Assessing extent and impact of ship-transported alien species in the Black Sea

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Enclosed or semi enclosed ecosystems, as the Black Sea, seem particularly sensitive to two modern anthropogenic impacts: eutrophication and biological invasions. Whilst the Black Sea was known as an oligotrophic sea in the 1940s, it became progressively mesotrophic and eutrophic in the 1980s and 1990s. With the increased shipping traffic, the Black Sea has become an important recipient (and donor) region for ship-transported invasive species.

According to Zaitsev and Ozturk (2001), there are 59 species of invasive marine organisms in the Black Sea, not taking into account the temporary planktonic fauna (mostly brought in with the deep current from the Marmara Sea) that may be present in significant numbers (Kovalev *et al.*, 1998a). As seen in Figure 1, the rate of introductions increase, particularly in the last decade.

Many of these introductions, as in the case of several species of copepods (Kovalev *et al.*, 1998a), have gone unnoticed however, the impact of others is unforgettable. Here I present the three most important invasions in the Black Sea: the ctenophores *Beroe ovata* Bruguière, 1789, and *Mnemiopsis leidyi* A.Agassiz 1865, and the gastropod *Rapana venosa* (Valenciennes, 1846) (synonym *R. thomasiana* Crosse, 1861). One might label them "the good, the bad and the ugly".

The original distribution of the veined Rapa whelk, *Rapana venosa* ("the ugly") is the temperate Sea of Japan, Yellow Sea and East China Sea (CIESM Atlas <http://www.ciesm.org/atlas/Rapanavenosa.html>). The whelk was first reported in the Novorossisk Bay in 1946 (Drapkin,

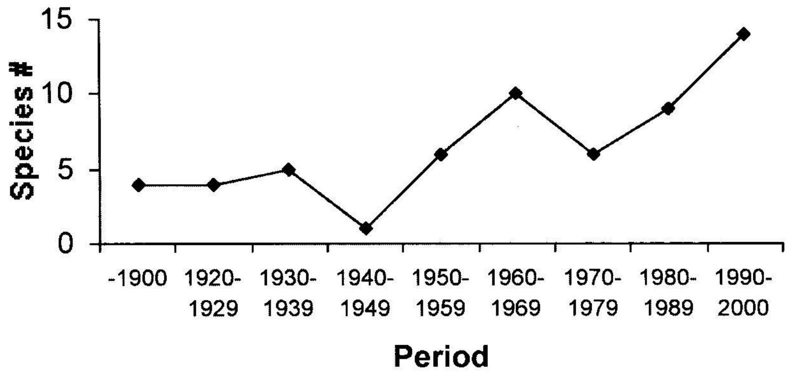

Fig. 1. Number of introduced species in the Black Sea through the 20th century (extracted from Zaitsev and Öztürk, 2001)

1953, cited in Zaitsev and Öztürk, 2001). Its shell is commonly less than 12 cm long in the Black Sea. From June to October it produces egg capsules that are fixed to subtidal hard surfaces (Karayücel *et al.*, 2001). The larvae hatch after 12-17 days and remain 14-17 days in the plankton before settling. It has been speculated that the planktonic larvae have arrived in ballast water, but it is more likely that egg masses have been transported either with the products of marine farming or as fouling on the hull of ships. Adults of *R. venosa* feed mainly on mussels, oysters and other bivalves. It is reported to adversely affect the main native bivalves including the oyster *Ostrea edulis*, the scallop *Pecten ponticus* and the mussel *Mytilus galloprovincialis* in many regions of the Black Sea. It is believed to deplete Gudauta oyster bank on the Caucasus shelf (Chukhchin, 1984, cited in Zaitsev and Öztürk, 2001). The whelk has no predator in the Black Sea. A commercially significant harvest has been developed since 1980s by several riparian nations for export, mainly to Japan and Korea. The Turkish catch was around 10,000 tons (without the shell) in 1988 and 1989, but decreased thereafter below 4,000 tons and in 1995 was only 1,198 tons. Since 1997 the annual catch increased again to around 4,000 tons, valued at around two million US Dollars (Zaitsev and Öztürk, 2001) (Fig. 2). On the Turkish Black Sea coast alone, there are 11 factories processing whelk's meat for export.

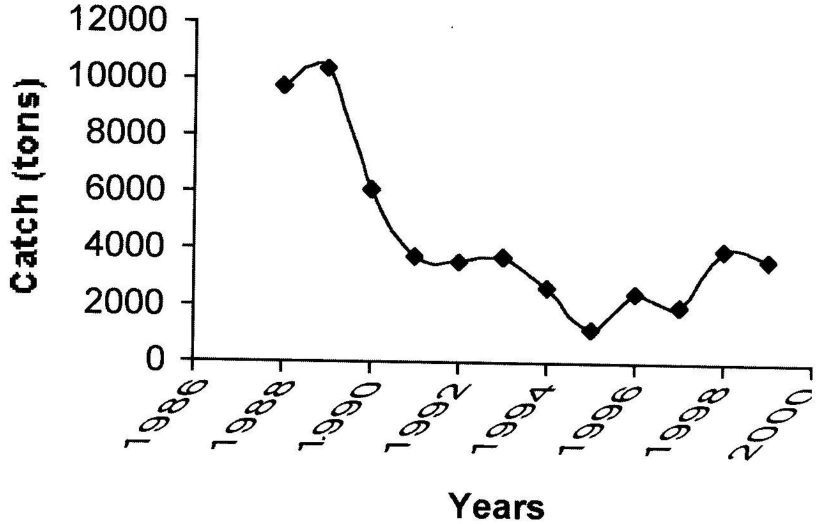

Fig. 2. Catch of the Rapa whelk *Rapana venosa* from Turkish waters (almost all from the Black Sea) (DIE, 1985-99).

The accidental introduction of the ctenophore *Mnemiopsis leidyi* (comb-jelly, "the bad") from the eastern coast of America into the Black Sea via ballast waters in the early 1980s caused unprecedented large-scale ecosystem change. After reaching astounding biomass levels of over 1 kg m^{-2} in the summer of 1989 (Vinogradov *et al.*, 1989), this voracious zooplankton predator devastated the entire basin. Following the ctenophore bloom, sharp decreases were reported by all riparian countries in the landings of the major planktivorous fish (i.e. the anchovy, see Fig. 3) (Kideys, 1994). At the height of *Mnemiopsis* impact, the metrics of landed fish resembled those resulting from overfishing, though fishermen landed fewer fish. The collapse of the pelagic fishery followed a decrease in non-gelatinous zooplankton biomass in all regions (including the deep and eastern Black Sea, Kovalev *et al.*, 1998b) resulting from predation by *Mnemiopsis*. The levels of non-gelatinous zooplankton remained low for several years. A modest increase in non-gelatinous zooplankton was observed in 1994, followed the next year by a secondary increase in *Mnemiopsis* populations. Prior to the mass appearance of *Mnemiopsis*, anchovy was the major consumer of non-gelatinous zooplankton. By feeding on the food, as well as the eggs and larvae, of anchovy, *Mnemiopsis* was responsible for the collapse of the pelagic fisheries (Tsikhon-Lukashina *et al.*, 1991). The economic damage to the Turkish fishery alone is conservatively estimated at several hundred million dollars.

By feeding on herbivorous zooplankton, *Mnemiopsis* brought about an increase in chlorophyll, phytoplankton biomass and primary productivity within the deep basin (Fig. 3). The high-

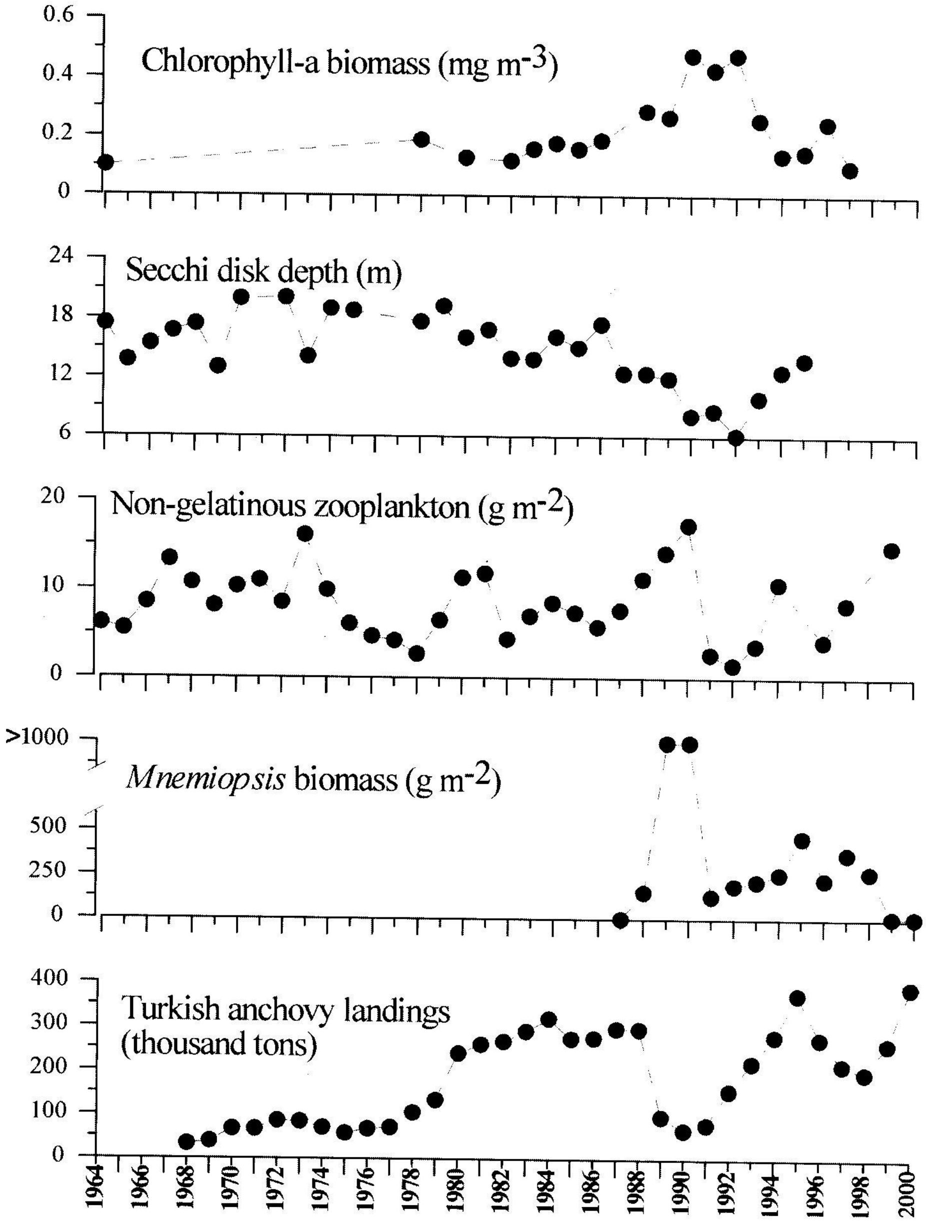

Fig. 3. Long-term variability for several eutrophication indices and the effects of the invading comb-jelly *Mnemiopsis* in the deep and eastern Black Sea (From Kideys, 2002).

est eutrophication indices for all regions of the Black Sea were reached in 1992, following peak biomass of *Mnemiopsis*. The total nutrient input via rivers stabilized or decreased by the mid 1980s. After 1992, eutrophication indices (surface chlorophyll and inorganic phosphate levels, water transparency, non-gelatinous zooplankton biomass and fish landings) improved in the deep and eastern Black Sea, indicating recovery, though *Mnemiopsis* was still present in significant biomass, though at much lower levels than previously (Fig. 3).

The appearance in 1997 of another alien ctenophore, *Beroe ovata* ("the good"), helped the ecosystem to recover further. *B. ovata*, possibly of northwestern Atlantic origin, feeds almost exclusively on *Mnemiopsis* (Finenko *et al.*, 2001). Since its appearance, the year-round abundance of *Mnemiopsis* in most regions has significantly decreased. High biomass levels of Mnemiopsis are now limited to a brief period in late summer (Finenko *et al.*, 2002), due to the effectiveness of its predator. Following the sharp decrease of *Mnemiopsis, Beroe* also almost disappears from the water column, indicating its dependence on *Mnemiopsis*. As a consequence of this biological control, increases were observed in non-gelatinous zooplankton, anchovy landings

(Kideys *et al.*, 2000, Fig. 3), and egg densities of this fish (Kideys *et al.*, 1999), along with increases in the biomass of two native schyphozoans (*Rhizostoma pulmo* and *Aurelia aurita*), particularly in summer 2001 (personal observation).

Eutrophication and invasive species are common problems in many regions of the world. *Mnemiopsis*, and to a certain degree, eutrophication, are present also in the neighbouring Caspian Sea. The Caspian Sea is comparable to the Black Sea in terms of surface area (about 400,000 km^2), low salinity (max. 13-14‰ in the southern part), and large catchment area (about 3.5 million km^2). It is mainly fed by a single large river (the Volga, providing 82% of total riverine inflow), supports a commercial fishery of small pelagic fish (the kilka, *Clupeonella* spp.) and has high endemism (Dumont, 1995). However, unlike the Black Sea, the Caspian Sea is landlocked. This characteristic renders the Caspian Sea even more susceptible to anthropogenic impacts, especially the effects of invasive species. *Mnemiopsis*, transported in ballast waters through the Volga-Don canal during the second half of the 1990s (Ivanov *et al.*, 2000), has already caused significant damage to the zooplankton (Shiganova *et al.*, 2001b) and the valuable kilka stocks (Kideys *et al.*, 2001). Some valuable or endemic species like the white sturgeon (*Huso huso*) and the endemic Caspian seal (*Phoca caspica*) which feed mainly on kilka are, at present, under serious threat due to this invasion. However, the effectiveness of de-eutrophication and biological control measures, even in a relatively large ecosystem as in the Black Sea, and over a comparatively short period, are an encouraging signal for the Caspian Sea and similar aquatic environments suffering from such catastrophic threats.

The invasive species in the Black Sea are instructive illustrations of "non-acceptable", "acceptable" and "desirable" invasions. The subsequent invasion of a successful natural predator of an ecologically or economically damaging invasive species may present a promising venue in dealing successfully with marine invasive species.

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