CONCLUSIONS AND RECOMMENDATIONS

The purpose of this chapter is to synthesize the information discussed in the previous chapters of this report and to identify topics for future research and focus. In addition, the participants of the technical workshop on nonfishing impacts identified activities that are known or suspected to have adverse impacts on fisheries habitat, and we have attempted to draw some conclusions (based upon the effects scores) concerning those activities and effects that deserve further scrutiny and discussion. While many of these activities clearly have known direct, adverse impacts on the quantity and quality of fisheries habitat, their effects at the population and ecosystem level are not well known or understood. For example, there are a number of ports and harbors in the northeast region that have been identified as the most contaminated sites in US coastal waters for polycyclic aromatic hydrocarbons, chlorinated hydrocarbons, and trace metals (USEPA 2004; Buchsbaum 2005). Although many of the effects of these pollutants at the cellular, physiological, and whole organism level are known, information on the effects at the population and ecosystem level is less understood.

There were some noteworthy results from the technical workshop, particularly regarding the geographic areas that scored high for some of the activity types and effects. As one might expect, the workshop participants considered impacts on fisheries habitats to be generally focused in nearshore coastal areas. These results are not particularly surprising considering the proximity of riverine and nearshore habitats to industrial facilities, shipping, and other coastal development. Rivers, estuaries, and coastal embayments are essential for fisheries because they serve as nurseries for the juvenile stages of species harvested offshore or as habitats for the prey of commercially important species (Deegan and Buchsbaum 2005). Estuarine and wetland dependent fish and shellfish species account for about 75% of the total annual seafood harvest of the United States (Dahl 2006). In the workshop session on alteration of freshwater systems, several effects scored high in the estuarine/nearshore ecosystem in addition to the riverine ecosystem. For example, impaired fish passage and altered temperature regimes scored high for the riverine and estuarine/nearshore ecosystems in the dam construction/operation and water withdrawal activity types, suggesting that the participants viewed these activities to have broad ecosystem impacts.

Most effects in both the chemical and physical effects workshop sessions scored high in the riverine and estuarine/nearshore ecosystems. In addition, a few of these effects also scored high in the marine/offshore ecosystem. For the chemical effects session, the release of nutrients/eutrophication, release of contaminants, development of harmful algal blooms, contaminant bioaccumulation/biomagnification, and all effects under the combined sewer overflows impact type scored high in all ecosystem types. The concern of the workshop participants regarding these impacts seems to reflect recently published assessments on threats to coastal habitats (USEPA 2004; Deegan and Buchsbaum 2005; Lotze et al. 2006). For example, the 2004 National Coastal Condition Report (USEPA 2004) assessed the condition of estuaries in the northeast to be poor, with 27% of estuarine area as impaired for aquatic life, 31% impaired for human use, and an additional 49% as threatened for aquatic life use. One of the primary factors contributing to poor estuarine conditions in the northeast region is poor water quality, which is typically caused by high total nitrogen loading, low dissolved oxygen concentrations, and poor water clarity. In the northeast region, the contributing factors associated with nutrient enrichment are principally high human population density and, in the mid-Atlantic states, agriculture (USEPA 2004). In addition, harmful algal blooms (HABs) have been associated with eutrophication of coastal waters, which can deplete oxygen in the water, result in hypoxia or anoxia, and lead to large-scale fish kills (Deegan and Buchsbaum 2005). HABs may also contain species of algae that produce toxins, such as red tides, that can kill or otherwise negatively affect large numbers of fish and shellfish, contaminate shellfish beds, and cause health problems in humans. The extent and severity of coastal eutrophication and HABs will likely continue and may worsen as coastal human population density increases. Considerable attention should be focused on the effects of eutrophication on habitat and water quality, the populations of fish and shellfish, and the role of natural versus anthropogenic sources of nutrients in the occurrence of HABs.

For the workshop session on physical effects, entrainment and impingement effects scored high in all ecosystem types. Entrainment and impingement of eggs, larvae, and juvenile fish and shellfish are increasingly being identified as potential threats to fishery populations from a wide variety of activities, including industrial and municipal water intake facilities, electric power generating facilities, shipping, and liquefied natural gas facilities (Hanson et al. 1977; Travnichek et al. 1993; Richkus and McLean 2000; Deegan and Buchsbaum 2005). Future research is needed to assess the long-term and cumulative effects that entrainment and impingement from these activities have on fish stocks, their prey, and higher trophic levels of the marine ecosystem.

The participants of the workshop session on global effects and other impacts scored most effects in the estuarine/nearshore ecosystem as high. However, several effects of climate change scored high for all ecosystems, including alteration of temperature and hydrological regimes, alteration of weather patterns, and changes in community structure. The effects of climate change related to commercial and recreational fisheries have not as of yet been the focus of extensive research. However, greater emphasis on this topic will likely be necessary as the effects of global warming become more pronounced (Bigford 1991; Frumhoff et al. 2007).

A number of activities and effects were identified during the workshop and in the preparation of this report that may pose substantial threats to fisheries habitat, but the extent of the problems they represent and their implications to aquatic ecosystems are not well understood. Some of these activities and effects have only recently been recognized as potential threats, such as the effects of endocrine disrupting chemicals on aquatic organisms and the threats to fisheries from global warming and will require additional research to have a clearer understanding of the mechanism and scope of these problems. However, other effects such as sedimentation on benthic habitats and biota have been the focus of considerable research and attention, but questions remain as to the lethal and sublethal thresholds of sedimentation effects on individual species and its effects on populations. For example, although sedimentation caused by navigation channel dredging is known to adversely affect the demersal eggs of winter flounder (*Pseudopleuronectes americanus*) (Berry et al. 2004; Klein-MacPhee et al. 2004; Wilber et al. 2005) a better understanding of how the intensity and duration of egg burial effects mortality is needed (i.e., lower lethal thresholds). In addition, how do grain size, the type and amount of contamination, and background suspended sediment concentrations affect egg and larvae survival rates, and what are the implications at the population level?

A number of energy-related activities were assessed for adverse effects on fisheries habitat in the technical workshop and in the corresponding report chapter, including offshore liquefied natural gas platforms, wind turbines, and wave and tidal energy facilities. Although various impacts were discussed, there have not been any facilities of this type constructed in the northeast region of the United States at the time of this report. Although we believe the resource assessments for these types of facilities have been based upon the best available information, further monitoring and assessments will be necessary once they are constructed.

The workshop participants identified a number of chemical effects in several sessions that may have a high degree of impact on fisheries, such as endocrine disrupting chemicals and pharmaceuticals in treated wastewater. Pharmaceuticals and personal care products (PPCP) can persist in treated wastewater and have been found in natural surface waters at concentrations of parts per thousand to parts per billion (Daughton and Ternes 1999). Although the range of concentrations of PPCPs may not pose an acute risk, because aquatic organisms may be exposed continually and for multi-generations, the effects on coastal aquatic communities are a major concern (USEPA 2007). Some of these PPCPs include steroid compounds, which may also be endocrine disruptors. Endocrine disruptors can mimic the functions of sex hormones, androgen and estrogen, and can interfere with reproductive functions and potentially result in population-level impacts. Some chemicals shown to be estrogenic include polychlorinated biphenyl (PCB) congeners, pesticides (e.g., dieldrin, dichlorodiphenyl trichloroethane [DDT]), and compounds used in some industrial manufacturing (e.g., phthalates, alkylphenols) (Thurberg and Gould 2005). In addition, some metal compounds have also been implicated in disrupting endocrine secretions of marine organisms (Brodeur et al. 1997). Additional investigation into the effects of PPCPs and endocrine disruptors on aquatic organisms and their potential impacts at the population and ecosystem level is needed.

In addition, the workshop participants identified a number of adverse effects on aquatic ecosystems from introduced/nuisance species, particularly in the estuarine/nearshore ecosystem. Introduction of nonnative invasive species into marine and estuarine waters poses a significant threat to living marine resources in the United States (Carlton 2001). Nonnative species introductions occur through a wide range of activities, including hull fouling and ballast water releases from ships, aquaculture operations, fish stocking and pest control programs, and aquarium discharges (Hanson et al. 2003; Niimi 2004). The rate of introductions has increased exponentially over the past 200 years, and it does not appear that this rate will level off in the near future (Carlton 2001). Increased research focused towards reducing the rate of nonnative species introductions is needed, in addition to a better understanding of the effects of nonnative species on fisheries in the United States.

Overfishing, including fishing effects on habitat, is likely the greatest factor in the decline of groundfish species in New England (Buchsbaum 2005) and is responsible for the majority of fish and shellfish species depletions and extinctions worldwide (Lotze et al. 2006). However, habitat loss and degradation through nonfishing activities (including pollution, eutrophication, and sedimentation) closely follow exploitation as a causative agent in fishery declines and may be equally or more important for some species such as Atlantic salmon (*Salmo salar*) (Buchsbaum 2005; Lotze et al. 2006). Cumulative effects likely play a role in a large majority of historic changes in fish stocks. Worldwide, nearly half of all marine and estuarine species depletions and extinctions involve multiple human impacts, most notably exploitation and habitat loss (Lotze et al. 2006). It is imperative that management measures intended to reduce exploitation, increase habitat protection, and improve water quality be applied holistically and that the cumulative effects of multiple human interactions be considered in both management and conservation strategies (Lotze et al. 2006). The challenges of quantifying the cumulative effects of nonfishing impacts are vast and complex. Nonetheless, the importance of nonfishing impacts on the coastal ecosystem will likely become greater in the future, and we believe fishery managers would be well served by beginning to collaborate with coastal resource managers and integrate signals from nonfishing effects and stresses on the ecosystem with traditional stock assessment models.

References for Conclusions and Recommendations

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