The anticipated effects of oil spill on fish populations in case of an accident along the Turkish Straits System – a review of studies after several incidents from the world

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OIL SPILL ALONG THE TURKISH STRAITS SEA AREA; ACCIDENTS, ENVIRONMENTAL POLLUTION, SOCIO-ECONOMIC IMPACTS AND PROTECTION

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PREFACE

Oil spill and ship-originated pollution is one of the core issues for many years due to the importance of the protection of the world oceans and seas. Oil contamination from the ships and shores are not negligible amount as well.

Turkey, surrounded by four different seas, has experienced some major ship incidents, mainly in the Turkish Straits System, more particularly in the Istanbul Strait. You might freshly recall that thousands of tons of oil dispersed over the sea and some evaporated to atmosphere during the Independenta and Nassia incidents. That was also a real inferno for the local people.

It is already known that ecological catastrophes will continue for many years after the incidents. I remember that I was writing to Financial Times about this and it appeared in that renowned newspaper on 15 January 2004 like this: "Istanbul Strait is a place for refreshment, for drinking Turkish coffee, for fishing - not a dangerous oil tanker route". After more than a decade, supertankers still thrill us in the Istanbul Strait with huge amount of oil in their tanks.

The idea of this book is to present how Turkish waters are under the threat of oil spills, even though several extra precautionary measures have been taken recently. In fact, Turkey has a longest coastline in the Mediterranean and Black Sea, which makes it more responsible to prevent any kind oil contamination.

I congratulate my colleagues, Dr. Selma ÜNLÜ and Dr. Bedri ALPAR, for their invaluable effort to compile and edit this very comprehensive book. Besides, I am very grateful to all the authors who contributed to this book with their effort, namely, their time and extended knowledge.

Fighting with pollution is not simple and detailed information is of utmost importance. I believe that this book will fill the gaps in knowledge necessary for preventing oil pollution in the Turkish Straits System.

Prof. Dr. Bayram ÖZTÜRK
Director, Turkish Marine Research Foundation (TÜDAV)

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CONTENTS

"The waves swam like the mountains in the froth of Bosphorus, often climbed up over the clouds and seemed to fill the boat. No one thought he could get away with it anymore. Because death was wandering over the ship and in the clouds, as if it says he came nearby. Even though the waves were so terrible, they would quickly become docile when a clever and experienced pilot keep the helm."

Rhodesian Apollonius

THE ANTICIPATED EFFECTS OF OIL SPILL ON FISH POPULATIONS IN CASE OF AN ACCIDENT ALONG THE TURKISH STRAITS SYSTEM – A REVIEW OF STUDIES AFTER SEVERAL INCIDENTS FROM THE WORLD

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1. Introduction

Fish species are extremely diverse in Mediterranean and Black Seas because of the heterogeneity of the seas with respect to hydrography, bathymetry and productivity (Zenetos et al., 2002) but also to the varying cultural, social and economic conditions across the Mediterranean coastline (Papaconstantinou and Farrugio, 2000; Stergiou et al., 2016). Nearly 400 species of fish, crustacean, and molluscs are being exploited by numerous fishing gears and methods in the Mediterranean Sea, yielding over one million tonnes of catches according to official statistics (FAO, 2016). Classical fisheries science maintains that when there are more fish in the water, sustained catches could be obtained with much less fishing effort and much less impact on the ecosystem (Beverton and Holt, 1957; Murawski, 2010). The potential catch increases do not account for interactions among species such as prey-predator relationships and competition for resources (Horbowy and Luzenczyk, 2016), changes in the fishing tactics and new fisheries regulations (McGarvey et al., 2016) as well as human factor, environmental changes and climate forcing (Alheit et al., 2014) may also play a role in fish population dynamics.

FAO (2003) states ecosystem approach to fisheries (EAF): "*(…) the purpose of EAF is to plan, develop and manage fisheries in a manner that addresses the multiplicity of societal needs and desires, without jeopardizing the options for future generations to benefit from marine ecosystems*" (FAO, 2016).

There are two types of barriers indicated for implementing ecosystem approach under major knowledge gaps which are defined as deficiency of scientific understanding of the ecosystem dynamics including human factor and science as basis for management (Hansson et al, 1999). On the other hand, if time series of fishing pressure and biomass change namely fisheries reference points for fish stocks can be assessed, a baseline for stock status can be achieved and lead to focus on how stocks can be affected by other ecosystem components in the past for evaluating existing literature and can be affect in future hypothetically.

It is generally accepted that Exxon Valdez oil spill (Peterson et al., 2003) and the Deepwater Horizon disaster (Crone and Tolstoy, 2010; Kerr et al., 2010, Langangen et al., 2017) were caused suffering of fish populations. Overall post spill analysis of a few major events constitute our basic understanding on the consequences of oil uptake by fish stocks (Peterson et al., 2003; French-McCay, 2004; Incardona et al., 2014; Carroll et al., 2018). Among them, short-term monitoring studies conducted right after the disasters, conclude that oil spill influences to populations evolve almost solely from acute mortality (Peterson et al., 2003). For example, according to Rice et al. (2001), oil impact to fishes was anticipated mainly on testing acute toxicity for short term (~4 days) laboratory exposures to the water-soluble fraction with majority of 1- and 2- ringed aromatic hydrocarbons (PAHs), through acute narcosis mortality at ppm concentrations. However, Peterson et al. (2003), assume this as an old paradigm and described an emerging appreciation on oil toxicity as, fish embryos' long-term exposure to weathered oil (3- to 5- ringed PAHs) at ppb concentrations which causes populations to have indirect effects like growth abnormalities and behavior with long-term effects on mortality and reproduction.

Whilst only few studies have exhibited enhanced mortality of fish as a consequence of oil spills (IPIECA, 1997; Hjermann et al., 2007; Fodrie et al., 2014), fish stocks which spawning areas or egg and larval distribution extensions, close to oil spillage location are considered to be especially vulnerable (Hjermann et al., 2007; Rooker et al., 2013, Langangen et al., 2017).

Besides being an exceptional marine ecosystem, Turkish Straits System (TSS) is a very important marine transportation route. However, the heavy maritime traffic through TSS gives rise to accidents and consequently oil spills, which can toxify this peculiar environment. According to Bozkurtoğlu (2017), there have been over 40 heavy accidents occurred in the İstanbul Strait since 1960.

The aim of this study is to draw attention to an oil spill accident's potential in initiating a sequence of destructive alterations and finally leading to collapse of delicate fish stocks. We tried to gather available knowledge of oil spill effects on fish species, considering the changes in their bio-ecological situations. In the scope of several studies conducted after major oil spill incidents worldwide, we target to present a basic guide for scientists and authorities to intervene efficiently and to evaluate the effected fish populations properly in case of an accident along the TSS.

2. Importance of the Subject Area in terms of Fish Diversity, Species Bio-ecology and Fisheries Industry

From north to south; the İstanbul Strait, the Sea of Marmara and the Dardanelles Strait constitute the Turkish Straits System which is unique as a transitional zone between the Mediterranean and the Black Sea, owing to its geographical and hydrological characteristics. It extends along, a corridor, as a barrier, or/and an acclimatization zone for marine life (Öztürk and Öztürk, 1996). The Sea of Marmara functions as a barrier by limiting the dispersal of high saline Mediterranean species and/or low saline Black Sea species. The Sea of Marmara is also a substantial biological corridor for many migratory species of fish including economically important and endangered species, also marine mammals and birds. As an acclimatization zone, some Mediterranean species adjust to the conditions of the Black Sea and/or the Black Sea species to the Aegean Sea (Öztürk, 2006).

Fishes of the Turkish Straits System: According to current studies, the Sea of Marmara hosts 257 fish species and it is the third in terms of species diversity, after Aegean Sea and the Mediterranean coasts of Turkey (Bilecenoğlu et al., 2014).

Fishery in the Sea of Marmara covers about 8% of Turkish marine fish production and largest part of this rate belongs to the small pelagic species. 10% of the small pelagic fish catch in Turkey is obtained from the Sea of Marmara. The most abundant small pelagic species are anchovy (*Engraulis encrasicolus*), European pilchard (*Sardina pilchardus*) Mediterranean horse mackerel (*Trachurus mediterraneus*), European sprat (*Sprattus sprattus*) amd Atlantic horse mackerel (*Trachurus trachurus*). Additionally, there are economically important large pelagic predators like swordfish (*Xiphias gladius*), tuna (*Thunnus thynnus*), bluefish (*Pomatomus saltatrix*) and bonito (*Sarda sarda*). Main demersal fishes can be listed as whiting (*Merlangius merlangus*), surmullet (*Mullus surmuletus*), goatfish (Mugilidae spp.), European hake (*Merluccius merluccius*), anglerfish (*Lophius piscatorius*) and salema (*Sarpa salpa*) (Demirel and Gül, 2016).

A total of 49 fish species from the Sea of Marmara are protected under several international protocols (Bern, Bonn and Barcelona) and/or listed in IUCN Red List, with the highest 4 conservation status; Critically endangered (CR), Endangered (EN), Vulnerable (VU) and Near threatened (NT) (Table 1.).

These 49 species are extracted from:

- Appendix II (Strictly Protected Fauna Species) and Appendix III (Protected Fauna Species) of Bern Convention as known as: “Convention on the Conservation of European Wildlife and Natural Habitats” (https://www.coe.int/en/web/conventions/full-list/-/conventions/treaty/104),

- Appendix I (Endangered Migratory Species) and Appendix II (Migratory Species Conserved Through Agreements) of Bonn Convention as known as: “Convention on the Conservation of Migratory Species of Wild Animals (CMS)” (https://www.cms.int/en/species),

- Annex II (List of Endangered or Threatened Species) and Annex III (List of Species Whose Exploitation is Regulated) of Barcelona Convention as known as: “Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean (SPA / BD)” (UNEP/MAP-SPA/RAC, 2018a,b)

- IUCN Red List of Threatened Species (Table 1.) (https://www.iucnredlist.org/search)

The Sea of Marmara as a Spawning Area: Owing to its high nutritious content and high density of plankton, the Sea of Marmara represents a spawning and nursing habitat of many species. Economically valuable fishes like Atlantic mackerel (*Scomber scombrus*), bonito and bluefish enter the Sea of Marmara for breeding and feeding and spend a part of their life here (Demir,1961; 1969; 1975). Eggs and larvae of 21 fish species have been determined in the area according to a doctoral dissertation and master thesis as well as final reports of research projects (Yüksek, 1993, Okuş et al., 1998; Demirel 2014).

Table 1. Fish species from the Sea of Marmara, protected under several international protocols (A.: Appendix/Annex, *: Economically important).

Scientific name	**Common name**	**IUCN status**	**Bern A.II**	**Bern A.III**	**CMS A.I**	**CMS A.II**	**SPA/BD A.II**	**SPA/BD A.III**
Hexanchus griseus	Bluntnose sixgill shark	NT						
Carcharodon carcharias	Great white shark	VU	+		+	+	+	
Lamna nasus	Porbeagle	VU		+		+	+	
Alopias superciliosus	Bigeye tresher shark	VU				+		
Alopias vulpinus	Common tresher shark	VU				+		+
Scyliorhinus stellaris	Nursehound	NT						
Galeorhinus galeus	Tope shark	VU					+	
Mustelus asterias	Starry smooth-hound							+
Mustelus mustelus	Common smoothhound	VU						+
Prionace glauca	Blue shark	NT		+		+		+
Dalatias licha	Kitefin shark	NT						
Oxynotus centrina	Angular roughshark	VU					+	
Centrophorus granulosus	Gulper shark							+
Squalus acanthias	picked dogfish	VU				+		+
Squatina oculata	Smoothback angelshark	**CR**					+	
Squatina squatina	Angelshark			+	+	+	+	
Dipturus batis	Blue skate	**CR**					+	
Dipturus oxyrinchus	Longnose skate	NT						
Raja asterias	Starry ray /skate	NT						
Raja clavata	Thornback ray / skate	NT						
Raja radula	Rough ray / skate	**EN**						
Gymnura altavela	Spiny butterfly ray	VU					+	
Chimaera monstrosa	Rabbitfish	NT						
* *Acipenser gueldenstaedtii*	Danube sturgeon	**CR**				+		
* *Acipenser nudiventris*	Fringebarbel sturgeon	**CR**				+		
* *Acipenser stellatus*	Starry sturgeon	**CR**		+		+		
* *Acipenser sturio*	Atlantic sturgeon		+		+	+	+	
* *Huso huso*	Beluga		+	+		+	+	
* *Alosa fallax*	Twaite shad			+				+
* *Anguilla anguilla*	European eel	**CR**				+		+
Hippocampus guttulatus	Long-snouted seahorse		+				+	
Hippocampus hippocampus	Short-snouted seahorse		+				+	
Syngnathus abaster	Black striped pipefish			+				
* *Epinephelus marginatus*	Dusky grouper	**EN**		+				+
* *Pomatomus saltatrix*	Bluefish	VU						
* *Trachurus trachurus*	Atlantic horse mackerel	VU						
* *Dentex dentex*	Common dentex	VU						
* *Pagellus bogaraveo*	Blackspot seabream	NT						
* *Sciaena umbra*	Brown meagre	NT		+				+
* *Umbrina cirrosa*	Shi drum			+				+
Labrus viridis	Green wrasse	VU						
Ponticola syrman	Syrman goby			+				
Pomatoschistus minutus	Sand goby			+				
Zosterisessor ophiocephalus	Grass goby			+				
* *Thunnus alalunga*	Albacore	NT						
* *Thunnus thynnus*	Atlantic bluefin tuna	**EN**						+
* *Xiphias gladius*	Swordfish							+
Balistes capriscus	Grey triggerfish	VU						
Mola mola	Ocean sunfish	VU						

3. Major Oil Spill Accidents and Studies on Affected Fish Populations

Exxon Valdez Oil Spill (EVOS), 1989: According to Peterson et al. (2003), before EVOS, in case of a contamination, mainly short-term monitoring studies and acute toxicity observations on laboratory-tolerant species were conducted in order to construct risk assessment models to anticipate ecological effects of PHCs. Peterson et al. (2003) also suggest a change on the prevailing practices used to assess ecological risks of oil other toxic sources and note that ecosystem-based toxicology should be developed for a better understanding and prediction on chronic, delayed, indirect long-term threats and impacts. There are studies documenting consecutive events affecting the survival or reproduction of organisms indirectly, following sub-lethal exposures. Sub-lethal consequences such as abnormal development in the early life stages of fish species were revealed by controlled laboratory studies. Oil exposure led to reduced growth rates in salmon fry, Pink salmon survival was also decreased indirectly, due to size dependent predation in the marine stage of their life cycle (Rice et al., 2001; Willette et al., 2000). Heintz et al., (1999) demonstrated, returning pink salmon (which had been exposed to oil previously in 1993, while they were embryos and fry) have reduced survival for their embryos. This is an impressive example to the reproductive impairment from sub lethal dosing. Definitive experimental studies revealing sub lethal exposure as a reason to compromised survival and reproduction, adjust our knowledge on xenobiotics exposure during sensitive early stages in vertebrate development causing increased mortality and reproductive deterioration in later life stages by means of endocrine perturbation and abnormalities in development (Arkoosh and Collier, 2002). Abnormal development occurred in herring and salmon after exposure to the Exxon Valdez oil (Marty et al., 1997; Carls et al., 2001).

Prestige Oil Spill (POS), 2002: Martínez-Gómez et al., (2006) declare that there were no studies conducted in the northern Iberian Shelf with biomarkers of contaminant exposure or impacts on fish. They aimed examine series of biomarkers on fish species after the accident in order to determine impairment from toxicity, and to find out the effectiveness of the chosen biomarkers in *L.boscii* (four-spotted megrim) and *C.lyra* (dragonet), to be evaluated for bio monitoring programmes along the area. In conclusion they explained the applied biomarkers in these two demersal species can be used to determine various biological responses among regions of Iberian shelf. The results also show, *C. lyra* and *L. boscii* as favorable target species to be evaluated in biomonitoring programmes. The findings also suggest that oxidative stress increase in *L. boscii* may be caused by oil spill which led to exposure of hydrocarbons.

Deepwater Horizon Disaster (DHD), 2010: After the last major US oil spill (the 1989 EVOS in Alaska), developing fish embryos were exposed to be mostly sensitive to crude oil which is very toxic. The northern Gulf of Mexico where DHD took place, embraces important spawning and rearing habitats for many economically and ecologically valuable pelagic fish species like; mahi mahi (Figure 1), yellowfin tuna and bluefin tuna king, greater and lesser amberjack, and Spanish mackerels, sailfish, cobia and blue marlin, Yellowfin tuna (*Thunnus albacares*) and greater amberjack (*Seriola dumerili*) are very important for commercial fisheries. As well, Atlantic bluefin tuna (*T. thynnus*) was petitioned for the list under the US Endangered Species Act. Unfortunately the oil leakage into the ecosystem from the damaged DH/MC252 overlaps with the temporal spawning season of these pelagic fishes. The loss of early life phases of these and other pelagics, due to oil contamination in spawning habitats is a crucial issue for fisheries management and conservation (Incardona et al., 2011).

Regarding the results of their study, Incardona et al., (2011) declared the developing spawn (embryos and larvae) of large pelagic predator fish species were found to be potentially exposed to PAHs derived from crude oil. PAH induced cardiotoxicity that fish embryos are especially vulnerable, and abnormalities in heart physiology and morphology can lead to acute and delayed mortality. With their high aerobic demand, cardiac function is specifically crucial for fast-swimming pelagic predators. They have also indicated that, the cardiac development of local fishes, as being exceptionally delicate to and reliable indicator of crude oil effects should be focused on during vulnerability determination studies in different ocean habitats, including the Arctic.

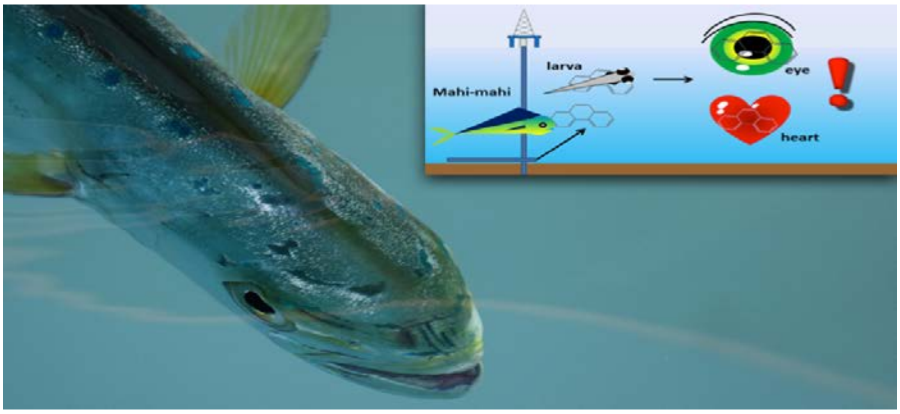

Figure 1. Study on the effects of oil spill exposure on mahi mahi (*Coryphaena hippurus*) after Deepwater Horizon accident (Xu et al, 2016).

4. Major Accidents in the Sea of Marmara and Necessary Strategy for Monitoring

Bozkurtoğlu (2017), pointed out the intense maritime traffic through the İstanbul Strait as having a potential to cause considerable ecological threats to the local environment. However, after a numerous accidents occurred, we still have a very few knowledge on the effects of oil on local fish populations.

Independenta / Evriali (Romanian tanker / Greek freighter - 1979): collided at Haydarpaşa. An enormous explosion occurred. The tanker sank and spilled approximately 94,000 tons of oil, 30,000 tons of which kept burning for days. Wreck stayed grounded and affected the area for some years. Crude oil sank to the bottom covering an area of approximately 5.5 km in diameter. Large amounts of dead fish were found in the Sea of Marmara (Baykut et al., 1985; Öztürk et al., 2006; İstikbal, 2006; Bozkurtoğlu, 2017). Following the Independenta/Evriali marine collision in 1979, which caused significant economic and ecological damages particularly for fisheries (damage of fishing nets, boats) fifteen fishery cooperatives were compensated with the total amount of 291,500 USD (Öztürk and Balcıoğlu, 2017).

Blue Star / Gaziantep (Panama tanker / Turkish crude oil tanker – 1988): Blue Star was loaded ammoniac and huge quantities of ammoniac polluted the area (İstikbal, 2006).

Nassia / Shipbroker (Southern Cyprus oil tanker / Southern Cyprus bulk carrier - 1994): collided at the northern entrance of the İstanbul Strait. 20 thousand tons of oil spilled into the Black Sea, İstanbul Strait and the Sea of Marmara. The tanker burned for several days. Thick oil and pitch covered the coastline, bays and beaches. Many marine mammals were found dead along the area as well as benthic organisms and sea birds (Öztürk et al., 2006; İstikbal, 2006).

Volganeft 248 (Russian oil tanker - 1999): grounded and broke in two and sank at the southern entrance of the İstanbul Strait. 1,200 tons of fuel oil spilled and caused 90% mortality of marine life. Black goby (*G. niger*), common sole (*S. solea*), flathead grey mullet (*M. cephalus*) and tub gurnard (*C. lucerna*) were among the marine organisms found dead along the polluted area (Öztürk et al., 2006; İstikbal, 2006; Bozkurtoğlu, 2017).

Gotia (Russian oil tanker - 2001): collided to Emirgan Harbour wall. 22 tons of oil spilled into the İstanbul Strait and exterminated all mussel beds (Güven, 2002).

Svyatoy Panteleymon (Georgian cargo ship - 2003): grounded close to Anadolu Feneri, northern entrance of İstanbul Strait. 220 tons of diesel and 260 tons of fuel oil spilled into the sea contaminating the fishing grounds of up to 2 miles off the shore. Spawning areas of commercially important demersal fish species like sole, flounder and turbot were spoilt (Öztürk et al., 2006; Bozkurtoğlu, 2017).

5. Conclusion

Fishes are one of the vital constituents of marine ecosystem. Especially, small pelagic fishes have an important role in this system, regarding their interaction with both lower and upper trophic levels of the food chain (Palomere et al., 2007). Small pelagic fish species, like pilchards and anchovies, stand in a fundamental position during transferring energy in food webs. They often constitute the main bond between primary (phytoplankton) and secondary (zooplankton) production and large predators. This trophic position is called the 'wasp's waist' since small pelagic fishes feed on many species and are eaten by many species. They are also short living species, with highly vulnerable egg and larval recruitment to changes in atmospheric and oceanographic conditions (FAO, 2016). Having 10% of the small pelagic fish catch of the country, the Sea of Marmara needs a special attention for the protection of its inhabitants. Among 257 fish species, 49 of them are evaluated vulnerable for protection and conservation. Angelsharks (*Squatina* spp.), first degree endangered species are known to distribute and consider the Sea of Marmara as a breeding zone (Yüksek, 1993), 17 species have high economic value such as; Atlantic horse mackerel (*T. trachurus*), common dentex (*D. dentex*), brown meagre (*S. umbra*), dusky grouper (*E. marginatus*) and Atlantic bluefin tuna (*T. thynnus*) etc. These sensitive species' populations may suffer rather badly from an oil contamination with regard to their status. Any stock decrease or even collapse may cause huge problems economically and environmentally.

In order to guide the authorities in determination of the short-term oil spill response and related operations, Bozkurtoğlu (2017), aimed to constitute a mathematical model predicting oil spill mobility on the surface waters. A basic yet operative transport model was established to lead civil protection authorities in the arrangement of contingency plans for İstanbul Strait and to manage and clean oil spills effectively. Bozkurtoğlu (2017) studied on three main subjects:

a) The speed of the spilt oil until it reaches the shoreline in certain circumstances
b) Directions of the spilt oil's dispersion until it reaches the shoreline
c) Time span the spilt oil remains in the region

Results of the model reveals that in case of an oil spill in İstanbul Strait, the contamination is likely to reach both European and Asian coasts in a couple of hours. An oil slick originated from a spill in the northern entrance of the strait can spread through İstanbul Strait and reach both eastern and western sides in 1-2 hours and the southern end in only 8-10 hours. Thus it is important to act immediately and to carry out an emergency action plan in accordance with the procedures gathered from scientific simulation studies.

Regarding the results of many studies conducted after major oil spill incidents we can clearly see, fish populations are subject to contamination from oil and other related chemical compounds those enhance acute, chronic and/or delayed diseases, also mortality, that can still be observed even in the decades following the exposure. Therefore reviewing all existing knowledge on bio-ecological characteristics of fish populations and performing monitoring studies to understand effects of a possible oil spill exposure is crucial.

For this reason, following information for fish populations and accident pattern should be taken into consideration:

a) Spatial structure of natural mortality,
b) Spawning season and regions,
c) Behavior of fish larvae such as vertical migration,
d) Current speed and direction to understand water movement,
e) Location and covered area of the oil spill,
f) Toxic level of various oil-components,
g) Sensitivity of species and their life stages of different toxicity.

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