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ScienceDirect
Estuarine, Coastal and Shelf Science 71 (2007) 170–180
ESTUARINE COASTAL AND SHELF SCIENCE
www.elsevier.com/locate/ecss

A descriptive account of benthic macrofauna and sediment from an area of planned petroleum exploration in the southern Caspian Sea

T.D. Parr [a], R.D. Tait [b,*], C.L. Maxon [c], F.C. Newton III [d], J.L. Hardin [d]

[a] *Terry Parr Environmental Consulting Services, 7924 Grape Street, La Mesa, CA 91924, USA*
[b] *ExxonMobil Upstream Research Company, 3 Greenway Plaza, Houston, TX 77027, USA*
[c] *Maxon Consulting, 2546 San Clemente Terrace, San Diego, CA 92122, USA*
[d] *Battelle, 5205 Avenida Encinas, Suite J, Carlsbad, CA 92008, USA*

Received 18 April 2006; accepted 24 July 2006
Available online 11 September 2006

Abstract

As a precursor to petroleum exploration and potential development in the offshore southern Caspian Sea, sediment was collected from 42 stations (67–692 m water depths) and analyzed for grain size, total organic carbon, and species abundance, diversity, and biomass of benthic macrofauna. Sediment ranged from very fine sands to very fine silts, with moderately enriched organic carbon levels (avg. 2.3%). A significant positive correlation between finer grain size, organic carbon, and water depth was evident. The macrofauna was numerically dominated by annelid worms (44% of total organisms), crustaceans (37%), and molluscs (18%). Of 71 species identified, the greatest diversity was represented by two crustacean orders (22 amphipod species, 11 cumacean species), 14 gastropod mollusc species, and six oligochaete worm species. Except for annelids, all major taxa exhibited significant decline in abundance, species density, and biomass with increasing water depth. Low species dominance and abundance characterized deeper stations, indicating stressed habitat from hypoxia/anoxia at the sediment–water boundary. Petroleum exploration and development at slope depths greater than 150 m should have relatively little impact upon a macrofauna that is naturally impoverished due to oxygen deficiency. Shelf depths (<150 m) are not oxygen limited and support a more diverse macrofaunal community, which could be more vulnerable to discharged cuttings and adhered drilling muds, but able to recover more quickly than deeper biota.

Keywords: Caspian Sea; benthic macrofauna; hypoxia; anoxia; petroleum exploration

1. Introduction

This report presents results of an environmental study conducted in August 1998 to document baseline conditions for assessment of potential impacts of planned petroleum exploration in the offshore Nakhchivan oil and gas exploration Contract Area of the south Caspian Sea, located 90 km south of Baku, Azerbaijan (Fig. 1).

The deep sediment of the southern basin of the Caspian Sea contains potentially large reserves of producing and undiscovered oil and natural gas deposits. The present study describes physical, chemical, and biological properties of sediment from 42 sampling stations (Fig. 1), located more than 50 km offshore at depths ranging from 67 to 692 m (avg. = 180 m) over one of the potential deposits (Nakhchivan). Sediment physical properties control such biologically meaningful variables as porosity, compaction, adsorption of organic matter, porewater chemistry, and microbial activity. Benthic macrofauna are effective sentinel organisms for monitoring point source pollutants and broader regional impacts because of their relative immobility, sensitivity to physical–chemical changes in sediment, and their typically short life spans (Gray et al., 1990; Olsgard and Gray, 1995; Peterson et al., 1996). Petroleum production can impact benthic populations as a result of discharge and seafloor deposition of drilling cuttings and associated muds, and chronic low level

* Corresponding author.
E-mail addresses: terparr@cox.net (T.D. Parr), russell.d.tait@exxonmobil.com (R.D. Tait), maxonc@san.rr.com (C.L. Maxon), newtonf@battelle.org (F.C. Newton), hardinj@battelle.org (J.L. Hardin).

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doi:10.1016/j.ecss.2006.07.018

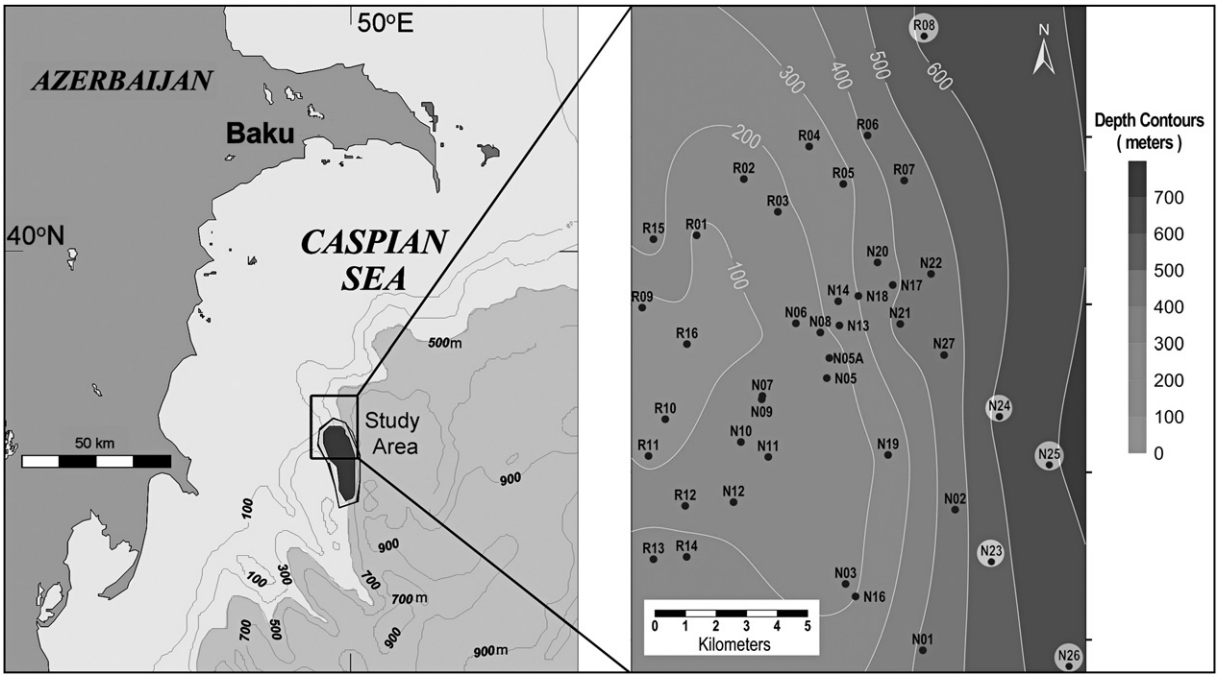

Fig. 1. Nakhchivan study area (left), and sediment and water sampling stations with bathymetry (right) in the southern Caspian Sea.

release of hydrocarbons (Gray, 1995; Peterson et al., 1996). Documented long term effects from discharged cuttings include smothering and organic enrichment of sediment, and toxicity from heavy metals and hydrocarbons. Depending on water depth and hydrodynamic conditions, discernible gradient effects around oil and gas platforms typically extend from a few hundred meters to a distance of 3 km (Olsgard and Gray, 1995; Peterson et al., 1996).

Four depth strata were selected for analysis: a shallow stratum (<150 m), representing Caspian outer shelf depths that have been characterized as having greater biological diversity and biomass (Karpinsky, 1992), and three successive strata of 150–250 m, >250–400 m and >400 m, delineated to encompass specific assessment areas where exploration drilling and development could occur. Stations were sampled for species composition, abundance, biomass, sediment grain size and total organic carbon (TOC). Sediment hydrocarbons also were analyzed and results are presented in Tait et al. (2004).

2. Environmental setting

The Caspian Sea is 1207 km in length and is the largest landlocked water body on earth, containing 40% of the earth's continental water mass (Dumont, 1998). Sea salinities presently range from 1 to 7 in the northern Volga River delta region, grading to 10–14 in the middle and deeper southern basins. The latter, with an average depth of 325 m and maximum depth of 1025 m, contains 65% of the sea volume and is separated from northern and central basins by the Apsheron Bank, extending from the Apsheron Peninsula (Fig. 1). The Caspian Sea has been a lacustrine brackish water body for at least the past five million years, with repeated salinity fluctuations resulting from vicissitudes of evaporation and freshwater inflow, including glacial melt. Adaptive radiation in the benthos has produced wide salinity tolerances amongst species flocks within a few ancestral lineages, notably gammarid amphipod, mysid, and cumacean groups within the Crustacea, and cardiid and pyrgulid families of molluscs. Nearly 400 Caspian benthic species have been described (Kosarev and Yablonskaya, 1994) and the majority are endemic (Dumont, 2000). The geographic isolation of the Caspian Sea is now in the process of rapid change, as euryhaline species from the Black Sea and the Sea of Azov are now being introduced by shipping activities (e.g., through the Volga–Don canal, which opened in 1954, Grigorovich et al., 2003). The south Caspian basin has been categorized as persistently hypoxic (<2 ml L^{-1} dissolved oxygen) at moderate to severe levels (Diaz and Rosenberg, 1995). At present, surface salinities are around 11, the upper water column is density stratified in the summer, and oxygenation of deep waters persists due to sluggish convective mixing in the winter as surface temperatures cool (Dumont, 1998). Complete mixing seldom extends to the seafloor and hypoxia is common at depths greater than 300 m. Macrofaunal populations are typically impaired (reduced diversity and biomass) under hypoxia (Rosenberg et al., 1991; Ritter and Montagna, 1999).

During a period of increased freshwater input from the Volga River in the early 20th century, the sea level was elevated and the water column remained stratified throughout the year. Bottom waters stagnated and became anoxic, accompanied by buildup of sulfides in sediment with concomitant elimination of deepwater macrofauna (Zenkevich, 1963). Dumont (1998) has suggested that prolonged past anoxic episodes have prevented the evolution and establishment of a well-developed deepwater fauna. A large carbon-rich sediment overburden typifies the entire south Caspian Basin.