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Status of Fish and Shellfish Stocks

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ABSTRACT

Fisheries in the Adriatic Sea and Chesapeake Bay are heavily exploited, with some overfished. Adriatic landings fluctuated around 140,000 t year^{-1} from 1992 to 2002, increasing to ~185,000 t year^{-1} in 2016. Over the same period, Chesapeake landings decreased from ~350,000 to ~200,000 t year^{-1}, so that 2016 landings were roughly equivalent between systems. While Chesapeake landings per unit of the bay's surface area were three times higher than for the Adriatic, landings per unit phytoplankton production were one and a half times higher in the Adriatic. Although fish migrations from adjacent water bodies can affect harvests, landings per unit area may reflect the Chesapeake's higher phytoplankton production, while landings per unit phytoplankton production may reflect differences in the fraction of phytoplankton production deposited in the benthos. Adriatic fisheries exploit several small pelagic species, whereas only one Chesapeake fishery targets a pelagic species. Both regions harvest a variety of demersal species. Adriatic invertebrate fisheries involve a variety of crustaceans and mollusks but Chesapeake invertebrate fisheries target just one crustacean and three mollusk species. Coupled benthic–pelagic food webs are important ecologically in both systems, but food webs have become decoupled in the seasonally hypoxic mid-Chesapeake. Dams, coastal structures, sediment, altered river flows, and diminished water quality and habitat affect fishery species negatively. Management in both regions involves interagency collaboration and cooperative agreements.

10.1. INTRODUCTION

Fisheries have long played an important role as a source of livelihood for populations around the Adriatic Sea and the Chesapeake Bay. Fisheries in the eastern Adriatic date to 100–200 CE (Županović, 1997), with the earliest records of a fishing industry dating to 995 CE (Rački, 1877; Županović, 1997). Fisheries have also been important for local communities around Chesapeake Bay (CB), although the later settlement of the Chesapeake region by Europeans means that fishery records cover just a few centuries rather than millennia (Kennedy, 2018). We compare and contrast the major components of each system's fisheries, explain regional management structures and challenges, and briefly illustrate how anthropogenic changes in both regions affect their fisheries.

Management of multistate fisheries such as in the Adriatic and the Chesapeake involves data collection by federal and state agencies. Data for the Adriatic (FAO Area 37.2.1) are reported by the Food and Agricultural Organization (FAO) of the United Nations (UN). A further subdivision by the General Fisheries Council for the Mediterranean (GFCM) sorts the fisheries into two Geographical Sub-Areas (GSA): GSA 17 (northern and central Adriatic) and GSA 18 (southern Adriatic). Croatia,

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Bosnia-Herzegovina, Italy (NE coast), and Slovenia border GSA 17; Albania, Italy (SE coast), and Montenegro are included in GSA 18. When presenting data, we refer either to the FAO or the GFCM designation. Our Chesapeake data are from reports by the US National Oceanic and Atmospheric Administration (NOAA).

10.1.1. Adriatic Sea

With its moderate slope and soft sea bottom, the Adriatic continental shelf (most of which is in the northern Adriatic Sea (NAS)) is particularly well suited for trawling for demersal fish and dredging for clams. The bottom trawl fishery targets red mullet *Mullus barbatus*, European hake *Merluccius merluccius*, and Norway lobster *Nephrops norvegicus*. Coastal small-scale or artisanal fisheries (extending to 50 km from the shore or out to 200 m) also occur, and some countries land significant catches, e.g., Croatia landed 1991 t year^{-1} during 2000–2010. Recreational fisheries also are important in Croatia, where catches averaged 3150 t year^{-1} during 2000–2010.

The Adriatic Sea is one of the largest and best-defined regions of shared fish stocks in the Mediterranean, which makes shared management of fisheries essential in order to ensure sustainability of the fisheries. The Adriatic Sea is one of the most productive and most exploited regions in the Mediterranean. Although it has a small surface area (5.5% of the Mediterranean area), it yields ~15% of total Mediterranean catches

The fisheries sector is diverse, is largely made up of small-scale fisheries, and has an important role in many national economies. According to the European Fleet Register (2014), the Italian fishing fleet is composed of ~5000 motorized fishing boats, Croatia's fishing fleet includes just over 4000 vessels, and Slovenia's fleet consists of ~186 vessels. The largest percentage of the fleet (over 80%) is comprised of vessels shorter than 12 m, which also constitute the largest segment of the fleet capacity in terms of engine power as measured in kilowatts (i.e., ~50%). Fleet capacity as described either by number of vessels or fishing power varies widely among national fleets. Italy has the highest catches (79% of the total catch in tonnes (metric tons), t), followed by Croatia (16%), Albania (2.6%), Slovenia (2%), and Montenegro (0.3%). Currently, exploitation of fishery resources is heavy in the Adriatic, and although some stocks may be recovering, for others the situation remains critical. Conflicts with other sectors may arise, particularly with oil and gas developments, which could occupy large areas of the NAS in the next 20 years. Conflicts may also arise with the recreational fisheries sector and with the artisanal fishery sector, especially between different fishing-gear types.

Several factors have affected Adriatic fisheries, often interacting simultaneously. The population dynamics of fisheries are based not only on resource availability but are also strongly driven by market demand and prices and other socioeconomic forces such as political changes (e.g., Croatia's entry into the European Union (EU)). The main legislative framework influencing the sector is the Common Fisheries Policy (CFP), the EU instrument for the management of fisheries that sets the maximum quantities of fish that can be caught sustainably every year. National strategies (e.g., the National Strategic Plan for Development of Fisheries in Croatia) are also particularly important in shaping the future of commercial fisheries in the Adriatic.

The European Commission (EC) estimates that 88% of European stocks are overfished and 30% may not be able to replenish because they are outside safe biological limits (European Commission, 2009a). More recently, Froese et al. (2018) indicated 69% of the 397 European stocks were subject to ongoing overfishing and 51% were outside safe biological limits, while Colloca et al. (2017) indicated >90% of the Mediterranean stocks lie outside safe biological limits. These high fishing pressures not only affect the biological resources, but also have socioeconomic consequences. Overfishing, declines in the biomass and size of fish caught, low economic resilience, and fleet overcapacity inevitably debilitate the fishery sector (European Commission, 2009b). Colloca et al. (2013) demonstrated that the current fishing regime, characterized by high fishing mortality combined with inadequate selectivity patterns, compromises stock productivity and fleet profitability.

An analysis of Adriatic fishing effort on demersal fish during 1969–2013 highlighted three periods of effort (Bombace, 2017). During the first period (1969–1984) when fishing effort was in the range of 196,225–426,038 kW, catches increased and populations seemed to be in a steady state. A second period (1985–2003), when effort increased to 485,321 kW in 1991, was characterized by a continuous decline in catches and catch per unit effort. The last period (2004–2013) was also characterized by a negative trend in catches even though fishing effort declined to 305,061–207,800 kW. A small recovery in catches was observed in the last 2 years (2012–2013). A more detailed focus on the last period highlighted a strong reduction of demersal catches (Bolognini et al., 2017). Considering differences between 2004 and 2012 in GSA 17, the reduction was 11,009 t (42%) and €70,495 million (36%). Only the last years of this period showed a slight recovery in catches, especially for European hake, sole (*Solea solea*), and penaeid shrimp or prawn (*Penaeus kerathurus*).

10.1.2. Chesapeake Bay

When European explorers and colonists arrived in the Chesapeake region in the 1600s and 1700s, they were impressed by the abundance of fish and shellfish. One report described the seasonal entry of anadromous fish into CB as including large schools of American shad (*Alosa sapidissima)*, two species of river herring (*Alosa pseudoharengus* and *Alosa aestivalis*), and "multitudes" of Atlantic sturgeon *Acipenser oxyrinchus* (Whitaker, 1624). The two *Alosa* species supported an intense spring harvest of millions of fish over the next two centuries, until depressed catches led to the fisheries being closed near the end of the 20th century. Thus, in 1896 the annual shad harvest was ~7711 t but by 1980 it was ~454 t. The river herring harvest in CB was ~13,608 t in 1896 and, as for shad, ~454 t in 1980. Atlantic sturgeon landings in the mid-Atlantic region, including CB, have decreased to the point that the species is considered endangered and fishing is banned. The declines in landings for these four species were due mostly to overfishing and habitat degradation (ASMFC, 2007, 2012, 2017a).

For the eastern oyster, *Crassostrea virginica*, in the late 1800s, Chesapeake Bay was the greatest oyster-producing region of the world (Stevenson, 1894). In 1891–1892, Virginia's oyster harvest was about equal to that of the combined harvests of all foreign oyster-producing nations, and Maryland's harvest was twice that amount. Twenty percent of Americans in the US fishing industry (50,697 individuals) were involved in the CB oyster industry in 1891 (Smith, 1895). As with finfish, overharvesting and habitat destruction led to steady declines in landings and present-day oyster landings are about 3% of the 1891–1892 landings (NMFS, 2016).

10.2. RECENT FISHERIES YIELDS AND TRENDS

10.2.1. Adriatic Sea: Annual Catch Statistics

Total annual landings in FAO Area 37.2.1 (northern and central Adriatic, GFCM, 2018) fluctuated between 127,000 and 160,000 t from 1992 to 2013 and then increased to 185,000 t in 2016 (Figure 10.1). Italy accounted for most landings during this period, although landings in Croatia increased rapidly beginning in 2004. Four species accounted for 71% of the annual catch (2014–2016): sardines *Sardina pilchardus* (42%), anchovies *Engraulis encrasicolus* (19%), striped Venus clams *Chamelea gallina* (8%), and European hake (2%).

10.2.2. Chesapeake Bay: Annual Catch Statistics

From 1950 to 2016, total commercial catch in CB and the adjacent coastal ocean varied between 117,000 and 384,000 t annually, with a mean of 248,000 t (Figure 10.2). Commercial catch more than doubled from 1950 to 1995 and then declined to ~200,000 t in 2016, so that total landings are roughly equivalent to that of the Adriatic in 2016. The decline reflects not only changes in abundance of some species, but also substantial changes in management

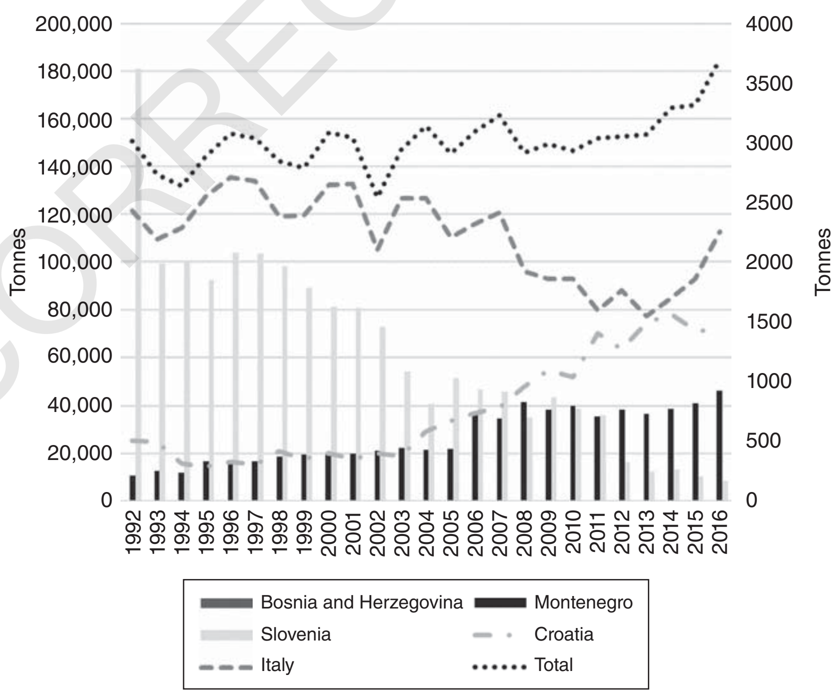

Figure 10.1 Total and national catch from FAO Area 37.2.1 (GFCM, 2018): (left axis) total, Italian, and Croatian landings; (right axis) Bosnia and Herzegovina, Slovenia, and Montenegro landings (bars).

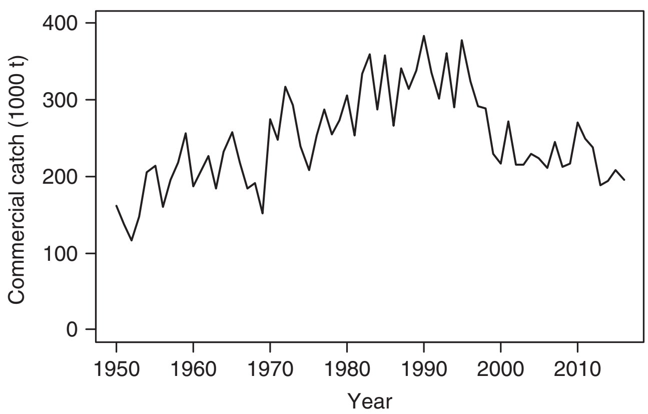

Figure 10.2 Total commercial harvest of finfish and shellfish in Chesapeake Bay and the adjacent coastal ocean during 1950–2016 (https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index). (National Oceanic and Atmospheric Administration NOAA).

and fishing effort, with management of many species adopting restrictive quotas. These management changes cause the changes in catch to not necessarily reflect changes in abundance. Decreasing catches of Atlantic menhaden (*Brevoortia tyrannus*) were the primary driver of the decreasing total commercial catch. The recreational fisheries for some species (e.g., striped bass *Morone saxatilis*) are larger than the commercial fisheries, but marine recreational landings statistics for the US Atlantic coast are currently in a state of uncertainty due to a redesign of the monitoring survey (https://www.fisheries.noaa.gov/recreational-fishing-data/evolution-marine-recreational-information-program)

10.3. FISHERIES RESOURCES

Although fish landings from the two systems were roughly equivalent in 2016 (~185,000 t compared to ~200,000 t for the Adriatic and Chesapeake Bay, respectively), landings in km^{-2} year^{-1} were three times higher in the Chesapeake than in the Adriatic. This likely reflects higher phytoplankton production in the Chesapeake, although the effect of fish migrations from adjacent water bodies may also be a factor.

10.3.1. Pelagic Fish

10.3.1.1. Adriatic Sea

Species of small pelagic fish are widely distributed in the Adriatic Sea and play an important role in the commercial fisheries of all countries located along the coast, accounting for a large share of the total catches. The main species in capture fisheries are sardines, anchovies, and sprat (Figure 10.3), as well as Atlantic mackerel *Scomber scombrus* and chub mackerel *Scomber japonicas*. Their stocks are regularly assessed by the FAO-GFCM Working Group on Small Pelagics. Today, the two main countries contributing to total catches are Italy (targeting mainly anchovy) and Croatia (targeting mainly sardine) (Figure 10.1). The Croatian fishery saw a period of forced closure in the 1990s due to the war in former Yugoslavia. When the war ended, the fleet was renewed with the appearance of large purse seiners that now constitute the main component of their fishing fleet. Currently, the Italian share of anchovy and sardine accounts for ~30% of total national catches; in Croatia, small pelagic fish represent ~80% of the total national catches.

Pelagic catch dominated marine fish landings, particularly in the east coast fishery. The annual sardine catch fluctuated between 20,000 and 40,000 t during 1992–2010 and increased to 80,000 t from 2010 to 2016 (Figure 10.3). In contrast, annual anchovy catches increased from ~10,000 t in 1992–1994 to a peak near 60,000 t in 2006 and then declined to ~37,000 t in 2016 (Figure 10.3). From the mid-1980s the contribution of pelagic fish to total landings decreased remarkably because of a lack of proper management measures, which led to the successive downsizing of the anchovy and sardine stocks and, more recently, to economic changes (due to the war in former Yugoslavia) that took place in the eastern coastal countries.

10.3.1.2. Chesapeake Bay

Unlike the role played by several pelagic species in the Adriatic Sea, pelagic fisheries in CB and adjacent continental shelf waters are dominated by one fishery, the Atlantic menhaden fishery (Figure 10.4). The commercial catch of menhaden experienced substantial interannual variability over time. This purse seine fishery is predominately a reduction fishery (i.e., used for fish meal and fish oil). The number of reduction plants on the US east coast decreased to a single plant in the late 1990s from more than 20 in the 1960s (ASMFC, 2017b). There is also a smaller bait fishery that is primarily prosecuted with pound nets. Since 2006, there has been a cap on reduction fish landings within CB (87,000 t year^{-1} in the beginning; reduced to 51,000 t year^{-1} today). With an estimated value of ~US$29 million since 2011, the fishery is currently the second most valuable commercial fishery in the Chesapeake. Despite the decreasing commercial catch since the early 1990s, estimated abundance of Atlantic menhaden has increased in recent years (ASMFC, 2017b). Nonmenhaden fisheries as a group (American shad, alewife, and blueback herring in the past; these fisheries are now suspended) accounted for a very small fraction of the pelagic finfish catch (Figure 10.4).

10.3.2. Demersal Fish

10.3.2.1. Adriatic Sea

Demersal fisheries involve trawlers operating on the continental shelf (NAS) and parts of the continental slope in the southern Adriatic. Of the 280 species identified during the Mediterranean International Trawl Survey

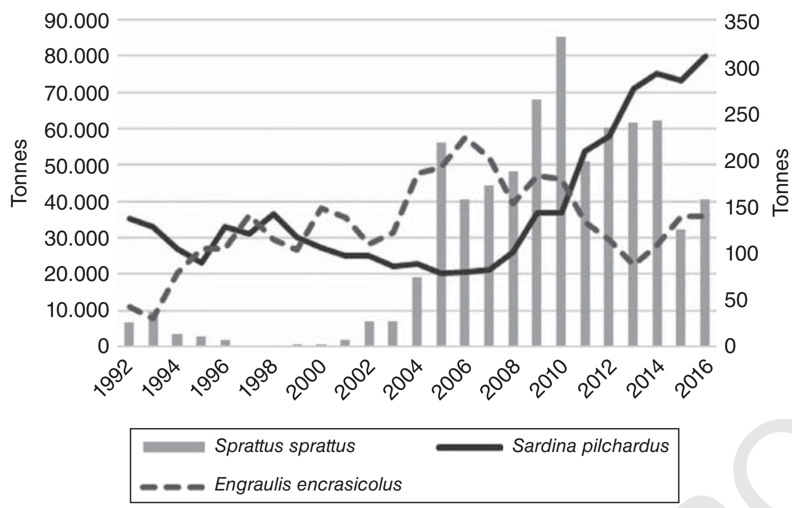

Figure 10.3 Yearly catch in FAO Area 37.2.1 Adriatic Sea of anchovy *Engraulis encrasicolus* and sardine *Sardina pilchardus* on the left axis and sprat *Sprattus sprattus* on the right axis (GFCM, 2018).

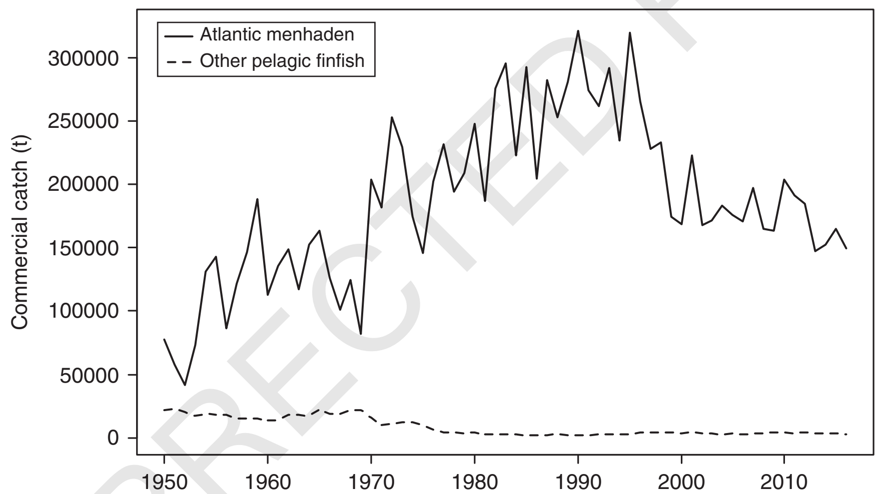

Figure 10.4 Commercial catch of Atlantic menhaden and other pelagic finfish in Chesapeake Bay and the adjacent coastal ocean during 1950–2016 (https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index). (National Oceanic and Atmospheric Administration NOAA).

(MEDITS), 80–90 species are commercially important (Piccinetti et al., 2012). European hake and red mullet dominate the demersal fish catch (Figure 10.5). Decadal variations in annual hake landings featured biomass peaks in 1994 (~7500 t) and 2006 (~5500 t), lows in 2001 (~2600 t) and 2011 (~2270 t), and an increase during 2011–2016 (Figure 10.5)

Assessments of European hake show a sharp increase in recruitment in 2005 and thereafter a level similar to or higher than in past years (Figure 10.5). In 2008 a new, though lower, peak was observed. Total fishing mortality (*F*) decreased to 2004, then increased in 2005 and 2006. Catches, and thus *F*, were dominated by the trawl fishery. As GFCM considered the stock to be overfished, they recommended a sizable reduction of *F* (GFCM-SAC, 2012). Annual sole landing increased from ~1000 t to > 2000 t, while annual sea-bream landings were <1000 t throughout (Figure 10.5).

Adult red mullet (Figure 10.5) are distributed along the central and eastern Adriatic, while juveniles are found in the western coastal area, where they remain until early winter when they move deeper. Annual landings declined from near 4000 t in 2005 to < 3000 t between 2010 and 2013, and then increased to > 4000 t in 2016. Spawning stock biomass decreased slightly from 9000 t in 2008 to 6300 t in 2011. Total biomass decreased by 50% from 2008 (50,000 t) to 2011 (25,000 t) (GFCM-SAC, 2012). The GFCM recommended reducing fishing mortality on new recruits, which could be obtained by a longer closed season for trawling along the western Adriatic coast where, in autumn, age-0 recruits born in summer are concentrated.

The common sole (Figure 10.5) is distributed in the northern and central Adriatic depending on age. Adults are present along the Istrian coast, while juveniles are present in Italian coastal waters, especially at the Po River mouth. Most of the population moves from north to south along the Italian coast, and probably from south to north along the eastern coast. Highest catches occur in the fall. Rapido trawl landings are traditionally dominated by small 0+, 1, and 2 year old fish. The stock in GSA 17 is subjected to overfishing, with the current *F* (as of 2011) higher than the GFCM reference point (GFCM-SAC, 2012). A reduction of fishing pressure has been recommended (GFCM-SAC, 2012), while considering that the exploitation is mainly orientated towards juveniles and the success of recruitment seems to be strictly related to environmental conditions.

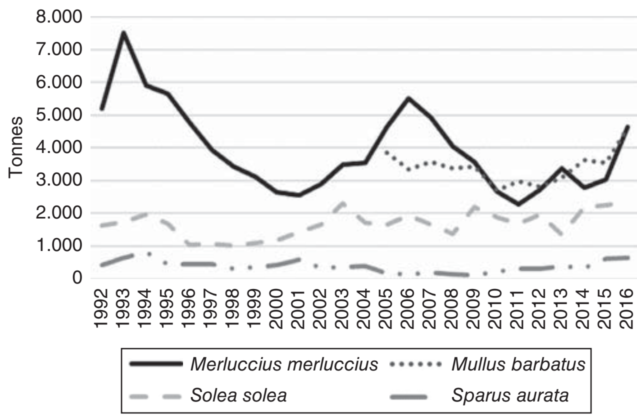

Figure 10.5 Yearly catch in FAO Area 37.2.1 Adriatic Sea of European hake *Merluccius merluccius*, red mullet *Mullus barbatus*, sole *Solea solea,* and sea bream *Sparus aurata* (GFCM, 2018).

Catch of miscellaneous coastal fisheries (fishes other than sardines and anchovies) by Italy trended downward from ~8000 t in 1996 to a low of ~5000 t in 2009, and then increased to ~7700 t in 2016. In contrast, Croatian landings decreased from ~2100 t in 1992 to ~500 t in 2003 and then increased to ~2100 t from 2010 to 2016 (Figure 10.6).

Landings of the elasmobranch fisheries in FAO Division 37.2.1 from 1992 to 2016 show a peak in landings of ~1176 t in 2005 followed by a decrease to 486 t in 2012 and an increase to 935 t in 2016 (Figure 10.7). Smaller elasmobranchs, especially small sharks, rays, and skates are often commercially important species in trawls. In certain areas and during some seasons, dogfish and hound sharks are targeted with gillnets.

In recent decades, sport and recreational fisherman have targeted large sharks in big game fishing (thresher shark *Alopias vulpinus*, blue shark *Prionace glauca*, and porbeagle *Lamna nasus*). In 1982, the houndshark (*Mustelus* spp.) catch was 1704 t, or ~64% of the total elasmobranch landings (2649 t; the maximum of the period). That year was exceptional, with the second-highest

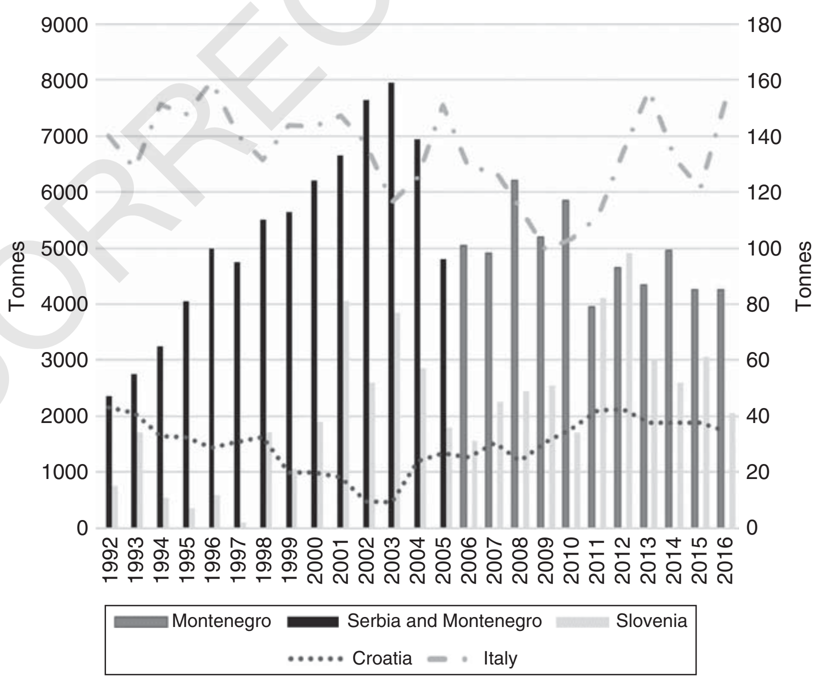

Figure 10.6 Yearly catch of miscellaneous coastal fish in FAO Area 37.2.1 Adriatic Sea. Italy and Croatia landings are shown as lines, with the axis on the left side; Serbia and Montenegro (aggregated), Slovenia, and Montenegro landings are shown as bars, with the axis on the right side (GFCM, 2018).

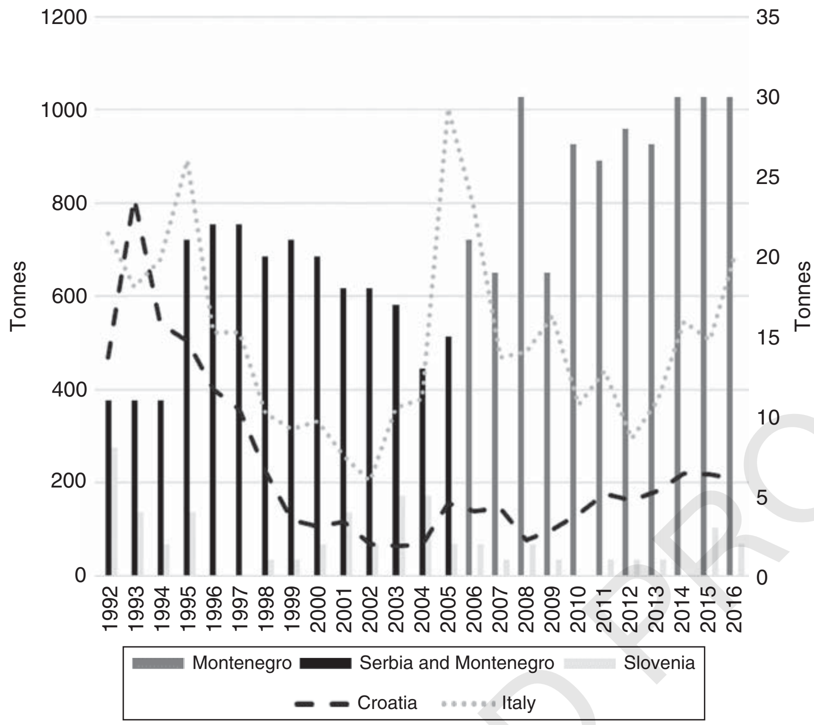

Figure 10.7 Yearly catch of sharks, rays and chimaeras in FAO Area 37.2.1 Adriatic Sea. Italy and Croatia landings are shown as lines, with the axis on the left side; Serbia and Montenegro (aggregated), Slovenia, and Montenegro landings are shown as bars, with the axis on the right side (GFCM, 2018).

landings of smooth hounds *Mustelus* spp. (824 t) occurring in 2005. Rays accounted for high percentages of total landings in 1986 (1097 t; 58%) and 1987 (1071 t; 56%). Highest landings of dogfish *Squalus acanthias* (537 t) were reported in 1993, but then a significant decline of landings was observed, especially in 2003, when only 41 t were reported for the whole Adriatic.

The main change in composition and distribution of demersal fish resources has been the decrease of elasmobranch diversity and frequency of capture (Jukić-Peladić et al., 2001). Of greatest significance was the decline in long-lived and slowly growing species. For example, small species such as the spotted catshark *Scyliorhinus canicula* and the brown ray *Raja miraletus* were frequently collected in both surveys, while some larger sharks and ray species disappeared or were rarely found during MEDITS 1998.

10.3.2.2. Chesapeake Bay

Commercial fisheries for demersal species have varied substantially over time and patterns differ among species (Figure 10.8). Unlike the Adriatic, commercial trawling is generally prohibited in Chesapeake Bay, and most of the catches of finfish are from pound nets and gill nets. Annual commercial catches of Atlantic croaker *Micropogonias undulatus* fluctuated widely about a mean of 2627 t, with peaks during the late 1950s, late 1970s, and mid-1990s to 2010. In contrast, annual commercial catches of the closely related sciaenid spot (*Leiostomus xanthurus*) fluctuated between ~3000 t and 500 t (mean, 1332 t) with a downward trend from 1950 to the early 1970s, an upward trend through the 1990s, and a downward trend thereafter to a minimum for the period in 2016 (Figure 10.8).

Annual commercial catches of summer flounder *Paralichthys dentatus* (mean, 1764 t) fluctuated between ~5000 t and ~1000 t during the late 1970s through the 1980s, but was more stable during previous and subsequent decades when catches fluctuated around 2000 t year^{-1} (Figure 10.8). Atlantic croaker productivity appears to vary with temperature (Hare et al., 2010), but drivers of productivity of spot and summer flounder have not been identified. Summer flounder are currently overfished stock-wide (Terceiro, 2015), and their abundance in the Chesapeake appears to be low, as indicated by bottom-trawl surveys. There is no commercial fishery for elasmobranchs in Chesapeake Bay.

10.3.3. Anadromous and Catadromous Fish

10.3.3.1. Adriatic Sea

Populations of shad *Alosa fallax* suffered a significant decline in recent decades (Sabatié et al., 2002) so that

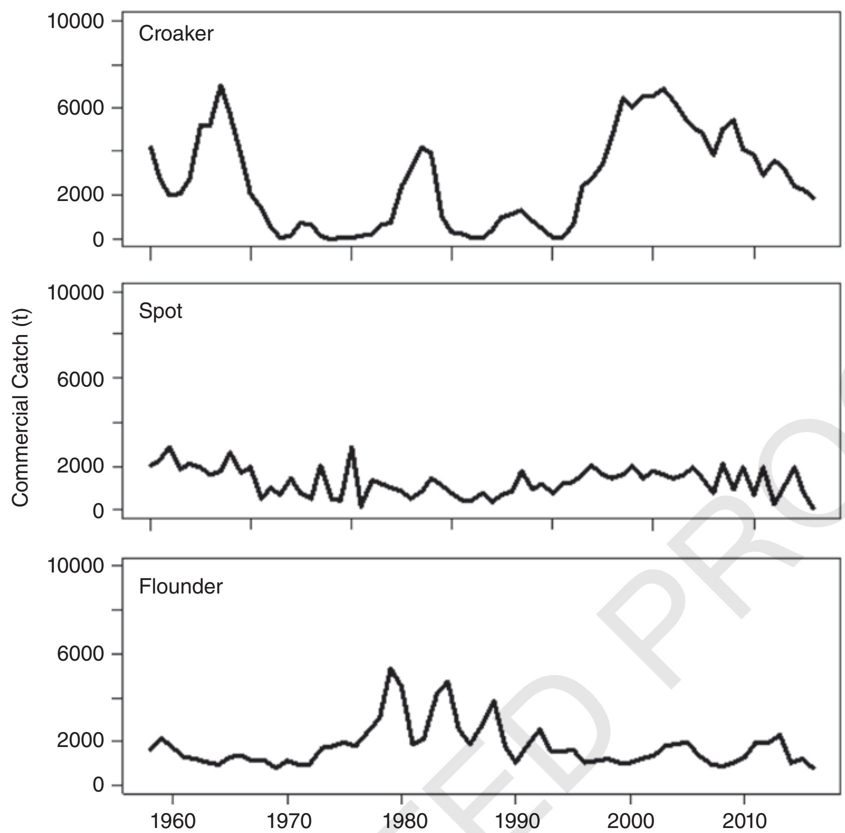

Figure 10.8 Trends in commercial catch for three main demersal finfish in Chesapeake Bay (Atlantic croaker, spot, summer flounder) (https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index). (National Oceanic and Atmospheric Administration NOAA).

application of management measures throughout the species' life cycle can be delayed no longer. The main causes for this decline are the construction of dams, river pollution, and overfishing of mature fish during spawning migration (Aprahamian et al., 2003; Maitland & Hatton-Ellis, 2003). Dams have progressively limited the presence of shad to the lower course of rivers. As a result of the observed decline, *A. fallax* (along with other species of the genus *Alosa*) is listed in Annexes II and V of the European Directive 92/43/ EEC. It is also included in the list of protected species of the Bern Convention (Appendix III) but is classified as "Least Concern" (they do not qualify as threatened, near threatened, or conservation dependent) by the International Union for Conservation of Nature (IUCN; Freyhof & Kottelat, 2008).

The catadromous eel *Anguilla anguilla* is caught primarily by Italy and catches were relatively stable until the 1990s when they declined rapidly from > 260 t in 1992 to < 33 t year^{-1} since 1998 (Aschonitis et al., 2017) (Figure 10.9). In the past few years there has been a decline in the eel population due to pollution from the construction of hydroelectric stations along the river to power the industrial port of Ploče and the construction of vacation homes (tourism has expanded rapidly in the area).

10.3.3.2. Chesapeake Bay

The primary anadromous and catadromous species that have been harvested in CB include striped bass, white perch *Morone americanus*, several species of alosines (primarily American shad, alewife, and blueback herring), and American eel *Anguilla rostrata* (Figure 10.10). Striped bass is one of the fishery management success stories in the Chesapeake. They reached very low abundances in the mid-1980s, and a coastwide moratorium was declared. Driven by several years of good recruitment, the fishery was reopened in 1989 and the population rebuilt by the late 1990s (ASMFC, 2016). White perch support important commercial fisheries in the region, with harvest remaining relatively consistent since the 1950s at an average of 631 t year^{-1} (Figure 10.10). The fishery for alosines was once one of the most important on the US Atlantic coast, but populations have declined substantially because of habitat loss (primarily from dams), overfishing, and pollution, as in the Adriatic. In 2005, a moratorium was placed on the directed at-sea fishery for American shad, but bycatch still occurs in other commercial fisheries. The most recent stock assessments for alosines indicate that abundances continue to remain low relative to historical abundances (ASMFC, 2007, 2012). The American eel fishery has fluctuated substantially, and harvest may not reflect local abundance. Fenske et al. (2011) estimated an 86% decline in estimated abundance of American eel in the Potomac River during 1980 to 2008.

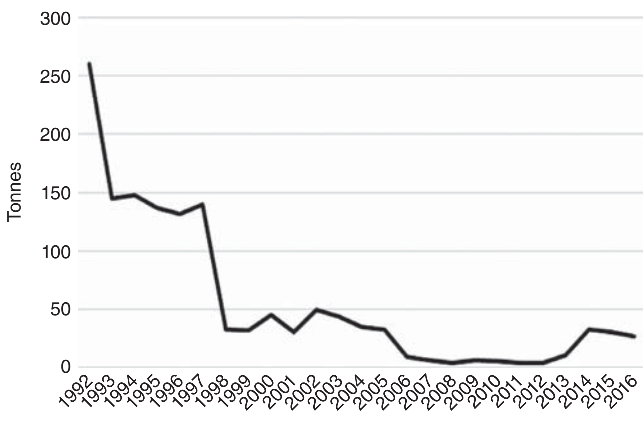

Figure 10.9 Yearly catch of river eel in FAO Area 37.2.1 Adriatic Sea (GFCM, 2018).

10.3.4. Invertebrates: Mollusks and Crustaceans

10.3.4.1. Adriatic Sea

The fishery for bivalve mollusks is significant in the Adriatic Sea, especially in the NW basin where the best environmental and trophic conditions for propagation of these species are met. Major rivers flowing into this part of the Adriatic, together with extended lagoons along the coast and muddy and sandy bottoms with minor slopes, are the main factors that make this area rich in biodiversity with important bivalve species. There are also extended beds of the ark clam *Anadara inaequivalvis*, an invasive species introduced to the Adriatic towards the end of the 1960s, that now proliferates between 0.6 and 6 km from the coast but has yet to be commercially exploited.

Mussels *Mytilus edulis* are usually collected by hand, and less frequently by a bottom-trawl fishery from lagoons where rich beds are present. The most exploited areas are close to rocky coasts, among which the Conero promontory in the Marche region stands out. Equally

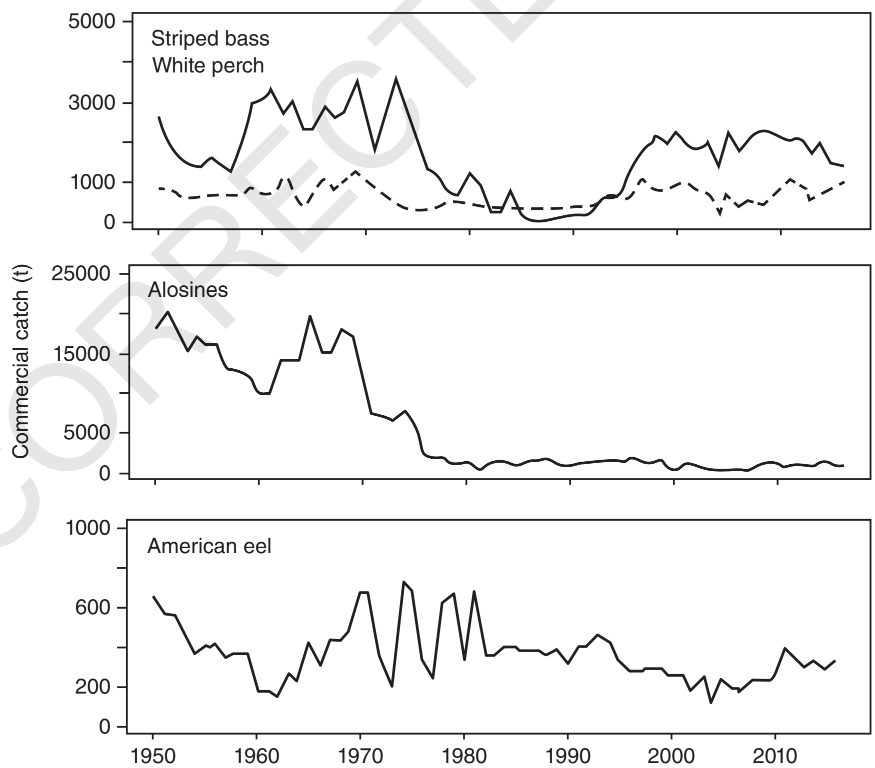

Figure 10.10 Trends in commercial catch of anadromous (striped bass, white perch, and alosines) and catadromous (American eel) species in Chesapeake Bay and the adjacent coastal Atlantic Ocean during 1950–2016 (https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index). (National Oceanic and Atmospheric Administration NOAA).

important are quantities collected on methane-producing platforms during cleaning and maintenance activities of the platforms. Striped Venus clams (*Chamelea gallina*; Figure 10.11) are usually caught by vessels equipped with a hydraulic dredge. In 2000, out of 728 dredge boats registered in Italy, 685 were operative along the Adriatic coast. This fishery system operates on sandy bottoms within 0.6 km of the coast. The laws governing this capture system regulate the following: gear dimensions, catch limits, vessel dimensions, engine power, and clam size. Fishing areas are managed by compartmental management consortiums with which all fishermen are affiliated. Some vessels are also used in other bivalve fisheries, such as for smooth callista *Callista chione* and razor clams *Solen* spp. and *Ensis* spp. Mollusk harvest is ~30,000 t year^{-1}.

In Croatia, particularly along the Istrian peninsula coast, the scallop *Pecten jacobaeus* is an important dredged species. Although Pectinidae species (scallops and queen scallops) were once collected in the NAS with bottom trawls, the fishery is now marginal. There has been a modest increase in flat-oyster landings during the past few years, reaching 500 t in 2015. Natural harvesting of Japanese littleneck clams *Tapes semidecussatus*, an introduced species in NAS lagoons, is highly developed and yields ~30,000 t year^{-1}. Harvesting is regulated according to gear, quota, and area regulations in specific regions, identified by hygienic and sanitary parameters. Finally, cephalopod capture has generally decreased in recent years (Figure 10.12).

The prawn fishery has become highly valuable in the northern and central Adriatic in recent years (Figure 10.13). Annual landings, estimated to be ~500 t, peak in the last quarter of the year when a new generation, born in summer, moves offshore and is fully recruited to the fishery (Froglia et al., 2013).

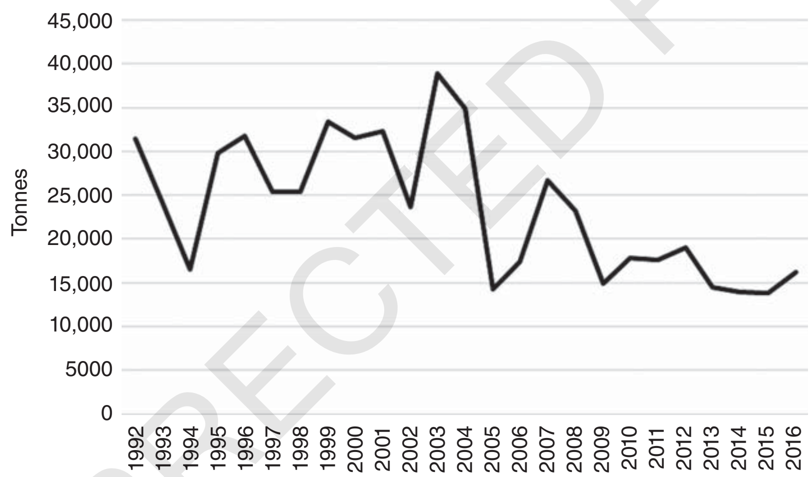

Figure 10.11 Yearly catch of striped Venus clam *Chamelea gallina* in FAO Area 37.2.1 Adriatic Sea (GFCM, 2018).

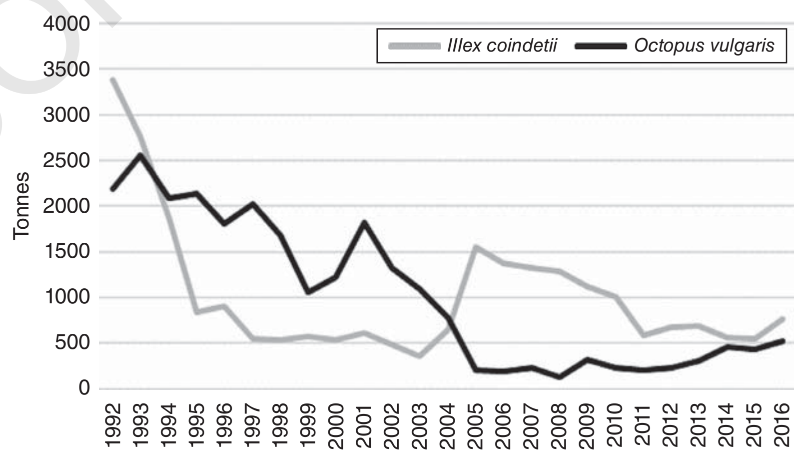

Figure 10.12 Yearly catch of squid *Illex coindetii* and octopus *Octopus vulgaris* in FAO Area 37.2.1 Adriatic Sea (GFCM, 2018).

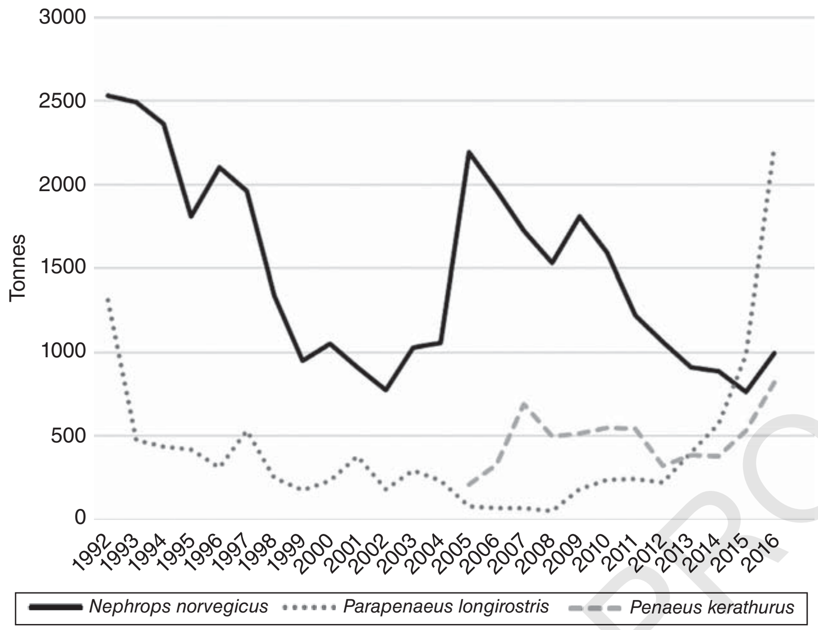

Figure 10.13 Yearly catch (metric tons) of Norway lobster *Nephrops norvegicus*, deepwater rose shrimp *Parapenaeus longirostris*, and prawn *Penaeus kerathurus* in FAO Area 37.2.1 Adriatic Sea (GFCM, 2018).

Norway lobster is widely distributed in the central and northern Adriatic at depths > 50 m, but the most important densities are located on Pomo Pit grounds. Juveniles are concentrated in deep areas > 200 m. There are substantial differences in average length between the population of the Pomo Pit and those of the rest of the Adriatic, the result of a diversity of ecological factors that lead to a reduction in the growth of Norway lobster (and other benthic decapods) in the Pomo Pit. The species is of great commercial importance in the NE Atlantic and Mediterranean. In the Adriatic, it ranks first of all crustacean species exploited in terms of value, and second in terms of weight, with a decreasing trend in catches since 1993 (Vrgoč et al., 2004) (Figure 10.13).

The abundance of deepwater rose shrimp grew steadily from 1999 to 2005, declined in 2006–2007, increased in 2008 and 2009, and again decreased in 2010 and 2011 (GFCM-SAC, 2012) (Figure 10.13). Current assessments by virtual population analysis show that the highest fishing mortalities affect age groups 1 and 2 (GFCM-SAC, 2012). The stock is considered overfished and fishing mortality should be reduced. This could be achieved with a multi-year plan based on fishing activity limitations and possibly decreased fishing capacity (GFCM-SAC, 2012).

The mantis shrimp *Squilla mantis* occurs over a wide band parallel to the coast between 15 and 70 m depth in the upper and middle Adriatic, where it is exploited by bottom otter trawls, gillnets, and rapido trawls. It is exploited year-round essentially by Italian trawlers and ranks first among crustaceans landed in Adriatic ports. Slovenian annual landings are much lower, while the species is absent in Croatian landings. Trawl catch is mainly composed of individuals aged 1–2 years, while older age classes are poorly represented. For artisanal fisheries, *S. mantis* is an alternate target of gillnetters targeting sole, especially during spring–summer seasons in the coastal area. The species is not present in the list of shared stocks of GFCM as it is present and commercially fished mainly in Italian Territorial Waters.

10.3.4.2. Chesapeake Bay

The number of species of commercial mollusks and crustaceans in CB is much smaller than in the Adriatic. Major commercial mollusks include the eastern oyster (*Crassostrea virginica*), the northern quahog (*Mercenaria mercenaria*), and the soft-shell clam (*Mya arenaria*) (MacKenzie, 1997). The blue crab (*Callinectes sapidus*) is the main species of commercial crustacean (BBCAC, 2001).

Commercial catches of invertebrates have fluctuated about a relatively constant mean for crustaceans but have declined over time for mollusks (Figure 10.14). Blue crab supports the most valuable commercial fishery in CB, with an average annual dockside value of $84 million USD (mean catch, 29,373 t year^{-1}) since 2011, and has comprised almost all the crustacean catch in the bay. Eastern oyster is the most important mollusk for commercial fisheries in the bay, but catches have declined from 16,000 t year^{-1} on average in the early 1950s to ~1800 t year^{-1} since 2011 due to disease, overfishing, and

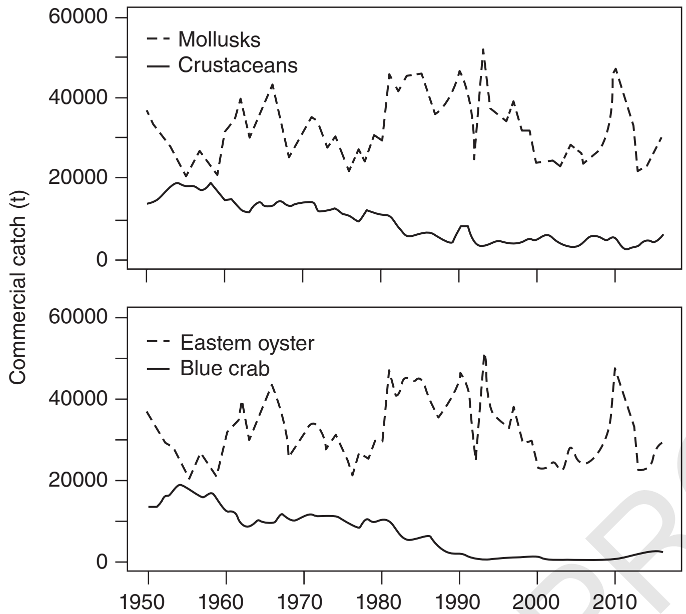

Figure 10.14 Commercial catch of crustaceans and mollusks (upper panel) and eastern oyster and blue crab (lower panel) in Chesapeake Bay and the adjacent coastal Atlantic Ocean during 1950–2016 (NOAA; https://www.st.nmfs.noaa.gov/commercial-fisheries/commercial-landings/annual-landings/index). (National Oceanic and Atmospheric Administration NOAA).

habitat loss (Hargis & Haven, 1999; Rothschild et al., 1994; Wilberg et al., 2011). In recent years, oyster harvests and abundance have increased somewhat since their lows in the early 2000s. Major restoration efforts are currently underway (Bersoza Hernández et al., 2018).

10.4. PREDATOR–PREY DYNAMICS

10.4.1. Adriatic Sea

Clupeoid fishes (sardines, anchovy, sprat) dominate and support major harvests. They also provide a prey resource for predator species and, as such, are an important trophic link between plankton and piscivores (bluefish *Pomatomus saltatrix*, Atlantic bluefin tuna *Thunnus thynnus*, and European hake). Clupeoid fishes (primarily zooplanktivores) are subject to intensive fishing and are the primary prey of piscivores. Although many aspects of the ecology and population biology of key species are known, the functional linkages between prey abundances, habitat quality, and predator production have yet to be defined quantitatively.

Annual landings of elasmobranchs, which are believed to regulate benthic community dynamics and contribute to "biological equilibrium" in benthic communities, have fluctuated nearly tenfold during the first half of the 20th century. Fluctuations in abundances of these species may have unmeasured but important effects on demersal fish and benthic invertebrate communities (e.g., Carpi et al., 2015; Grbec et al., 2002; Santojanni et al., 2006; Vrgoč et al., 2004).

10.4.2. Chesapeake Bay

Forage fish and invertebrates are important prey for economically important higher trophic level fish such as striped bass and summer flounder (Baird & Ulanowicz, 1989, CBFEAP, 2006). An analysis of long-term diet data by Ihde et al. (2015) showed that benthic invertebrates are particularly important to predatory fish (striped bass, summer flounder, Atlantic croaker, clearnose skate *Raja eglanteria*, and white perch) in the mainstem of CB. Key invertebrate prey includes polychaetes, small-to-medium sized crustaceans (mysid shrimp, amphipods and isopods, mantis shrimp *Squilla empusa*, sand shrimp *Crangon septemspinosa*), and bivalves (stout razor clam *Tagelus plebeius*). Fish accounted for the remaining four of the ten most important prey groups by biomass among the predators, but only one of those fish species fits the typical definition of a small pelagic forage fish (bay anchovy). Young-of-the-year of three important fisheries species, weakfish (*Cynoscion regalis*), spot, and Atlantic croaker, were the other most important fish prey. Other forage fish that were identified as important but not dominant across predators included Atlantic menhaden, Atlantic silversides (*Menidia menidia*), and a suite of species belonging to the genus *Fundulus* (e.g., mummichog *F. heteroclitus*, striped killifish *F. majalis*). While

Atlantic menhaden was not one of the top 10 prey species, its importance for large piscivores, and probably for avian predators (e.g., osprey *Pandion haliaetus*), may be grossly underestimated (Buchheister et al., 2017).

Unlike the Adriatic, most small-bodied, pelagic forage fish are not harvested commercially, although recreational harvest of forage fishes for use as bait occurs. Bay anchovies are the most abundant fish taxon in terms of biomass (Baird & Ulanowicz, 1989; Houde et al., 1999) and have been identified as the most important prey taxon in terms of biomass (Ihde et al., 2015). Other important forage fish that are not commercially harvested include Atlantic silversides and *Fundulus* spp. Atlantic menhaden represents the only major pelagic forage species that is commercially harvested. While juveniles of the three demersal fish species identified by Ihde et al. (2015) are not harvested, all three support commercial and recreational fisheries as adults. Despite the absence of large-scale fisheries for most of the small pelagic forage fish, the dominant role of Atlantic menhaden in the fisheries harvest and the ecosystem food web underscores the need to balance ecosystem trophic demand with fishery demand in the system. The dominance of the small pelagic fisheries harvest by a single species in the Chesapeake is a key difference between fisheries harvest in CB and the Adriatic Sea.

10.5. ANTHROPOGENIC IMPACTS: PROBLEMS AND CONCERNS

10.5.1. Overfishing

10.5.1.1. Adriatic Sea

A trophic mass-balance model was developed to characterize the structure and function of food webs in the northern and central Adriatic Sea and to quantify the ecosystem effects of fishing during the 1990s (Coll et al., 2007). Forty functional groups were described, including target and nontarget fish and invertebrate groups, and three detritus groups (natural detritus, discards, and bycatch of cetaceans and marine turtles). Results underscored the importance of pelagic–benthic coupling (Chapter 8) for trophic interactions between pelagic and benthic communities (Coll et al., 2007).

Organisms at low and medium trophic levels (benthic invertebrates, zooplankton, and anchovies) and dolphins were identified as keystone groups; and 98% of the total production of the system is due to phytoplankton, zooplankton, noncrustacean benthic invertebrates, and jellyfish (Coll et al., 2007). Jellyfish were important in terms of consumption and production of trophic flows within the ecosystem (Chapter 6). The analysis of trophic flows of zooplankton and detritus groups underlined the importance of the microbial food web in the NAS (Chapter 7).

Analysis of biomass distribution along functional groups and trophic levels indicates that protected areas support a higher mean community trophic level, higher biomasses, lower production, and generally lower transfer efficiency than fished areas. The biomass ratios of pelagic/demersal fish and fish/invertebrates are higher in protected areas than in exploited areas due to fishing-induced changes (Libralato et al., 2010). Overall, the Adriatic Sea is overfished. Out of 446 fish species recorded in the Adriatic Sea, ~120 are exploited. High fishing effort (overfishing) and "fishing down the food chain" inflicted notable changes in the northern and central Adriatic during the 1990s and early 2000, e.g., declines in pelagic and demersal fish stocks and decreases in the mean trophic level of fish landings (Coll et al., 2007; Coll, Santojanni, et al., 2010). Bottom trawling (strascico), midwater trawling (volante), and beam trawling (rapido) fleets had the greatest effects on both target and nontarget ecological groups (Coll et al., 2007; Coll, Santojanni, et al., 2010). By contrast, purse seining (lampara) showed medium to low effects on the ecosystem; cetaceans, marine turtles, and sea birds did not significantly compete with fishing activity.

The negative influence of fishing affects fish populations both directly through overfishing (fish mortality) and indirectly because intensive fishing in many areas disrupts the food chain, thus affecting stock consistency, whole communities, and the entire biological balance. Moreover, this disruption reduces the nutritional base of top predators and changes the relationship between predators and prey. Fishing with some bottom-fishing gear also results in degradation or disappearance of habitats. The immediate effect of fishing on fish species is reflected in the decreased density of their populations, sometimes to the point of extirpation. This is illustrated in the open Adriatic where benthic cartilaginous fishes (*Scyliorhinus canicula*, *Raja* spp., *Mustelus* spp., *Squalus* spp., etc.) have almost disappeared. Another immediate effect is the reduced body length and weight of individuals (left asymmetry in the body length pattern) and the decline in the number of sexually mature individuals, which is responsible for slow population renewal or for preventing such renewal (e.g., Jukić-Peladić et al., 2001; Krstulović Šifner et al., 2009).

10.5.1.2. Chesapeake Bay

As in the Adriatic, overfishing has been an issue in CB, but fishing mortality for most species is thought to be at or near sustainable levels. Oysters, river herring, shad, flounder, and sturgeon likely suffered historical overfishing. Atlantic sturgeon was declared endangered and fisheries for river herring and shad have been closed. Despite closures and restrictions on landings, these species have not shown substantial recovery. Overfishing in coastal waters was found for summer flounder in a 2015 stock assessment (Terceiro, 2015) and indices of abundance in the bay have been at low levels for several years. Similarly, a new stock assessment for eastern oyster in Maryland portions of the CB documented overfishing in 19 of 36 state regions in 2017–2018 (MDDNR, 2018). Historical analyses indicate that oyster abundance and biomass are < 1% of those present in the 19th century, before heavy fishing began (Rothschild et al., 1994, Wilberg et al, 2011).

The biomass size spectra of pelagic fish are bimodal, with small planktivorous fish (the anchovy *Anchoa mitchilli*) associated with one peak and larger fish from multiple trophic levels with the second (dominated by croaker and white perch) (Jung & Houde, 2005). Regionally, biomass levels of larger fish were higher than anchovies in the oligohaline (white perch) and polyhaline (croaker) reaches of CB, but were low in the mesohaline reach where summer bottom-water hypoxia–anoxia occurs, a pattern that appears to be related to enhanced pelagic–benthic coupling in the upper and lower bay relative to the oxygen minimum zone of the mesohaline reach (Jung & Houde, 2005).

Decadal changes in the ratio of pelagic to benthic fish harvests (Figure 10.15) show that from 1950 to the mid-1990s, pelagic harvest increased more rapidly than benthic harvest, leading to a threefold to fourfold increase in the ratio of pelagic to benthic fisheries catch (P/B). This shift is due almost exclusively to increased pelagic harvests and stagnant benthic harvests. The increase in P/B coincided with increasing phytoplankton productivity and summer deoxygenation of bottom water (Kemp et al., 2005). Starting in the early to middle 1990s and progressing through 2016, there is evidence of a reversal in the P/B harvest trend. Over this period, pelagic harvest rates declined more rapidly than benthic harvest rates, with mean decadal P/B ratios dropping from ~5/1 to 4/1 (Figure 10.15). Part of this reversal resulted from management measures that capped the Atlantic menhaden purse-seine fishery within CB at 87,000 t year^{-1} from 2006–2017 and which is now capped at 51,000 t year^{-1} (ASMFC, 2017c). Despite these cap reductions, the coast-wide total allowable catch for Atlantic menhaden in 2018–2019 is 216,000 t (ASMFC, 2017c).

Despite decisions by management and industry and probable shifts in biological productivity, the Atlantic menhaden reduction fishery still dominates the pelagic fisheries harvest in CB. Historically, changes in fisheries P/B track the Atlantic menhaden harvest (Figure 10.16). Houde et al. (1999) described an increasing trend in pelagic catches through the 1980s. In recent decades (1990–present), the P/B trended downward driven by industry reductions in Atlantic menhaden landings (from ~300,000 t in the early 1990s to ~150,000 t in 2016; Figure 10.16). Menhaden are an important food source for predators

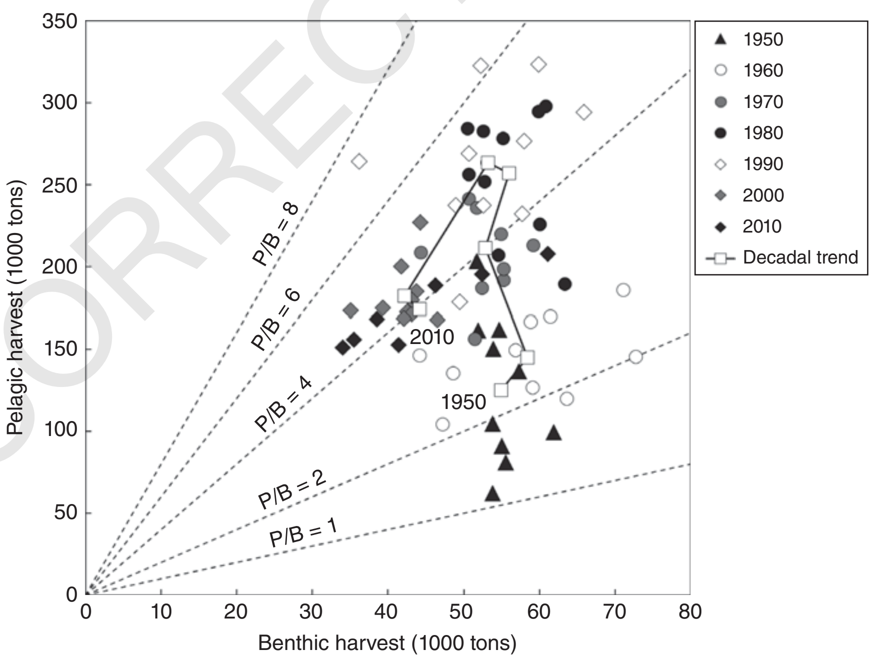

Figure 10.15 Phase diagram of pelagic and benthic fisheries harvest in Chesapeake Bay from 1950 to 2016. Fisheries years are coded by decade and decadal means are shown as open squares and connected in rank-order from the 1950s through 2010s. Pelagic/benthic (P/B) fisheries catch ratio isoclines associated with different catch patterns are shown for reference (dashed lines). Atlantic menhaden harvest values (allocated to pelagic harvest) are based on coast-wide landings due to the absence of landings data specific to Chesapeake Bay.

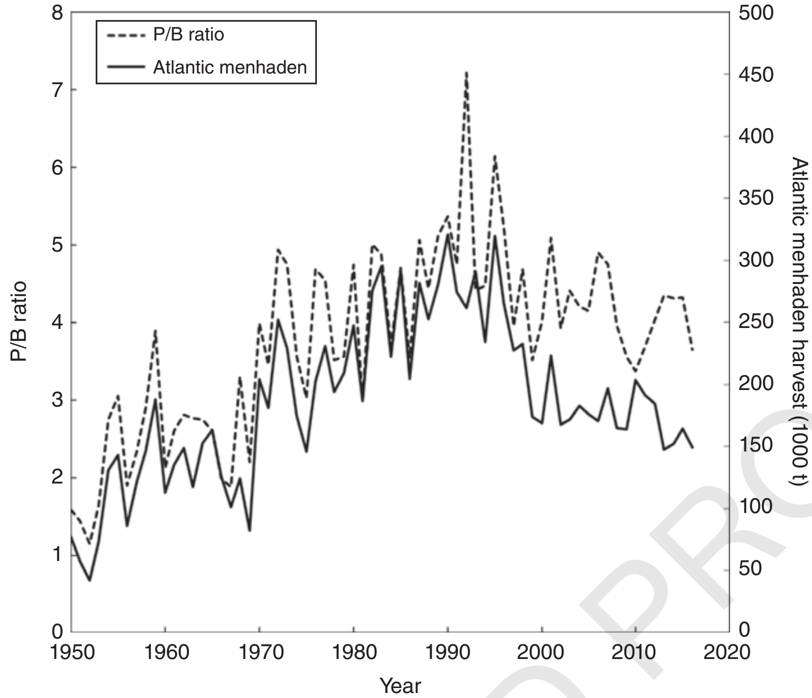

Figure 10.16 Time series of pelagic/benthic (P/B) fisheries catch biomass ratio ratio and of Atlantic menhaden biomass landings from 1950 to 2016. Atlantic menhaden harvest values are based on coast-wide landings due to the absence of landings data specific to Chesapeake Bay.

(e.g., osprey, loon, bald eagle, bluefish, weakfish, cod, striped bass, king mackerel, and humpback whale) and the menhaden harvest may be affecting the abundance of their food. Thus, the Atlantic States Marine Fisheries Commission (ASMFC) reduced the catch limit in CB by nearly half due to ongoing concerns about the bay's health.

Overfishing also appears to be responsible for the more recent decline in the standing stock of striped bass during the 1970s and early 1980s (Richards & Rago, 1999). As a consequence, a 2-year moratorium on fishing was declared in Maryland in 1985 followed by Virginia's 1-year moratorium in 1989. As a result, the population rebounded to a peak in 2004. However, a new decline appears to be underway. According to the ASMFC, the abundance of striped bass (including populations from CB and the Delaware and Hudson river estuaries) has been declining since 2004. In an effort to reverse this trend, starting in 2015 the commission reduced the catch limit by up to 25% in the bay.

Nearly a decade of low catches of blue crab led to concerns about sustainability of the fishery in the late 1990s and early 2000s. Because of poor fishery performance, Maryland and Virginia developed a Bi-state Blue Crab Advisory Commission (BBCAC) to develop recommendations for management of blue crab (BBCAC, 2001). In 2008, Virginia closed the winter dredge fishery that mostly targeted female crabs (Miller et al., 2011). Since then, fishing mortality has been below the target level and the blue crab fishery has recovered from its lows in the early 2000s (Houde, 2011). However, blue crab abundance remains below its target level (Miller et al., 2011).

10.5.2. Effects of Habitat Modification and Loss on Fisheries

10.5.2.1. Adriatic Sea

Degradation and loss of critical natural habitats are major concerns in Europe (Laffoley, 2000). It is estimated that only a small percentage of European coastal habitats (< 15%) are in "good" condition (European Environment Agency, 1999). Coastal habitats have been severely affected by changes in demographics and coastal development (Chapter 3). In some regions of Italy, built-up coastal areas exceed 45% of land cover (European Environment Agency, 2006). Uncontrolled construction of private and tourist facilities on the Croatian coast and the expansion of facilities like marinas, breakwaters, anchorages, bathing places, and anthropogenic sand beaches in closed coves have affected coastal ecosystems. For example, in recent years there has been an explosion in construction of marinas. At present they number 51 with 14,000 berths on the sea, and there is a campaign underway to construct ~100 more. Unfortunately, their environmental effect is not monitored.

Habitat degradation has had adverse effects on ecosystems, primarily on vulnerable benthic habitats of the infralittoral belt (transitional area between the littoral and sublittoral zones), e.g., canopy seaweeds (*Cystoseria*) and seagrass meadows, which are critical habitats (Chapter 3). *Cystoseria* dominates the vegetation of immersed rocky seabeds at depths from 0.5 to 5 m. Other critical habitats affected include seagrasses *Posidonia oceanica*, *Cymodocea nodosa*, and *Zostera* sp. that are experiencing fragmentation in some places. The meadows of *P. oceanica* support a diverse biocenosis between 0.5 and 50 m that includes > 20% of known Mediterranean marine species. Such communities ventilate and strengthen the seafloor, mitigate effects of waves, and slow coastal erosion. For more than 100 fish species, most of which are economically important, these habitats represent dwelling, spawning, growing, and feeding grounds.

Frequent physical changes in natural habitats of early development stages of numerous fishes change interactions among species within complex food webs, disrupting the normal development of individual species and their population dynamics. Seagrass meadows also suffer from intensive fishing operations, primarily by fishing gear used to catch benthic fishes, such as picarel. Such benthic towing gear includes coastal trawls (tartana), "kogol" and "strašin," and beach-seines such as "girarica," coastal beach-seines, and "šabakun." Most of all, seagrass meadows are endangered by yachts and small vessels coming to anchor.

Physical changes in the environment also include degradation of the cliff-studded coast caused by once-common fishing for date shell *Lithophaga lithophaga*. Such fishing denudes the surface layer of algae inhabiting the cliff-studded coast that serves as a sanctuary, spawning, growing, and rich feeding ground for many fish species. Therefore, the ban imposed on date shell fishing in 2002 (Date Shell Protection Ordinance, Official Gazette No. 86/02) is targeted at the "protection of the cliff-studded coast as a special habitat of the sea fishing waters" rather than the date shell's protection, because, despite excessive poaching, the biological potential for the reproduction and survival of their populations is not at risk.

Although dredging sediments for construction projects is limited in spatial extent, it can affect local populations of fish species such as common stingray *Dasyatis pastinaca*, lesser weaver *Echiichthys vipera*, sand steenbras *Lithognathus mormyrus*, and the soles *Solea* spp. and *Pegusa* spp., etc., through degradation of habitat quality and disturbance. Finally, species of the sea horse genus *Hippocampus* (especially *H. guttulatus*) are adversely affected by taking them from the sea as souvenirs.

Diadromous fish species suffer from barriers raised in watercourses in the form of waterworks and hydropower plants. Due to the geomorphological character of the area, the rivers of the Adriatic's catchment area are well suited for the construction of hydropower plants. Thus, five plants have been built on the Cetina River, four on the Neretva River, and others on the Krka River, etc., which prevents the undisturbed migration of fish to their spawning and feeding grounds.

10.5.2.2. Chesapeake Bay

Human alteration of important habitats also poses a major threat to CB fisheries. Dam construction, sedimentation, altered river flow regimes, hardened shorelines, impaired water quality, and the loss of living habitats such as oyster reefs and seagrass beds are all challenges facing fishery managers. Loss of access to bottom habitats due to hypoxia in some areas during summer months poses a threat to bottom-associated fishes and their forage base. In addition to overfishing, the construction of dams has been a key element in the decline of diadromous species, particularly American shad, river herring, and American eel (Limburg & Waldman, 2009). By blocking access to upstream spawning or rearing habitat to these species, dams have drastically reduced the availability of suitable reproductive habitat to a fraction of what was historically available.

Other forms of habitat loss or alteration are more difficult to tie directly to fisheries productivity. It is estimated that 99.7% of the oyster population was lost between the early 1800s and 2009 and that ~70% of oyster habitat was lost between 1980 and 2009 (Wilberg et al., 2011). The loss of oyster reefs has had multiple effects through the loss of the ecological filtering function of oysters, loss of biologically engineered habitat, and the loss of productivity (Grabowski & Peterson, 2007; Kennedy, 1996). Oyster reef habitat supports highly productive invertebrate and vertebrate (fish) prey assemblages (Rodney & Paynter, 2006), the loss of which has likely reduced the productivity of these areas for fish species such as bluefish *Pomatomus saltatrix*, black sea bass *Centropristis striata*, sheepshead *Archosargus probatocephalus*, and toadfish *Opsanus tau* (Harding & Mann, 2001; Peterson et al., 2003).

In the Chesapeake, large expanses of oligohaline and freshwater tidal reaches create the need to define submerged aquatic vegetation (SAV) as a category of littoral habitat. As in the seagrass beds of the Adriatic, SAV habitat serves as juvenile habitat for many commercial species including blue crabs, Atlantic croaker, weakfish, and summer flounder. However, the occurrence of these species in these habitats as juveniles does not necessarily translate to these habitats being critical to juvenile survival or subsequent adult recruitment (Beck et al., 2001). Quantifying and identifying critical nursey habitat is difficult given the propensity for juveniles to use a variety of different habitats and the logistical requirements needed to relate habitat losses directly to changes in fisheries productivity (e.g., Heck et al., 2003).

The SAV suffered major declines in spatial coverage during the middle to late 20th century (Kemp et al., 2005). Documented declines in the 1960s and 1970s are an important indicator that the Chesapeake had undergone a regime shift (Orth et al., 2017), and restoration targets for spatial SAV coverage are used to measure the success of efforts to achieve total maximum daily load (TMDL) targets for nitrogen, phosphorus, and sediments from the watershed. Recent work has focused on the recovery of SAV in the Chesapeake associated with improved water clarity (e.g., Lefcheck et al., 2018). A comprehensive aerial monitoring program supported since the 1980s has been used to document the re-colonization of 170 km^2 since 1984 (Lefcheck et al., 2018). Nevertheless, it is not clear whether this has been beneficial to fisheries (Wainger et al., 2017). However, there are some local sites where the resurgence of SAV may have enabled fish stocks to rebound, e.g., the resurgence of largemouth bass (*Micropterus salmoides*) in Mattawoman Creek, a subestuary of the Potomac River (Boynton et al., 2014).

Excess nutrient loading has also resulted in bottom-water anoxia–hypoxia in the mesohaline reach of the mainstem bay, as well as portions of tributaries and tidal creeks, and may imply associated habitat loss (Chapter 9). At the ecosystem level, there are signs that this shift in ecosystem function has propagated to the fish community in the form of changes in the ratio of benthic and pelagic fish biomass (e.g., Diaz & Rosenberg, 1995). Seitz et al. (2009) documented effects on secondary production of the benthos where biomass, density, and diversity were positively correlated with dissolved oxygen concentrations; and Hanks & Secor (2011) provide evidence for a decline in growth rates of juvenile white perch under low oxygen conditions. In the Rappahannock River, a loss of species diversity, especially in the benthos, has been linked with intermittent hypoxic conditions (Llansó, 1992). However, numerical modeling suggests that hypoxia may have a positive effect on striped bass via increases in the concentration of prey and predation efficiency (Costantini et al., 2008).

10.5.3. Climate Change

10.5.3.1. Adriatic Sea

In addition to natural temperature and salinity fluctuations (Buljan, 1953; Civitarese et al., 2010), climate-driven warming of Adriatic waters may have an adverse effect on the survival of boreal fish species (e.g., sprat and whiting) that are relatively more widespread in the Adriatic, especially in the northern part, than elsewhere in the Adriatic and Mediterranean Seas. Unfortunately, no clear historical trends of such parameters are available for statistical analysis about potential consequences on fisheries.

The prawn (*Penaeus kerathurus*), not recorded in the Northern Adriatic before the 20th century, has supported a valuable fishery for the past decade (Figure 10.13). The stock increase may be related to warming of the Adriatic and the build up of suitable nursery grounds along the west coast after the construction of detached breakwaters to reduce sandy beach erosion (Froglia et al., 2013).

Barausse et al. (2011) postulated that increases in temperature and the duration of warm weather combined with increases in the flow of the Po Rivers and fishing pressure have altered the composition of the Adriatic marine community from large, late-maturing species with relatively low fecundity to smaller, earlier-maturing species with relatively high fecundity. The species diversity of food webs has shifted towards smaller, lower trophic-level species, and model simulations of species losses indicate that today's ecosystems may be less robust to species extinctions than in the past (Fortibuoni et al., 2017; Lotze et al., 2011).

10.5.3.2. Chesapeake Bay

Climate-driven warming may affect living resources by favoring warm-temperate species at the expense of cold-temperate species (Najjar et al., 2010; Kennedy, 1990), thus affecting ecosystem dynamics and fisheries productivity. For CB, such warming may affect the distribution of species whose southern range is the Chesapeake region. For example, adults of the commercial soft-shell clam die at summer temperatures of 32–33°C (Kennedy & Mihursky, 1971). These temperatures now occur during anomalously warm summers in the CB region (Ding & Elmore, 2015) and the species may be lost from the bay as waters continue to warm (Houde, 2011; Kennedy, 1990). On the other hand, species such as penaeid shrimps (white *Litopenaeus setiferus*, brown *Farfantepenaeus aztecus*, and pink *Farfantepenaeus duorarum*) whose northern limit of their commercial fisheries is North Carolina may find warmer water in the mid-Atlantic Bight suitable to support year-round populations of commercial abundances. Warmer temperatures may affect temporal patterns in species biology, and, potentially, species interactions. Wingate and Secor (2008) and Atkinson and Secor (2017) have shown that phenological shifts in response to warming can have important effects on hatch dates and growth of juvenile fish, especially during fall and winter.

Bottom-up trophic structure is also likely to be affected by climate change, although there is conflicting evidence about how these changes will manifest. For example, observations show that increases in temperature and associated increases in vertical stratification favor the growth of small phytoplankton at the expense of larger diatoms on regional scales (Guinder & Molinero, 2013; Li et al., 2009; Rousseaux & Gregg, 2015), while increases in nutrient concentration and vertical turbulence favor the growth of larger diatoms at the expense of smaller phytoplankton (Marinov et al., 2010). However, experimental results of Sett et al. (2018) show a shift towards larger diatoms in a natural phytoplankton assemblage under combined high-CO_2 and warming conditions.

10.5.4. Invasive Species

10.5.4.1. Adriatic Sea

Marine biodiversity of the Mediterranean Sea faces substantial structural changes in flora and fauna (Coll, Piroddi, et al., 2010), in part because of invasions of nonindigenous fishes, including in the Adriatic Sea where there are ~190 of known nonindigenous species (Zenetos et al., 2012). During recent decades, various factors such as climate-driven increases in water temperature have enabled nonindigenous species to establish themselves as invasive species, altering the composition of Adriatic ichthyofauna (Dulčić & Grbec, 2000; Lipej & Dulčić, 2004; Pečarević et al., 2013). Lessepsian migration (migration of species into the Adriatic from the Red Sea through the Suez Canal) has been a significant source of nonindigenous species since the construction of the Suez Canal. Three of the 14 Lessepsian fish migrants that have successfully established themselves in the southern Adriatic include the bluespotted cornetfish *Fistularia commersonii*, silver-cheeked toadfish *Lagocephalus sceleratus*, and dusky spinefoot *Siganus luridus* (Dulčić & Dragičević, 2011, 2014). It is not known if these species have affected the abundance and distribution of native fishes in the Adriatic, but they have substantially changed the composition of fish communities in the eastern Mediterranean Sea.

Warm-water species of green algae (*Caulerpa taxifolia* and *C. racemosa* var. *cylindracea*) have adversely affected the ecological balance in benthic communities and pose a threat to Adriatic biodiversity (Meinesz et al., 1993). In the infralittoral zone both species of noxious weed overgrow indigenous algae, seagrass meadows, and sessile animals, thus leading to substantial changes in biodiversity and ecology of infralittoral communities. Little is known about the ways in which *C. racemosa* var. *cylindracea* affects animal species, but preliminary surveys showed that within 2 years this alga can create sufficiently dense populations resulting in the loss of > 90% of indigenous algae species and sessile animals. Research into the effects of *C. taxifolia* on fish showed a substantial decline in the number of species, individuals, and biomass in areas with dense population versus areas where *C. taxifolia* is absent (Harmelin-Vivien et al., 1999). This plant species produces several toxic substances and secondary metabolites repellent to herbivore species and has an adverse effect on bacteria, monocellular organisms, eggs, and higher organisms, including algae and seagrasses.

10.5.4.2. Chesapeake Bay

As in the Adriatic Sea, CB has experienced numerous introductions, deliberate and inadvertent, of nonindigenous species (Ruiz et al., 2000, 2015). The protozoan parasite, MSX, that has killed eastern oysters for decades apparently was introduced to CB in association with the Pacific oyster *Crassostrea gigas*, which various agencies had introduced at different times to the bay in the 20th century (Burreson et al., 2000). A second invader, the veined rapa whelk *Rapana venosa* is a carnivorous snail first noted in the lower Chesapeake in 1998 (Harding & Mann, 1999; Mann & Harding, 2000). The whelk is a predator of the Bay's commercially important northern quahog (Savini et al., 2002). The Asian clam *Corbicula fluminea* has invaded some freshwater tributaries of the Chesapeake (Kennedy & Van Heukelem, 1985). In the Potomac River near Washington DC, this mollusk is thought to be responsible for SAV resurgence through its filtration activity that, in turn, improved water-column clarity (Phelps, 1994).

Two species of catfish were introduced to tributaries in the lower CB as recreational species (Bilkovic & Ihde, 2014). Flathead catfish *Pylodictis olivaris* were stocked in the James River in the late 1960s and blue catfish *Ictalurus furcatus* were introduced to three Virginia tributaries during the 1970s and 1980s. These two species, especially the blue catfish, have proliferated and expanded their range. Blue catfish are now common in tributaries throughout the Chesapeake watershed (Fabrizio et al., 2018). These species may be detrimental to native fish populations in the Chesapeake (Brown et al., 2005), so research into their biology is underway.

A third alien fish species, the northern snakehead *Channa argus*, first discovered in the Chesapeake in the early 2000s, has expanded its range over the years (Odenkirk & Owens, 2007). Its diet has been compared with the diets of largemouth bass, American eel, and yellow perch *Perca flavescens* from the same tidal freshwater habitat of the Potomac River (Saylor et al., 2012). Northern snakehead fed mostly on fish. Its diet overlapped with that of largemouth bass, but not eel or perch that fed more on invertebrates.

10.6. FISHERIES MANAGEMENT

10.6.1. Adriatic Sea

Small pelagic fish of commercial importance in the Adriatic are subject to intense commercial exploitation and are considered to be overexploited (Cataudella &

Spagnolo, 2011; FAO, 2016; ISMEA, 2013, 2015; STECF, 2013). Long-term time series (1970–2014) for small pelagics (GFCM-SAC, 2015a) and common sole (GFCM-SAC, 2015b; STECF, 2016) show that stocks began to decline much earlier than 2007. For the past 15 years, fish landings rose or remained above maximum sustainable yields in the Mediterranean Sea (Cardinale & Scarcella, 2017; Vasilakopoulos et al., 2014), and, until 2014, average annual landings for the main demersal and small pelagic stocks were around three times estimated levels of FMSY (STECF, 2015).

To address this problem, the Common Fisheries Policy (CFP) was established in 1970 as an instrument of the EU in order to achieve maximum sustainable yields and reduce bycatch on regional scales. It establishes binding measures and rules for the sustainable management of European fisheries. The CFP includes measures for "effort control" (i.e., controlling where and when fishers can fish, limiting vessel usage, and regulating gear usage) and for establishing catch limits for each fishery; the importance of using the best available scientific advice as a basis for implementing these measures is emphasized. Under the CFP, a Data Collection Framework is in force based on several key principles including accuracy, reliability and timeliness, safe storage in database systems, and compliance with laws on personal data protection. The concept of the CFP is, in theory, supported by the effort to develop an ecosystem approach to fisheries management (Carpi et al., 2017). Since its inception, the CFP has had mixed results with successes in the NE Atlantic (Cardinale et al., 2013; Fernandes & Cook, 2013) and failures in the Mediterranean Sea (Colloca et al., 2013; Vasilakopoulos et al., 2014). Recently a multiyear plan for small pelagic fish stocks in the Adriatic Sea was introduced (European Parliament, 2017), the objectives of which are to reach and maintain maximum sustainable yields. Targets are included for anchovy and sardine as advised by the Scientific, Technical and Economic Committee for Fisheries (STECF).

The problem of shared stocks (i.e., those that migrate seasonally into and out of jurisdictions and those that are distributed over multiple jurisdictions) is a major issue in the Adriatic. Regulation of fishing effort has been difficult and determining appropriate levels of effort and gears to achieve optimum harvests is problematic; the complexity of fishery management and associated controversies in the Adriatic were reviewed by Carpi et al. (2017). In addition, Cardinale and Scarcella (2017) have shown that fish landings and catch per unit effort can be decoupled because effort reduction does not necessarily correspond to reduced landings, and nominal effort may not be an accurate measure of the actual effort, especially for passive gears (Castro Ribeiro et al., 2015, 2016). The measures of effort used are adequate for trawling and purse seines, but less so for small-scale fisheries because catches are such a small percentage of total landings (Cardinale & Scarcella, 2017).

Using anchovy, sardine, and Norway lobster fisheries in the Adriatic Sea as examples, Carpi et al. (2017) assessed the efficacy of fisheries management over the past decade and highlight the need for sustained monitoring, skillful assessment models, regular external reviews of assessments, and shifting from effort control to a quota-based system in order to align Mediterranean management with the CFP and achieve maximum sustainable yield targets. They concluded that the CFP has not lived up to its goal of enhancing the sustainability of fish stocks.

10.6.2. Chesapeake Bay

As in the Adriatic Sea, fisheries in Chesapeake Bay are managed under a complex set of overlapping jurisdictions, including multiple state, interstate, and federal agencies. Four entities manage nonmigratory stocks within the bay: Maryland, Virginia, the Potomac River Fisheries Commission (PRFC), and the District of Columbia. Species that are managed separately by each organization include freshwater fishes, oysters, several species of clams, and white perch. Blue crab is managed through a joint agreement among the jurisdictions. Migratory species with fisheries primarily in coastal waters (< 3 nautical miles) are managed under the ASMFC, which includes representation from all the Atlantic coastal states of the United States and other fishery management agencies (PRFC and the District of Columbia). Species managed under ASMFC jurisdiction include Atlantic menhaden, Atlantic croaker, spot, Atlantic sturgeon, and striped bass. The most complex management arrangements with joint management between state and federal agencies are for migratory species with fisheries in both coastal waters and federal waters (> 3 nautical miles). Summer flounder and bluefish are examples of such species.

Major changes in management were instituted in the 1980s, including changes in interstate management on the US Atlantic coast in order to respond to the depleted striped bass stock (Richards & Rago, 1999). Changes were adopted that allowed the federal government to close or impose moratoria on state fisheries that were out of compliance with ASMFC management. These changes greatly strengthened ASMFC's ability to enforce consistent and coastwide management for many species fished in the Chesapeake. Thus, a moratorium was declared on striped bass fishing in Maryland, and Virginia imposed strong restrictions on landings that supported rebuilding healthy populations in the mid-1990s. Stock assessments that estimate abundance and fishing mortality rates are now used to set quotas for many finfish species. Another major management change occurred in the early 2000s after changes in the primary law that governs US federal fisheries (Magnuson-Stevens Fishery Conservation and Management Act), which required rebuilding of overfished stocks (Mace, 2002). Following this change, summer flounder was successfully rebuilt (Terceiro, 2015).

Historically, there was little coordination in fisheries management among Chesapeake jurisdictions for species that were not under ASMFC or US federal management. For the blue crab, the BBCAC was established in the early 2000s (see section 10.5.1.2). In 2008, after a rigorous stock assessment, several measures were adopted that included closing the Virginia winter dredge fishery (Miller et al., 2011). Management measures were effective, and the fishery has recovered from its low levels in the early 2000s.

Blue crab has a stock assessment specific to Chesapeake Bay (Miller et al., 2011). The stock assessments for all other species are at larger or smaller scales than the bay. This lack of abundance estimates at the CB level causes some problems for management. For example, one of the largest management issues in the region is currently how to manage the Atlantic menhaden fishery, because Atlantic menhaden not only support valuable bait and reduction fisheries but they are also important prey for many piscivorous species, including striped bass. The fishery for Atlantic menhaden is primarily conducted in CB and the coastal Atlantic Ocean and there are concerns about potential depletion of the species in the bay, which cannot be resolved with current stock-assessment estimates.

Fisheries in CB are currently still managed using, for the most part, species-specific approaches. However, a Fisheries Ecosystem Plan has been developed and adopted as a guide by the Chesapeake Bay Program (CBFEAP, 2006). Yet, the complex needs for ecosystem-based fisheries management (e.g., Houde, 2011) have not been incorporated into management plans. Important components of an ecosystem-based fisheries management plan include habitat and water quality considerations and predator–prey interactions as well as fish harvests. Major efforts have been undertaken to improve water quality in the Chesapeake through nutrient reduction efforts (Chapter 5). In addition, large programs are currently underway to increase oyster habitat and abundance (Bersoza Hernández et al., 2018). The Sustainable Fisheries Goal Implementation Team in the Chesapeake Bay Program is working to develop plans that incorporate ecosystem-based criteria, especially for forage fishes, oyster, blue crab, and invasive catfishes (Hunt et al., 2018). The ASMFC is currently developing approaches for Atlantic menhaden management that include defining "ecosystem reference points" (Buchheister et al., 2017) that account for menhaden's role as important prey in the diets of popular sportfish like striped bass. Lastly, in precautionary management, more conservative targets for fishing mortality rates have been adopted for major Chesapeake fisheries since 2000.

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REFERENCES

Aprahamian, M.W., Baglinière, J.-L., Sabatié, M.R., Alexandrino, P., Thiel, R., & Aprahamian, C.D. (2003). Biology, status, and conservation of the anadromous Atlantic twaite shad *Alosa fallax fallax*. *American Fisheries Society Symposium*, *35*, 103–124. www.researchgate.net/publication/279907758

Aschonitis, V., Castadelli, G., Lanzoni, M., Rossi, R., Kennedy, C., & Fano, E.A. (2017). Long-term records (1781–2013) of European eel (*Anguilla anguilla* L.) production in the Comacchio Lagoon (Italy): Evaluation of local and global factors as causes of the population collapse. *Aquatic Conservation: Marine and Freshwater Ecosystems*, *27*(2), 502–520. https://doi:10.1002/aqc.2701

ASMFC. (2007). *American shad stock assessment report for peer review* (Vol. 1, Stock Assessment Report No. 07-01 (Supplement), pp. 1–224). Arlington, VA: Atlantic States Marine Fisheries Commission. www.asmfc.org/uploads/file/2007ShadStockAssmtReportVolumeI.pdf

ASMFC (2012). *River herring benchmark stock assessment* (Vol. I, Stock Assessment Report No. 12-2, pp. 1–392). Arlington, VA: Atlantic States Marine Fisheries Commission. www.asmfc.org/uploads/file/riverHerringBenchmarkStockAssessmentVolumeIR_May2012.pdf

ASMFC (2016). *Atlantic striped bass stock assessment update 2016* (pp. 1–101). Arlington, VA: Atlantic States Marine Fisheries Commission. www.asmfc.org/uploads/file/581ba8f5AtlStripedBassTC_Report2016AssmtUpdate_Oct2016.pdf

ASMFC (2017a). *Atlantic sturgeon benchmark stock assessment and peer review report* (pp. 1–456). Arlington, VA: Atlantic States Marine Fisheries Commission. www.asmfc.org/files/Meetings/AtlMenhadenBoardNov2017/AtlSturgonBenchmarkStockAssmt_PeerReviewReport_2017.pdf

ASMFC (2017b). *2017 Atlantic menhaden stock assessment update* (pp. 1–180). Arlington, VA: Atlantic States Marine Fisheries Commission. www.asmfc.org/uploads/file/59832ee0MenhadenStockAssessmentUpdate_Aug2017.pdf

ASMFC (2017c). *Amendment 3 to the Interstate Fishery Management Plan for Atlantic menhaden* (Atlantic Menhaden Plan Development Team, November). Arlington, VA: Atlantic States Marine Fisheries Commission. www.asmfc.org/uploads/file//5a4c02e1AtlanticMenhadenAmendment3_Nov2017.pdf

Atkinson, A.N., & Secor, D.H. (2017). Influence of winter conditions on the age, hatch dates, and growth of juvenile Atlantic Menhaden in the Choptank River, Maryland.

Transactions of the American Fisheries Society, *146* (6), 1126–1136. https://doi.org/10.1080/00028487.2017.1348985

Baird, D., & Ulanowicz, R.E. (1989). The seasonal dynamics of the Chesapeake Bay ecosystem. *Ecological Monographs*, *59*, 329–364. https://doi.org/10.2307/1943071

Barausse, A., Michieli, A., Riginella, E., Palmeri, L., & Mazzoldi, C. (2011). Long-term changes in community composition and life-history traits in a highly exploited basin (northern Adriatic Sea): The role of environment and anthropogenic pressures. *Journal of Fish Biology*, *79*,1453–1486. https://doi:10.1111/j.1095-8649.2011.03139.x

BBCAC (2001). *Taking action for the Blue Crab: Managing and protecting the stock and its fisheries* (Bi-State Blue Crab Advisory Committee Final Report, pp. 1–28). Edgewater, MD: Chesapeake Bay Commission. www.chesbay.us/Publications/Archive%20Publications/BBCACReportfinal.pdf

Beck, M.W., Heck, K.L., Able, K.W., Childers, D.L., Eggleston, D.B., Gillanders, B.M., et al. (2001). The identification, conservation, and management of estuarine and marine nurseries for fish and invertebrateS.*Bioscience*, *51*, 633–641. https://doi.org/10.1641/0006-3568(2001)051[0633:TICAMO]2.0.CO;2

Bersoza Hernández, A., Brumbaugh, R.D., Frederick, P., Grizzle, R., Luckenbach, M.W., Peterson, C.H., & Angelini, C. (2018). Restoring the eastern oyster: how much progress has been made in 53 years? *Frontiers in Ecology and the Environment*, *16*, 463–471. https://doi.org/10.1002/fee.1935

Bilkovic, D.M., & Ihde, T.F. (2014). *Review of the final report of the sustainable fisheries goal implementation team invasive catfish task force.* (No. 14-007, pp. 1–46). Edgewater, MD. Chesapeake Bay Program Scientific and Technical Advisory Committee. www.chesapeakebay.net/documents/FINAL_STAC_Invasive_Catfish_Review_Report_11.7.14.pdf

Bolognini, L., Bombace, G., Grati, F., & Scarella, G. (2017). Andamento dello stato delle risorse demersali in Adriatico nel periodo 2004–2012 e considerazioni alieutiche, economiche ed ecologiche. In M. Marini, G. Bombace, G. Iacobone (Eds.), *Il Mare Adriatico e le sue risorse* (pp. 97–117). Ancona, Italy: Carlo Saladino Editore. www.coispa.it/docs/Il%20Mare%20Adriatico%20e%20le%20sue%20risorse%20-%202017.pdf

Bombace, G. (2017). Premessa al convegno ed alcune riflessioni sull'Adriatico. In M. Marini, G. Bombace, G. Iacobone (Eds.), *Il Mare Adriatico e le sue risorse* (pp. 15–38). Ancona, Italy: Carlo Saladino Editore www.coispa.it/docs/Il%20Mare%20Adriatico%20e%20le%20sue%20risorse%20-%202017.pdf

Boynton, W.R., Hodgkins, C.L.S., O'Leary, C.A., Bailey, E.M., Bayard, A.R., & Wainger, L.A. (2014). Multi-decade responses of a tidal creek system to nutrient load reductions: Mattawoman Creek, Maryland USA. *Estuaries and Coasts*, *37*(Supplement 1), 111–127. https://doi.org/10.1007/s12237-013-9690-4

Brown, J.J., Perillo, J., Kwak, T.J., & Horwitz, R.J. (2005). Implications of *Pylodictis olivaris* (flathead catfish) introduction into the Delaware and Susquehanna drainages. *Northeastern Naturalist*, *12*(4), 473–484. https://doi.org/10.1656/1092-6194(2005)012[0473:IOPOFC]2.0.CO;2

Buchheister, A., Miller, T.J., & Houde, E.D. (2017). Evaluating ecosystem-based reference points for Atlantic Menhaden. *Marine and Coastal Fisheries*, *9*, 457–478. https://doi.org/10.1080/19425120.2017.1360420

Buljan, M. (1953). Fluctuations of salinity in the Adriatic. In *The M.V. Hvar cruises—researches into fisheries biology, 1948–49* (Izvješća-Reports, 2(3), 64 pp). Split, Croatia: Institut za oceanografiju i ribarstvo.

Burreson, E.M., Stokes, N. A., & Friedman, C.S. (2000). Increased virulence in an introduced pathogen: *Haplosporidium nelsoni* (MSX) in the eastern oyster *Crassostrea virginicA*. *Journal of Aquatic Animal Health*, *12*(1), 1–8. dx.doi.org/10.1577/1548-8667(2000)012<0001:IVIAIP>2.0.CO;2

Cardinale, M., Dörner, H., Abella, A, Andersen J. L., Casey, J., Döring, R., et al. (2013). Rebuilding EU fish stocks and fisheries, a process under way? *Marine Policy*, *39*, 43–52. https://doi.org/10.1016/j.marpol.2012.10.002

Cardinale, M., & Scarcella, G. (2017). Mediterranean Sea: A failure of the European Fisheries Management System. *Frontiers in Marine Science*, *4*(72). https://doi:10.3389/fmars.2017.00072

Carpi, P., Santojanni, A., Donato, F., Colella, S., Čikeš Keč, V., Zorica, B., et al. (2015). A joint stock assessment for the anchovy stock of the northern and central Adriatic Sea: comparison of two catch-at-age models. *Scientia Marina 79*, 57–70. https://doi:10.3989/scimar.03903.29A

Carpi, P., Scarcella, G., & Cardinale, M. (2017). The saga of the management of fisheries in the Adriatic Sea: History, flaws, difficulties, and successes toward the application of the common fisheries policy in the Mediterranean. *Frontiers in Marine Science*, *4*, 423. https://doi:10.3389/fmars.2017.00423

Castro Ribeiro, C., Holmes, S., Scott, F., Berkenhagen, J., Demaneche, S., Prista, N., et al. (2016). *Report of the 2nd workshop on transversal variables* (Nicosia, Cyprus, 22–26 February; a DCF ad-hoc workshop; EUR 27897). https://doi:10.2788/042271

Castro Ribeiro, C., Holmes, S., Scott, F., Calvo Santos, A., Verlé, K., Vukov, I., et al. (2015) *Report of the workshop on transversal variables (Linking economic and biological effort data (call) design)* (Zagreb, 19–23 January). https://doi:10.2788/385049

Cataudella, S., & Spagnolo, M. (2011). *Lo stato della pesca e dell'acquacoltura nei mari Italiani*. Rome, Italy: Ministero delle Politiche Agricole Alimentari e Forestali. www.politicheagricole.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/5164#main

CBFEAP (2006). *Fisheries ecosystem planning for Chesapeake Bay (American Fisheries Society, Trends in Fisheries Science and Management 3)*. Bethesda, MD: Chesapeake Bay Fisheries Ecosystem Advisory Panel.

Civitarese, G., Gačić, M., Lipizer, M., & Eusebi Borzelli, G.L. (2010). On the impact of the Bimodal Oscillating System (BiOS) on the biogeochemistry and biology of the Adriatic and Ionian Seas (Eastern Mediterranean). *Biogeosciences*, *7*, 3987–3997. https://doi.org/10.5194/bg-7-3987-2010

Coll, M., Piroddi, C., Steenbeek, J., Kaschner, K., Ben Rais Lasram, F., Aguzzi, J., et al. (2010b). The biodiversity of the Mediterranean Sea: Estimates, patterns, and threats. *PLOS ONE*, *5*(8): e11842. https://doi.org/10.1371/journal.pone.0011842

Coll, M., Santojanni, A., Palomera, I., & Arneri, E. (2010a). Ecosystem assessment of the North-Central Adriatic Sea: towards a multivariate reference framework. *Marine Ecology Progress Series*, *417*(4): 193–210. https://doi.org/10.3354/meps08800

Coll, M., Santojanni, A., Palomera, I., Tudela, S., & Arneri, E. (2007). An ecological model of the Northern and Central Adriatic Sea: Analysis of ecosystem structure and fishing impacts. *Journal of Marine Systems*, *67*(1–2), 119–154. https://doi.org/10.1016/j.jmarsys.2006.10.002

Colloca, F., Cardinale, M., Maynou, F., Giannoulaki, M., Scarella, G., Jenko, K., et al. (2013). Rebuilding Mediterranean fisheries: a new paradigm for ecological sustainability. *Fish and Fisheries*, *14*(1), 89–109. https://doi.org/10.1111/j.1467-2979.2011.00453.x

Colloca, F., Scarcella, G., & Libralato, S. (2017). Recent trends and impacts of fisheries exploitation on Mediterranean stocks and ecosystems. *Frontiers in Marine Science*, *4*(244), 1–13. https://doi.org/10.3389/fmars.2017.00244

Costantini, M., Ludsin, S.A., Mason, D.M., Zhang, X., Boicourt, W.C., & Brandt, S.B. (2008). Effect of hypoxia on habitat quality of striped bass (*Morone saxatilis*) in Chesapeake Bay. *Canadian Journal of Fisheries and Aquatic Sciences*, *65*, 989–1002. https://doi:10.1139/F08-021

Diaz, R.J., & Rosenberg, R. (1995) Marine benthic hypoxia: a review of its ecological effects and the behavioural responses of benthic macrofauna. *Oceanography and Marine Biology Annual Review*, *33*, 245–303.

Ding, H., & Elmore, A.J. (2015). Spatio-temporal patterns in water surface temperature from Landsat time series data in the Chesapeake Bay, U.S.A. *Remote Sensing of Environment*, *168*, 335–348. https://doi.org/10.1016/j.rse.2015.07.009

Dulčić, J., & Dragičević, B. (2011). *New fishes of the Adriatic and the Mediterranean Sea (160 pp.)*. Split, Croatia: Institute of Oceanography and Fisheries/State Institute for Nature Protection.

Dulčić, J., & Dragičević, B. (2014). Occurrence of Lessepsian migrant *Lagocephalus sceleratus* (Tetraodontidae) in the Adriatic Sea. *Cybium*, *38*(3), 238–240.

Dulčić, J., & Grbec, B. (2000). Climate change and Adriatic ichthyofauna. *Fisheries Oceanography*, *9*(2), 187–191. https://doi.org/10.1046/j.1365-2419.2000.00128.x

European Commission (2009a). *Green paper reform of the Common Fisheries Policy* (22.04.2009). Brussels. https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2009:0163:FIN:EN:PDF

European Commission (2009b). *The Common Fisheries Policy: A Practical Guide*. www.europarl.europa.eu/document/activities/cont/200907/20090720ATT58547/20090720ATT58547EN.pdf

European Environment Agency (1999). Coastal and Marine Zones. In *Environment in the European Union at the turn of the century* (Environmental Assessment Report No 2, pp. 357–375).Copenhagen.www.eea.europa.eu/publications/92-9157-202-0/3.14.pdf/view

European Environment Agency (2006). *The changing faces of Europe's coastal areas* (EEA Report No 6/2006, pp. 1–107). Luxembourg.

European Fleet Register (2014). Fleet Register on the NeT. http://ec.europa.eu/fisheries/fleet/index.cfm

European Parliament (2017). *Proposal for a regulation of the European Parliament and of the Council establishing a multi-annual plan for small pelagic stocks in the Adriatic Sea and the fisheries exploiting those stocks* (EU Legislation in Progress). www.europarl.europa.eu/RegData/etudes/BRIE/2017/599351/EPRS_BRI(2017)599351_EN.pdf

Fabrizio, M.C., Tuckey, T.D., Latour, R.J., White, G.C., & Norris, A.J. (2018). Tidal habitats support large numbers of invasive blue catfish in a Chesapeake Bay subestuary. *Estuaries and Coasts*, *41*, 827–840. https://doi.org/10.1007/s12237-017-0307-1

FAO (2016). *Report of the Fortieth Session of the General Fisheries Commission for the Mediterranean (GFCM)* (St. Julian's, Malta, 22 May–3 June). Rome: Food and Agricultural Organization.

Fenske, K.H., Wilberg, M.J., Secor, D.H., & Fabrizio, M.C. (2011). An age- and sex-structured assessment model for American eels (*Anguilla rostrata*) in the Potomac River, Maryland. *Canadian Journal of Fisheries and Aquatic Sciences*, *68*(6), 1024–1037. https://doi:10.1139/F2011-038

Fernandes, P.G., & Cook, R.M. (2013). Reversal of fish stock decline in the Northeast Atlantic. *Current Biology*, *23*(15), 1432–1437. https://doi.org/10.1016/j.cub.2013.06.016

Fortibuoni, T., Giovanardi, O., Pranovi, F., Raicevich, S., Solidoro, C., & Libralato, S. (2017). Analysis of long-term changes in a Mediterranean marine ecosystem based on fishery landings. *Frontiers in Marine Science*, *4*(33), 1–16. https://doi:10.3389/fmars.2017.00033

Freyhof, J., & Kottelat, M. (2008). *Alosa fallax*. In *IUCN Red List of Threatened Species. Version 2013.2*. www.iucnredlist.org

Froese, R., Henning, W., Gianpaolo, C., Demirel, N., Tsikliras, A.C., Dimarchopoulou, D., et al. (2018). Status and rebuilding of European fisheries. *Marine Policy*, *93*, 159–170. https://doi.org/10.1016/j.marpol.2018.04.018

Froglia, C., Scarcella, G., & Lucchetti, A. (2013). On the recent increase of *Penaeus (Melicertus) kerathurus* stock in Northern and Central Adriatic Sea: Possible explanations. *Rapport, Commission Internationale pour L'exploration Scientifique de la Mer Méditerranée*, *40*, 780.

GFCM (2018). *GFCM capture production (1970–2016)*. General Fisheries Commission for the Mediterranean. www.fao.org/gfcm/data/capture-production

GFCM-SAC (2012). *Report of the working group on stock assessment of demersal species* (pp. 1–81). General Fisheries Commission for the Mediterranean, Scientific Advisory Committee on Fisheries. www.fao.org/3/a-ax859e.pdf

GFCM-SAC (2015a). *Report of the working group on stock assessment of small pelagic species (WGSASP),* 1–83. General Fisheries Commission for the Mediterranean, Scientific Advisory Committee on Fisheries. www.fao.org/gfcm/reports/technical-meetings/en/

GFCM-SAC (2015b). *Report of the working group on stock assessment of demersal species (WGSAD)* (pp. 1–60). General Fisheries Commission for the Mediterranean, Scientific Advisory Committee on Fisheries. www.fao.org/gfcm/reports/technical-meetings/en/

Grabowski, J.H., & Peterson, C.H. (2007). Restoring oyster reefs to recover ecosystem services. In K. Cuddington, J.E. Byers, W.G. Wilson, A. Hastings (Eds.), *Ecosystem engineers: plants to protists* (pp. 281–298). Burlington, MA: Elsevier/ Academic Press.

Grbec, B., Dulčić, J., & Morović, M. (2002). Long-term changes in landings of small pelagic fish in the eastern Adriatic—possible influence of climate oscillations over the Northern Hemisphere. *Climate Research*, *20*, 241–252. https://doi:10.3354/cr020241

Guinder, V.A., & Molinero, J.C. (2013). Climate change effects on marine phytoplankton. In A.H. Arias, M.C. Menendez (Eds). *Marine ecology in a changing world* (pp. 68–90). Boca Raton, FL: CRC Press. https://doi:10.1201/b16334-4

Hanks, D.M., & Secor, D.H. (2011). Bioenergetic responses of Chesapeake Bay white perch (*Morone americana*) to nursery conditions of temperature, dissolved oxygen, and salinity. *Marine Biology*, *158*(4), 805–815. https://doi.org/10.1007/s00227-010-1608-0

Harding, J.M., & Mann, R. (1999). Observations on the biology of the veined rapa whelk, *Rapana venosa* (Valenciennes, 1846) in the Chesapeake Bay. *Journal of Shellfish Research*, *18*(1), 9–17.

Harding, J.M., & Mann, R. (2001). Diet and habitat use by bluefish, *Pomatomus saltatrix*, in a Chesapeake Bay estuary. *Environmental Biology of Fishes*, *60*(4), 401–409. https://doi.org/10.1023/A:1011071127930

Hare, J.A., Alexander, M.A., Fogarty, M.J., Williams, E.H., & Scott, J.D. (2010). Forecasting the dynamics of a coastal fishery species using a coupled climate–population model. *Ecological Applications*, *20*(2), 452–464. https://doi.org/10.1890/08-1863.1

Hargis, W.J. Jr., & Haven, D.S. (1999). Chesapeake oyster reefs, their importance, destruction and guidelines for restoring them. In M.W. Luckenbach, R. Mann, J.A. Wesson (Eds.), *Oyster reef habitat restoration: a synopsis and synthesis of approaches* (pp. 329–358). Gloucester Point, VA: Virginia Institute of Marine Science. https://doi.org/10.21220/V5NK51

Harmelin-Vivien, M., Francour, P., & Harmelin, J-G. (1999). Impact of *Caulerpa taxifolia* on Mediterranean fish assemblages: a six year study. In *Proceedings of the Workshop on Invasive* Caulerpa *species in the Mediterranean* (pp. 127–138). Athens: United Nations Environment Programme.

Heck, K.L., Jr., Hays, G., & Orth, R.J. (2003). Critical evaluation of the nursery role hypothesis for seagrass meadows. *Marine Ecology Progress Series*, *253*, 123–136. https://doi:10.3354/meps253123

Houde, E.D. (2011). *Managing the Chesapeake's fisheries: A work in progress* (UM-SG-CP-2011-01, pp. 1–121). Maryland Sea Grant College Program.

Houde, E.D., Jukić-Peladic, S., Brandt, S.B., & Leach, S.D. (1999). Fisheries: Trends in catches, abundances, and management. In T.C. Malone, A. Malej, L.W. Harding Jr., N. Smodlaka, R.E. Turner (Eds.), *Ecosystems at the land–sea margin: Drainage basin to coastal sea* (pp. 341–366). Washington, DC: American Geophysical Union.

Hunt, G., Bilkovic, D., Faulkner, S., Ihde, T.F., McGinty, M., Monaco, M., et al. (2018). *Factors influencing the headwaters, nontidal, tidal, and mainstem fish habitat function in the Chesapeake Bay watershed: Application to restoration and management decisions* (STAC Publication Number 18-006, 112 pp). Edgewater, MD: Chesapeake Bay Scientific and Technical Advisory Committee.

Ihde, T.F., Houde, E.D., Bonzek, C.F., & Franke, E. (2015). *Assessing the Chesapeake Bay forage base: Existing data and research priorities* (STAC Publication Number 15-005, pp. 1–198). Edgewater, MD: Chesapeake Bay Program Scientific and Technical Advisory Committee. www.chesapeake.org/pubs/346_Ihde2015.pdf

ISMEA (2013). *Il Settore Ittico in Italia: Check up Ittico 2013*. Roma. Istituto di Servizi per il Mercato Agri-colo Alimentare.

ISMEA (2015). *Congiuntura trimestrale—Ittico*. Roma. Istituto di Servizi per il Mercato Agri-colo Alimentare.

Jukić-Peladić, S., Vrgoč, N., Krstulović-Šifner, S., Piccinetti, C., Piccinetti-Manfrin, G., Marano, G. & Ungaro, N. (2001). Long-term changes in demersal resources of the Adriatic Sea: comparison between trawl surveys carried out in 1948 and 1998. *Fisheries Research*, *53*(1), 95–104. https://doi.org/10.1016/S0165-7836(00)00232-0

Jung, S., & Houde, E.D. (2005). Fish biomass size spectra in Chesapeake Bay. *Estuaries*, *28*, 226–240. https://doi.org/10.1007/BF02732857

Kemp, W. M., Boynton, W.R., Adolf, J.E., Boesch, D. F., Boicourt, W.C., Brush, G., et al. (2005) Eutrophication of Chesapeake Bay: historical trends and ecological interactions. *Marine Ecology Progress Series*, *303*, 1–29. https://doi:10.3354/meps303001

Kennedy, V.S. (1990). Anticipated effects of climate change on estuarine and coastal fisheries. *Fisheries (Bethesda)*, *15*(6), 16–24. https://doi.org/10.1577/1548-8446(1990)015<0016:AEOCCO>2.0.CO;2

Kennedy, V.S. (1996). The ecological role of the eastern oyster, *Crassostrea virginica*, with remarks on disease. *Journal of Shellfish Research*, *15*, 177–183. www.biodiversitylibrary.org/item/22068#page/183/mode/1up

Kennedy, V.S. (2018). *Shifting baselines in the Chesapeake Bay. An environmental history* (146 pp.). Baltimore, MD: Johns Hopkins University Press.

Kennedy, V.S., & Mihursky, J.A. (1971). Upper temperature tolerances of some estuarine bivalves. *Chesapeake Science*, *12*, 193–204. https://doi.org/10.2307/1350906

Kennedy, V.S., & Van Heukelem, L. (1985). Gametogenesis and larval production in a population of the introduced Asiatic clam, *Corbicula* sp. (Bivalvia: Corbiculidae), in Maryland. *Biological Bulletin*, *168*, 50–60. https://doi.org/10.2307/1541173

Krstulović Šifner, S., Vrgoč, N., Dadić, V., Isajlović, I., Peharda, M., & Piccinetii, C. (2009). Long-term changes in distribution and demographic composition of thornback ray, *Raja clavata*, in the northern and central Adriatic Sea. *Journal of Applied Ichthyology*, *26*, 40–46. https://doi.org/10.1111/j.1439-0426.2008.01204.x

Laffoley, D. d'A. (2000). Historical perspective and selective review of the literature on human impacts on the UK's marine environment. (DETR Working Group on the Review of Marine Nature Conservation, English Nature Research Report 391). Peterbrorough, UK: English Nature. www.jncc.gov.uk/pdf/ENRR391.pdf

Lefcheck, J.S., Orth, R.J., Dennison, W.C., Wilcox, D.J., Murphy, R.R., Keisman, J., et al. (2018). Long-term nutrient reductions lead to the unprecedented recovery of a temperate coastal region. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(14), 3658–3662. https://doi.org/10.1073/pnas.1715798115

Li, W.K.W., McLaughlin, F.A., Lovejoy, C., & Carmack, E.C. (2009). Smallest algae thrive as the Arctic Ocean freshens. *Science*, *326*, 539–539.

Libralato, S., Coll, M., Tempesta, M., Santojanni, A., Spoto, M., Palomera, I., et al. 2010. Food-web traits of protected and exploited areas of the Adriatic Sea. *Biological Conservation*, *143*(9), 2182–2194.

Limburg, K.E., & Waldman, J.R. (2009). Dramatic declines in North Atlantic diadromous fishes. *BioScience*, *59*(11), 955–965. https://doi.org/10.1525/bio.2009.59.11.7

Lipej, L., & Dulčić, J. (2004). The current status of Adriatic fish biodiversity. In H.I. Griffiths, B. Kryštufek, J.M. Reed (Eds.), *Balkan biodiversity: pattern and process in the European hotspot* (pp. 291–306). Dordrecht, The Neteherlands: Springer. https://doi.org/10.1007/978-1-4020-2854-0_17

Llansó, R.J. (1992). Effects of hypoxia on estuarine benthos: the lower RappahannockRiver (Chesapeake Bay), a case study. *Estuarine and Coastal Shelf Science*, *35*, 491–515. https://doi:10.1016/S0272-7714(05)80027-7

Lotze, H.K., Coll, M., & Dunne, J.A. (2011). Historical changes in marine resources, food-web structure and ecosystem functioning in the Adriatic Sea, Mediterranean. *Ecosystems*, *14*, 198–222. https://doi:10.1007/s10021-010-9404-8

Mace, P.M. (2002). A new role for MSY in single-species and ecosystem approaches to fisheries stock assessment and management. *Fish and Fisheries*, *2*(1), 2–32. https://doi.org/10.1046/j.1467-2979.2001.00033.x

MacKenzie Jr., C.L. (1997). The molluscan fisheries of Chesapeake Bay. In C.L. MacKenzie Jr., V.G. Burrell Jr., A. Rosenfield, W.L. Hobart (Eds.), *The history, present condition, and future of the molluscan fisheries of North and Central America and Europe, Volume 1, Atlantic and Gulf Coasts* (NOAA Technical Report, NMFS 127, pp. 141–169). Seattle, WA: US Department of Commerce. http://aquaticcommons.org/id/eprint/2687

Maitland, P.S., & Hatton-Ellis, T.W. (2003). *Ecology of the allis and twaite shad Alosa alosa and Alosa fallax* (Conserving Natura 2000 Rivers. Ecology Series No. 3, 28 pp.). Peterborough, UK: English Nature.

Mann, R., & Harding, J.M. (2000). Invasion of the North American Atlantic coast by a large predatory Asian mollusc. *Biological Invasions*, *2*(1), 7–22. https://doi.org/10.1023/A:1010038325620

Marinov, I., Doney, S.C., & Lima, I.D. (2010). Response of ocean phytoplankton community structure to climate change over the 21st century: partitioning the effects of nutrients, temperature and light. *Biogeosciences*, *7*, 3941–3959. https://doi:10.5194/bg-7-3941-2010

MDDNR (2018). *A stock assessment of the Eastern Oyster,* Crassostrea virginica*, in the Maryland waters of Chesapeake Bay* (Final Report, November, pp. 1–329). Annapolis, MD. Maryland Department of Natural Resources. https://dnr.maryland.gov/fisheries/Documents/StockAssessment_EasternOysterMD.pdf

Meinesz, A., de Vaugelas, J., Hesse, B., & Mari, X. (1993). Spread of the introduced tropical green alga *Caulerpa taxifolia* in northern Mediterranean waters. *Journal of Applied Phycology*, *5*, 141–147. https://doi:10.1007/BF00004009

Miller, T.J., Wilberg, M.J., Colton, A.R., Davis, G.R., Sharov, A., Lipcius, R.N., et al. (2011). *Stock assessment of blue crab in Chesapeake Bay (2011)* (Technical Report Series No. TS-614-11, pp. 1–214). University of Maryland Center for Environmental Science. http://hjort.cbl.umces.edu/crabs/Assessment.html

Najjar, R.G., Pyke, C.R., Adams, M.B., Breitburg, D., Hershner, C., Kemp, M., et al. (2010). Potential climate-change impacts on the Chesapeake Bay. *Estuarine, Coastal and Shelf Science*, *86*(1), 1–20. https://doi:10.1016/j.ecss.2009.09.026

NMFS 2016. *Fisheries economics of the United States, 2014* (NOAA Technical Memorandum NMFS-F/SPO-163, pp. 1–237). Seattle, WA: National Marine Fisheries Service, US Department of Commerce. www.st.nmfs.noaa.gov/economics/publications/feus/fisheries_economics_2014/index

Odenkirk, J., & Owens, S. (2007). Expansion of a northern snakehead population in the Potomac River system. *Transactions of the American Fisheries Society*, *136*, 1633–1639. https://doi.org/10.1577/T07-025.1

Orth, R.J., Dennison, W.C., Lefcheck, J.S., Gurbisz, C., Hannam, M., Keisman, J., et al. (2017). Submersed aquatic vegetation in Chesapeake Bay: Sentinel species in a changing world. *BioScience*, *67*(8), 698–712. https://doi.org/10.1093/biosci/bix058

Pećarević, M., Mikuš, J., Bratoš Cetinić, A., Dulčić, J., & Čalić, M. (2013). Introduced marine species in Croatian waters (Eastern Adriatic Sea). *Mediterranean Marine Science*, *14*/1, 224–237. dx.doi.org/10.12681/mms.383

Peterson, C.H., Grabowski, J.H., & Powers, S.P. (2003). Estimated enhancement of fish production resulting from restoring oyster reef habitat: Quantitative valuation. *Marine Ecology Progress Series*, *264*, 249–264. https://doi:10.3354/meps264249

Phelps, H.L. (1994). The Asiatic clam (*Corbicula fluminea*) invasion and system-level ecological change in the Potomac River Estuary near Washington, D. C. *Estuaries*, *17*, 614–621. https://doi.org/10.2307/1352409

Piccinetti, C., Vrgoč, N., Marčeta, B., & Manfredi, C. (2012). *Recent state of demersal resources of the Adriatic Sea* (Acta Adriatica, Monograph Series No. 5, pp. 1–220). Split, Croatia: Institute of Oceanography and Fisheries.

Rački, F. (1877). *Documenta ocumenta historae chroaticae periodum antiquam illustrantia*. Zagreb: HAZU.

Richards, R.A., & Rago, P.J. (1999) A case history of effective fishery management: Chesapeake Bay striped bass. *North American Journal of Fisheries Management*, *19*(2), 356–375. https://doi.org/10.1577/1548-8675(1999)019<0356:ACHOEF>2.0.CO;2

Rodney, W.S., & Paynter. K.T. (2006). Comparisons of macrofaunal assemblages on restored and non-restored oyster reefs in mesohaline regions of Chesapeake Bay in Maryland. *Journal of Experimental Marine Biology and Ecology*, *335*(1), 39–51. https://doi.org/10.1016/j.jembe.2006.02.017

Rothschild, B.J., Ault, J.S., Goulletquer, P., & Héral, M. (1994). Decline of the Chesapeake Bay oyster population: a century of habitat destruction and overfishing. *Marine Ecology Progress Series*, *111*, 29–39. https://doi:10.3354/meps111029

Rousseaux, C.S., & Gregg, W.W. (2015). Recent decadal trends in global phytoplankton composition. *Global Biogeochemical Cycles*, *29*,1674–1688. https://doi:10.1002/2015GB005139

Ruiz, G.M., Fofonoff, P.W., Carlton, J.T., Wonham, M.J., & Hines, A.H. (2000). Invasion of coastal marine communities in North America: Apparent patterns, processes, and biases. *Annual Review of Ecology and Systematics*, *31*, 481–531. https://doi.org/10.1146/annurev.ecolsys.31.1.481

Ruiz, G.M., Fofonoff, P.W., Steves, B.P., & Carlton, J.T. (2015). Invasion history and vector dynamics in coastal marine ecosystems: A North American perspective. *Aquatic Ecosystem Health & Management*, *18*, 299–311. https://doi.org/10.1080/14634988.2015.1027534

Sabatié, M. R., Baglinière, J. L., & Boisneau, P. (2002). Shad of the northeastern Atlantic and the western Mediterranean (*Alosa alosa* L. 1758 and *A. fallax* Lac., 1803): Biology, ecology and harvesting. In P. Safran (Ed.), *Fisheries and Aquaculture* (Vol. III, pp. 93–117). Encyclopedia of Life Support Systems (EOLSS online).

Santojanni, A., Arneri, E., Bernardini, V., Cingolani, N., Di Marco, M., & Russo, A. (2006). Effects of environmental variables on recruitment of anchovy in the Adriatic Sea.*Climate Research*, *31*, 181–193. https://doi:10.3354/cr031181

Savini, D., Harding, J.M., & Mann, R. (2002). Rapa whelk *Rapana venosa* (Valenciennes, 1846) predation rates on hard clams *Mercenaria mercenaria* (Linnaeus, 1758). *Journal of Shellfish Research*, *21*(2), 777–779.

Saylor, R.K., Lapointe, N.W.R., & Angermeier, P.L. (2012). Diet of non-native northern snakehead (*Channa argus*) compared to three co-occurring predators in the lower Potomac River, USA. *Ecology of Freshwater Fish*, *21*, 443–452. https://doi:10.1111/j.1600-0633.2012.00563.x

Seitz, R.D., Dauer, D.M., Llansó, R.J., & Long, W.C. (2009). Broad-scale effects of hypoxia on benthic community structure in Chesapeake Bay, USA. *Journal of Experimental Marine Biology and Ecology*, *381*, S4–S12. https://doi:10.1016/j.jembe.2009.07.004

Sett, S., Schulz, K.G., Bach, L.T., & Riebesell, U. (2018). Shift towards larger diatoms in a natural phytoplankton assemblage under combined high-CO_2 and warming conditions. *Journal of Plankton Research*, *40*(4), 391–406. https://doi:10.1093/plankt/fby018

Smith, H.M. (1895). A statistical report on the fisheries of the Middle Atlantic States. *Bulletin US Fish Commission for 1894*, *14*, 341–467.

STECF (2013). *Review of scientific advice for 2014—consolidated advice on fish stocks of interest to the European Union* (STECF-13-27, EUR 26328 EN, JRC 86158, pp. 1–575). Luxembourg: Publications Office of the European Union, Scientific, Technical and Economic Committee for Fisheries. http://publications.jrc.ec.europa.eu/repository/handle/JRC86158

STECF (2015). *Monitoring the performance of the Common Fisheries Policy* (STECF-15-04, EUR 27152 EN, JRC 95185, pp. 1–147). Luxembourg: Publications Office of the European Union, Scientific, Technical and Economic Committee for Fisheries. http://publications.jrc.ec.europa.eu/repository/handle/JRC95185

STECF (2016). *Reports of the scientific, technical and economic committee for fisheries—Mediterranean assessments part 2* (STECF-16-08, EUR 27758 EN, JRC 101548, pp. 1–483). Luxembourg: Publications Office of the European Union, Scientific, Technical and Economic Committee for Fisheries. http://publications.jrc.ec.europa.eu/repository/handle/JRC101548

Stevenson, C.H. (1894). The oyster industry of Maryland. *Bulletin US Fish Commission for 1892*, *12*, 205–297.

Terceiro, M. (2015). *Stock assessment update of summer flounder for 2015* (Reference Document, 15-13, pp. 1–18). Seattle, WA:US Department of Commerce, Northeast Fisheries Science Center. https://doi:10.7289/V57D2S4G

Vasilakopoulos, P., Maravelias, C.D., & Tserpes, G. (2014). The alarming decline of Mediterranean fish stocks. *Current Biology*, *24*(14), 1643–1648. https://doi.org/10.1016/j.cub.2014.05.070

Vrgoč, N., Arneri, E., Jukić-Peladić, S., Krstulović Šifner, S., Mannini, P., Marčeta, B., et al. (2004). *Review of current knowledge on demersal shared stocks of the Adriatic Sea*(GCP/RER/010/ITA/TD-12, AdriaMed Technical Documents, 12, pp. 1–91). Termoli, Italy: Food and Agriculture Organization. www.faoadriamed.org/pdf/publications/web-td-12.pdf

Wainger, L.A., Secor, D.H., Gurbisz, C., Kemp, W. M., Glibert, P.M., Houde, E.D., et al. (2017). Resilience indicators support valuation of estuarine ecosystem restoration under climate change. *Ecosystem Health and Sustainability*, *3*(4), 1–19. https://doi.org/10.1002/ehs2.1268

Whitaker, A. (1624). Good news from Virginia, sent from James his towne this present moneth of March, 1623. In A. Brown (1890), *The Genesis of the United States* (Vol. II, pp. 579–588). Cambridge, MA: The Riverside Press.

Wilberg, M.J., Livings, M.E., Barkman, J.S., Morris, B.T., & Robinson, J.M. (2011). Overfishing, disease, habitat loss, and potential extirpation of oysters in upper Chesapeake Bay. *Marine Ecology Progress Series*, *436*, 131–144. https://doi.org/10.3354/meps09161

Wingate, R.L., & Secor, D.H. (2008). Effects of winter temperature and flow on a summer-fall nursery fish assemblage in the Chesapeake Bay, Maryland. *Transactions of the American Fisheries Society*, *137*(4), 1147–1156. https://doi.org/10.1577/T07-098.1

Zenetos, A., Gofas, S., Morri, C., Rosso, A., Violanti, D., García Raso, J.E., et al. (2012). Alien species in the Mediterranean Sea by 2012. A contribution to the application of European Union's Marine Strategy Framework Directive (MSFD). Part 2. Introduction trends and pathways. *Mediterranean Marine Science*, *13*(2), 328–352. https://doi:10.12681/mms.327

Županović, Š. 1997. The Croats and the Sea. A short history of the Croatian Fisheries, 995–1995. In *Znanstveni Skup "Tisuću godina prvoga spomena ribarstva u Hrvata* (10-18.10. 1995, HAZU, 692 str). Zagreb: Croatian Academy of Sciences and Arts; Split: Institute of Oceanography and Fisheries.