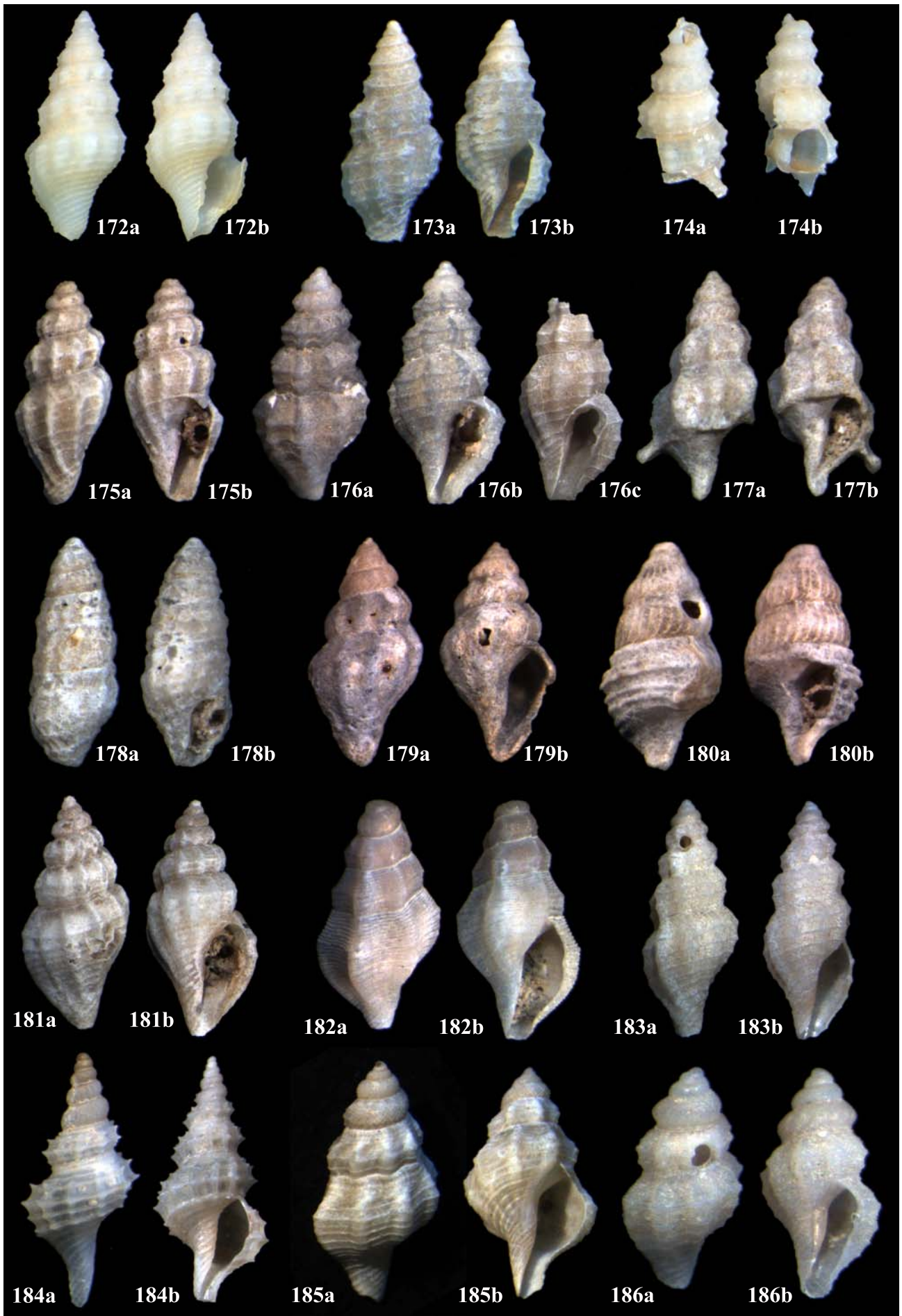


PLATE 16

Conoidea

187. Turridae sp.4-MAR50top [2.5 mm]
188. Turridae sp.5-MAR50top [4 mm]
189. Turridae sp.6-MAR50top [2.5 mm]
190. Turridae sp.7-MAR50top [3.5 mm]
191. Turridae sp.8-MAR50top [3 mm]
192. Turridae sp.9-MAR50top [2.5 mm]
193. Turridae sp.10-MAR50top [2 mm]
194. Turridae/Fusinidae? [2.5 mm]
195. ?Turridae FF90bot [2.5 mm]
196. Turridae MAR70top(cf. NAVY50top) [3.5 mm]
197. Turridae sp.2 MAR70top [3 mm]
198. Turridae sp.3 MAR70top [3.5 mm]
199. Turridae sp.4 MAR70top [5 mm]
200. Turridae sp.5 MAR70top [2 mm]
201. Turridae sp.5 BIUV40bottom [1.5 mm]
202. Turridae sp.6 BIUV40bottom [2.5 mm]

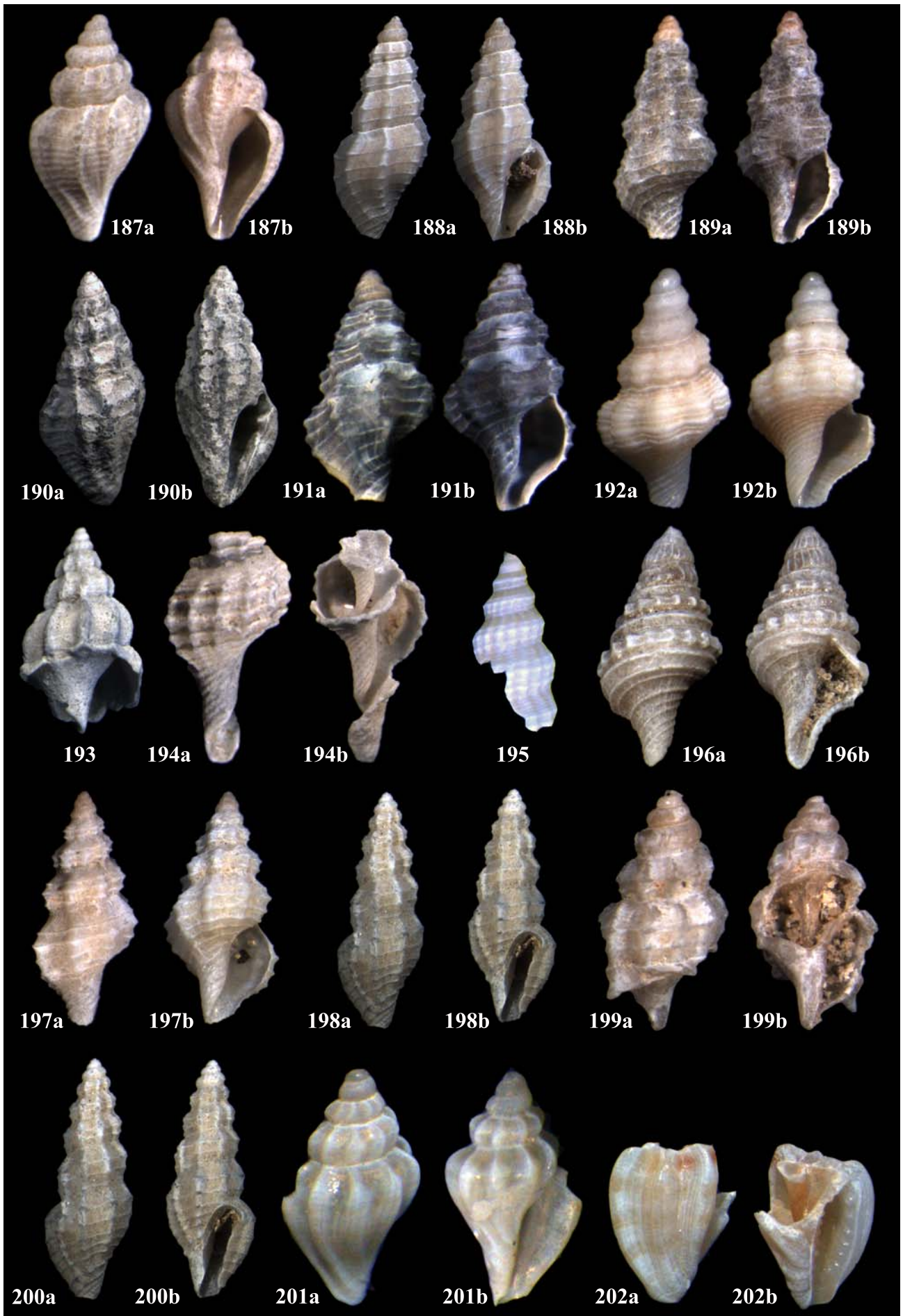


PLATE 17

Conoidea

203. Turridae sp. 18 [2.5 mm]
204. Turridae sp. 21 [3 mm]
205. Turridae sp. 10 [4 mm]
206. Turridae sp. 11 [2.5 mm]
207. Turridae1 MAR70top (juvenile) [1.5 mm]
208. Turridae MAR50bot1 [3.5 mm]
209. Turridae sp.2 MAR50bot [2.5 mm]
210. Turridae sp.1 BIUV40top [3 mm]
211. Turridae sp.2 BIUV40top [3 mm]
212. Turridae sp.3 BIUV40top [1.5 mm]
213. Turridae sp.4 BIUV40top [2 mm]
214. Turridae sp.3 BIUV40bottom [3.5 mm]
215. Turridae sp.4 BIUV40bottom [3.5 mm]
216. Turridae sp.40 [4 mm]
217. Turridae sp.4-FF90 bottom [3.5 mm]
218. Turridae sp.6 MAR70top [2 mm]

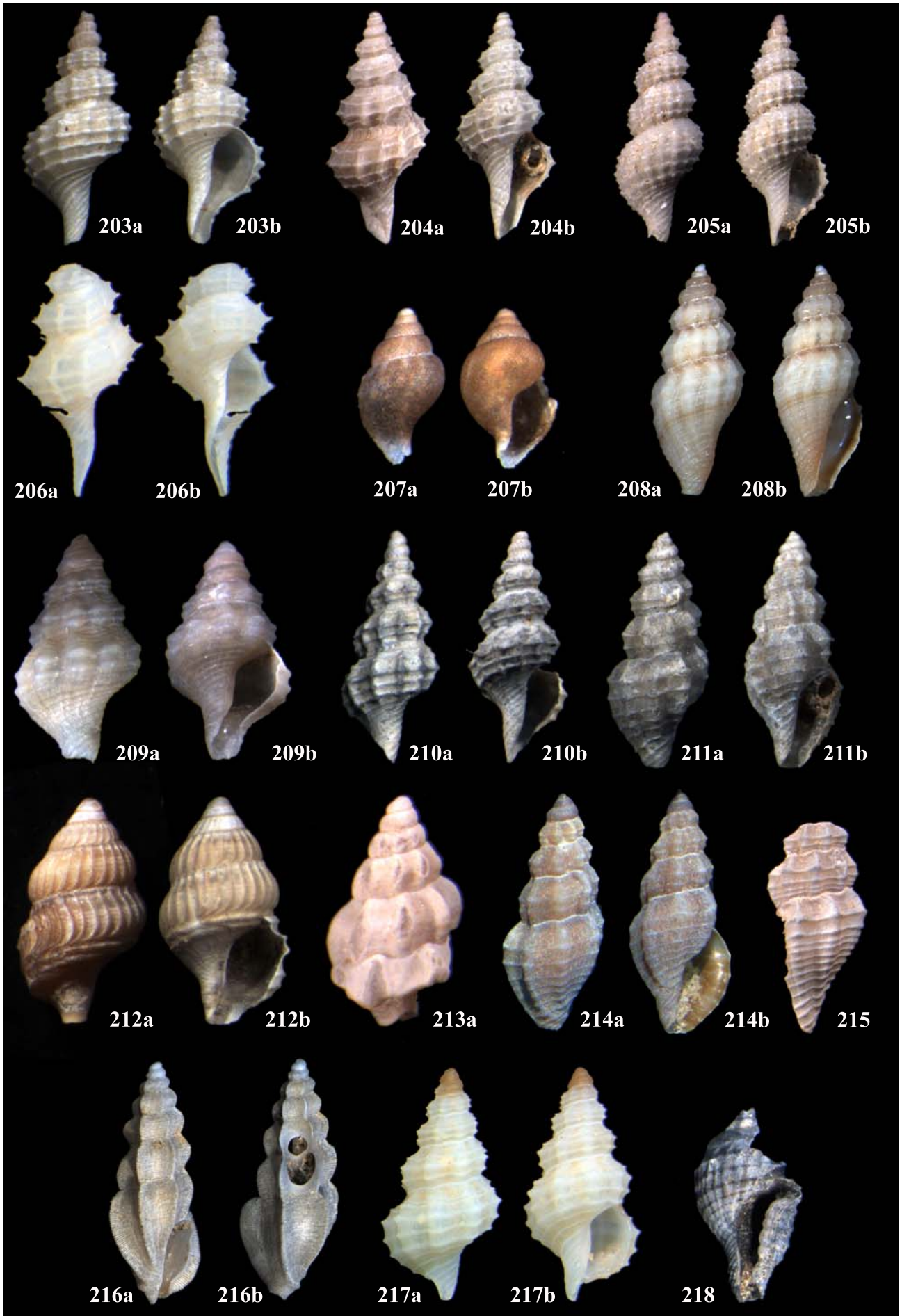


PLATE 18

Conoidea

- 219. *Terebra* sp. [3 mm]
- 220. *Eucithara* sp. [4 mm]
- 221. *Pseudorhaphitoma idolabiata* (Hornung & Mermod, 1928) [3 mm]

Architectonicoidea

- 222. *Heliacus implexus* (Mighels, 1845) [4 mm]
- 223. *Spirolaxis* sp. [1 mm]

Pyramidelloidea

- 224. *Chrysallida* sp. 1 NAVY50bottom [2 mm]
- 225. *Chrysallida* sp.2 BIUV40bottom [2 mm]
- 226. *Miralda noduslosa* (Hornung & Mermod, 1924) [2 mm]
- 227. *Odostomia* sp. [2.5 mm]
- 228. *Syrnola* sp.2 [2 mm]
- 229. *Syrnola* sp. [2.5 mm]
- 230. *Tiberia fasciata* (Jickeli, 1882) [1.5 mm]
- 231. Pyramidellidae sp.1 FF50Btop [3 mm]
- 232. Pyramidellidae sp.3 FF50Bbot [5 mm]

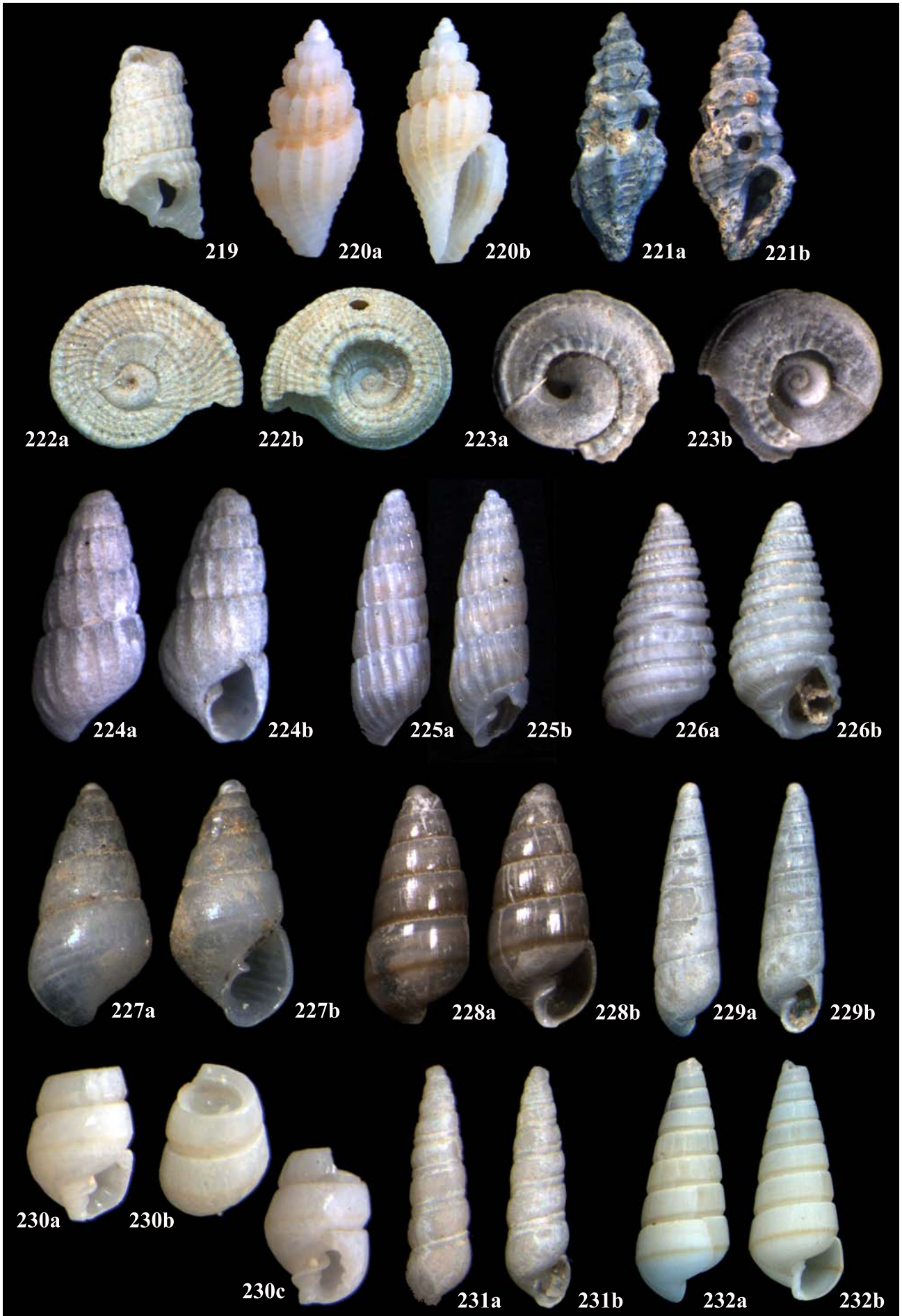


PLATE 19

Pyramidelloidea

- 233. Pyramidellinae sp. FF90bot [3 mm]
- 234. Pyramidellidae NAVY50bottom [2.5 mm]
- 235. Pyramidellidae sp. MAR70top [2.5 mm]
- 236. *Turbonilla nitidissima* Issel, 1869 [3 mm]
- 237. *Turbonilla* sp. 3 FF90bot (MAR70top) [3.5 mm]
- 238. *Turbonilla* sp.1 FF90bot [3 mm]
- 239. *Turbonilla* sp.4-FF50Btop [2.5 mm]
- 240. *Turbonilla* sp.2 FF90bot [2.5 mm]
- 241. *Turbonilla* sp.4 MAR50top [3 mm]
- 242. *Turbonilla* sp.4 FF90bot [3 mm]
- 243. *Leucotina* sp. [3 mm]

Philinoidea

- 244. *Acteocina inconspicua* (H. Adams, 1872) [2.5 mm]
- 245. *Pupa affinis* (A. Adams, 1854) [2.5 mm]
- 246. *Atys angustatus* Smith, 1872 [2.5 mm]
- 247. *Weinkauffia* Monterosato, 1884 [3 mm]



233



234a



234b



235a



235b



236a



236b



237a



237b



238a



238b



239a



239b



240a



240b



241a



241b



242a



242b



243a



243b



244a



244b



245a



245b



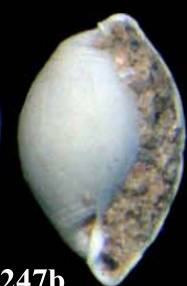
246a



246b



247a



247b

PLATE 20

Philinoidea

248. *Philine vaillanti* Issel, 1869 [3.5 mm]
249. Philinoidea [4 mm]
250. *Cylichnia* sp.1 [2.5 mm]
251. *Cylichnia* sp.2 [2.5 mm]
252. *Cylichnia* sp.3 [3 mm]
253. *Cylichnia* sp.4 [2 mm]
254. *Eocylichna villersii* (Audouin, 1826) [2.5 mm]
255. *Retusa desgenettii* (Audouin, 1826) [2.5 mm]
256. *Retusa tarutana* Smyth, 1979 [3 mm]
257. *Rhizorus* sp. [2.5 mm]
258. *Ventomnestia girardi* (Audouin, 1826) [3 mm]
259. *Ringicula acuta* Philippi, 1849 [2 mm]
260. *Ringicula minuta* H. Adams 1872 [2 mm]



248



249



250a



250b



250c



251a



251b



252a



252b



253a



253b



254a



254b



255a



255b



256a



256b



257a



257b



258a



258b



259a



259b



260a



260b

PLATE 21

Unidentified

261. unidentified 1 NAVY50top [4 mm]
262. unidentified 2 NAVY50top [2.5 mm]
263. unidentified 3 NAVY50top [2.5 mm]
264. unidentified 4 NAVY50top [3.5 mm]
265. unidentified 5 NAVY50top [4 mm]
266. unidentified sp.1 FF50Bbot [3 mm]
267. unidentified sp.10 MAR50top [2 mm]
268. unidentified sp.11 MAR50top [4 mm]
269. unidentified sp.12 MAR50top [2.5 mm]
270. unidentified BIUV20Btop [2.5 mm]
271. unidentified BIUV40bottom [2.5 mm]
272. gastropod unknown 1 FF70top [5 mm]



261



262a



262b



263a



263b



264a



264b



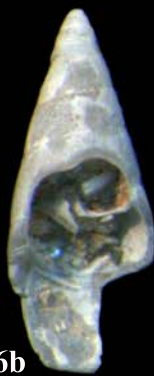
265a



265b



266a



266b



268a



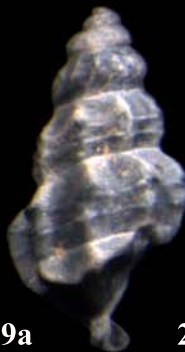
268b



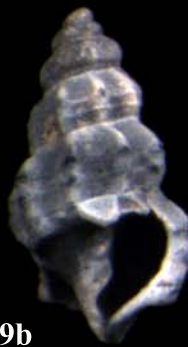
268c



267a



269a



269b



270



271a



271b



272a



272b

תודות

ברצוני להודות לדר' הנק מינס אחראי אוסף לאומי מולוסקה מהאוניברסיטה העברית על עזרתו וסבלנותו ועל הזמן הרב שהשקיע בזיהוי המאובנים.

תודה לדר' אהובה אלמוגי-לבין על עזרתה הרבה בדיגום הסדימנטים, בשיחות מועילות ובביקורת בונה.

תודה לצוות הטכנאים הנפלא של המכון הגיאולוגי ולצוות הנפלא של המכון הבינאוניברסיטאי למדעי הים באילת על עזרתם בדיגום הסדימנטים.

תודה למיכאל קיטין ואריק וולפבוסקי מהמעבדה הפלאונטולוגית על עזרתם בהכנת הדוגמאות לאנליזה.

תודה לחנה נצר-כהן, לבת-שבע כהן ונילי אלמוג על עזרתם בהכנת הדו"ח ו-PLATES.

כלובי הדגים, יש הבדל מובהק בין מאסף התמותה של הרכיכות בסדימנטים של פני השטח לעומת הסדימנטים, הבלתי מופרים בעומק.

מאסף מגוון ביותר של רכיכות מאפיין את הסדימנטים החוליים בעומקי מים שבין 20 ל-100 מטר ועד כה זוהו 272 מינים של שבלולים ו-124 מינים של צדפות. זיהוי המינים מלווה בעבודה זו בתצלומים איכותיים, דבר היוצר את התיעוד הנרחב ביותר הקיים עד כה, של הרכיכות של הקרקעית החולית של צפון מפרץ אילת. רקורד מפורט זה יוצר לראשונה תשתית מדעית שתאפשר בעתיד ביצוע מחקרים אקולוגיים נוספים על קבוצה זו באזור זה.

תקציר

המערכת האקולוגית של צפון מפרץ אילת נתונה מזה זמן להפרעות שונות מעשה ידי אדם המתבטאות בעיקר בירידה בתפקוד שוניות האלמוגים, בפריחות חריגות של הפיטו- והזואופלנקטון ובשינויים במבנה הבנתוס. אחראיים לכך בעיקר השילוב של ההידרוגרפיה הייחודית של צפון המפרץ יחד עם הגברת הלחץ האנטרופוגני המתבטא בין השאר בעלייה נכרת בשטף הנוטרינטיים. מרכיב מרכזי במערכת האקולוגית של צפון מפרץ אילת שטרם נבדק כראוי הוא קרקעית הים והיא בבחינת "החוליה החסרה" במערכת האקולוגית של מפרץ אילת הצוברת עדויות לתהליכים החלים במערכת זו לאורך זמן ובעיקר ב 30-50 השנים האחרונות. על רקע זה החלה לאחרונה עבודת מחקר נרחבת על קרקעית המפרץ העוסקת בבחינת ההשפעות הסביבתיות על המערכת האקולוגית הבנתונית בכללותה. אחת ממטרות המחקר היא לפתח מדדים לזיהוי התנאים הטבעיים של המערכת (baseline) לעומת המצב המופר הקיים בהווה תוך ניסיון לאתר את הגורמים לשינויים האקולוגיים והשפעתם לאורך זמן. מידע זה יסייע לחשיבה סביבתית נכונה אשר תאפשר שמירה טובה ויעילה יותר של משאבי הטבע והים והוא יהווה בסיס למערכת בקרה (ניטור סביבתי) ומשוב לצורך נקיטת פעילות מתקנת ומונעת.

בסדימנטים של קרקעית הים צפויים להישמר בין השאר עדויות להרכב ולנפיצות המאקרופאונה הגירית לפני ולאחר התערבות האדם באזור. ההרכב ונפיצות הרכיכות, אשר שלדיהם נשמרים היטב בסדימנטים, מתעדים את השינויים שחלו במהלך השנים במפרץ והם מהווים סמנים רגישים לשינויים בתנאי הסביבה. מאספי תמותה ממצעים שינויים אקולוגיים קצרי-טווח כמו שינויים עונתיים, עונות רביה והופעת מינים נדירים במאסף. הסתכלות על מאספי תמותה של רכיכות מאפשרת קבלת תמונה אקולוגית מלאה וכוללנית יותר מאשר מתקבל בדיגום ביולוגי. בנוסף לכך, רכיכות מספקות מידע חשוב על עומקי המים הרדודים ועומקי הביניים שהם האזורים העיקריים שנפגעים מהשינויים האנטרופוגניים.

במהלך מחקר זה נדגמו 47 תחנות. דו"ח זה מתמקד ב 16 דוגמאות של מאספי תמותה של רכיכות שנלקחו ב 8 תחנות מעומקי מים של 20-100 מטר מצפון מפרץ אילת באמצעות מחפרון סדימנטים בעל שטח פנים של 20 סמ"ר (SEDIMENT GRAB). בכל תחנה נבדקה דוגמת הסדימנט העליונה ביותר (2-0 ס"מ) והעמוקה ביותר (2 ס"מ תחתונים) ונערכה השוואה בין מאפייני הפאונה בדוגמאות אלו. בין השאר נקבעו בדוגמאות אלו מדדי מגוון המינים, מבנה החברה וטיב השימור. בנוסף לכך הוצאו 2 גלעינים קצרים מעומק מים של 50 ו- 70 מ' לצורך קביעת קצבי הסדימנטציה בשיטת עופרת 210.

על פי התוצאות הראשונות של תיארוך הסדימנטים, קצב הסדימנטציה נע בין 0.37-0.66 ס"מ/שנה. לפיכך דוגמאות הסדימנט העליונות מייצגות את 4-6 השנים האחרונות בעוד שהסדימנטים בעומק מייצגים את טווח הזמן שבין 32 עד 50 שנה לפני ההווה. מצב שימור קשוות הצדפות משתנה מקשוות במצב שימור מעולה (שלמות, ללא צמידה) לקשוות במצב שימור גרוע (קשוות נבורות עם צמידה).

נפיצות ומגוון הרכיכות אפשרו את חלוקת המינים לארבעה מאספים טיפוסיים תלויי עומק מים. מבדיקת הדוגמאות עולה כי השינויים הסביבתיים שקרו בעשרות השנים האחרונות במפרץ אילת לא השאירו את חותמם על מבנה חברת הרכיכות ולא חל כל שינוי בהרכבם ובמאפיינים האקולוגיים שלהם. יחד עם זאת, תוצאות ביניים מראות שבעומק מים של 50 מטר, באזור בו פעלו עד לאחרונה



משרד התשתיות הלאומיות
המכון הגיאולוגי

הרכיכות של מפרץ אילת: עדויות לשינויים סביבתיים

יעל אדלמן-פורסטנברג וגלינה פיירשטיין