IV.C.1.d (4) Fishes and Essential Fish Habitat

This section updates the assessment of effects on fishes and Essential Fish Habitat (EFH) as a result of the proposed action (Alternative VII). The section includes four sub-sections which summarize the multiple-sale EIS and 195 EA assessments that are being updated, update those effects, add the benefits of the standard mitigation, and summarize the new overall conclusion (i.e., the mitigated effect).

(1) SUMMARIES OF MULTIPLE-SALE EIS AND 195 EA ASSESSMENTS TO BE UPDATED

The Beaufort Sea multiple-sale EIS concludes the following about the effects of proposed Sale 202 on fishes (USDOI, MMS, 2003: Sec. IV.C.3.b):

> Noise and discharges from dredging, gravel mining, island construction and reshaping, pipeline trenching, and abandonment are likely to have no measurable effect on fish populations (including incidental anadromous species). While a few fish could be harmed or killed, most in the immediate area would avoid these activities and would be otherwise unaffected. Effects on most overwintering fish are likely to be short term and sublethal, with no measurable effect on overwintering fish populations.
>
> In the unlikely event of a large oil or diesel fuel spill, effects on arctic fishes (including incidental anadromous species) would depend primarily on the season and location of the spill; the lifestage of the fishes (adult, juvenile, larval, or egg); and the duration of the oil contact. Because of their very low numbers in the spill area, no measurable effects are likely on fishes in winter. Effects would be more likely to occur from an offshore oil spill moving into nearshore waters during summer, where fishes concentrate to feed and migrate. If an offshore spill did occur and contact the nearshore area, some marine and migratory fish may be harmed or killed. However, it likely would not have a measurable effect on fish populations, and recovery would be likely within 5-10 years. In general, the effects of fuel spills on fishes are likely to be less than those of crude oil spills.
>
> In the unlikely event of an onshore pipeline oil spill contacting a small waterbody supporting fish (for example, ninespine stickleback, arctic grayling, and Dolly Varden char) and that had restricted water exchange, it likely would kill or harm most of the fish within the affected area. Recovery would be likely in 5-10 years. However, because of the small amount of oil or diesel fuel likely to enter freshwater habitat, the low diversity and abundance of fish in most of the onshore area, and the unlikelihood of spills blocking fish migrations or occurring in overwintering areas or small waterbodies (containing many fish or fish eggs), an onshore spill of this kind is not likely to have a measurable effect on fish populations on the Arctic Coastal Plain.

The Beaufort Sea multiple-sale EIS concludes the following about the effects of proposed Sale 202 on EFH (USDOI, MMS, 2003: Sec. IV.C.4.c):

> The effects of an oil spill would be considered higher than in Sales 186 and 195 but still moderate, because in most cases salmon would recover within one generation. One year of salmon smolt would be affected and salmon populations likely would recover. Effects from disturbances and seismic activity in both the exploratory and development stages on freshwater and marine would be low, i.e., changes in abundance are limited to a population or portion of a populations (one stream, or in even or odd years for pink salmon) and/or for a short time period.

The 195 EA concludes the following about the effects of proposed Sale 202 on fishes and EFH (USDOI, MMS, 2004: Sec. IV.C.1.e (2)):

> In the unlikely event of a large oil or diesel fuel spill, effects on arctic fishes (including Pacific salmon) would depend primarily on the season and location of the spill; the lifestage of the fishes (adult, juvenile, larval, or egg) impacted; and the duration of the exposure. Impacts to local fish populations may include lethal and sublethal effects and require one to three generations for

> affected local populations to recover to their former status. Regional populations would not be substantially affected by the assumed oil spills. Fish populations exhibit considerable spatial and temporal variability with respect to their distribution and abundance in response to natural environmental factors. Natural environmental disturbances may complicate recovery rates by expediting or inhibiting growth, reproduction rates, trophic linkages, or habitat use. The interaction of natural disturbances and OCS impact-producing factors, such as a large oil spill, may substantially modify the anticipated effects of the Proposed Action.

2. UPDATE OF THOSE EFFECTS FOR THE PROPOSED ACTION—ALTERNATIVE VII

This section reports new or additional information to that discussed in the MultiSale EIS or the administrative file titled "Background Information on the Fish Resources of the Alaskan-Beaufort Sea Region" for the Lease Sale 195 EA. Recent literature reviewed for this assessment and incorporated by reference include: Carls et al. (2002, 2005); Elliott and Hemingway (2002); Lawrence and Hemingway (2003); Peterson et al. (2003); and Short et al. (2003); they are incorporated in this assessment by reference. Relevant key findings from some of these references are reported below.

Updated Oil-spill Effects

Carls et al. (2002) compared and reinterpreted published data from industry and government sources as relating to Pacific herring in Prince William Sound that were affected by the *Exxon Valdez* oil spill in 1989 and a 75% collapse in the adult population in 1993. They reported:

> Significant effects extended beyond those predicted by visual observation of oiling and by toxicity information available in 1989. Oil-induced mortality probably reduced recruitment of the 1989 year class into the fishery, but was impossible to quantify because recruitment was generally low in other Alaskan herring stocks. Significant adult mortality was not observed in 1989; biomass remained high through 1992 but declined precipitously in winter 1992-1993. The collapse was likely caused by high population size, disease, and suboptimal nutrition, but indirect links to the spill cannot be ruled out.

Short et al. (2003) concluded that habitat damage resulting from oil contamination is underestimated by acute toxicity assays. They describe that nearshore substrates oiled by spills may become persistent pollution sources of toxic polycyclic aromatic hydrocarbons (PAH). Their recent findings resulting from research following the *Exxon Valdez* oil spill include: (1) PAHs are released from oil films and droplets at progressively slower rates with an increasing molecular weight leading to greater persistence of larger PAHs; (2) eggs from demersally-spawned fish species accumulate dissolved PAHs released from oiled substrates, even when the oil is heavily weathered; and (3) PAHs accumulated by embryos from aqueous concentrations of < 1 ng/L can lead to adverse sequelae appearing at random over the lifespan of an exposed cohort, probably as a result of damage during early embryogenesis. They conclude that oil is thus a slow-acting poison, and that toxic effects may not manifest until long after exposure. Several highly pertinent points quoted from Short et al. (2003) include:

- Fish and oil do not mix,...the threat is not from acutely toxic concentration that result in immediate fish kills, but in the more subtle effects of low-level oil pollution to sensitive life stages. Incubating eggs are very sensitive to long-term exposure to PAH concentrations because they may sequester toxic hydrocarbons from low or intermittent exposures into lipid stores for long periods and because developing embryos are highly susceptible to the toxic effects of pollutants (citing Mary et al., 1997; Carls et al., 1999; Heintz et al., 1999, 2000). PAHs in weathered oil can be biologically available for long periods and very toxic to sensitive life stages. The result is that fewer juvenile fish survive, so that recruitment from the early life stages is reduced and adult populations may not be replaced at sustainable levels. Eventually, adult populations may gradually decline to extinction.
- Streams and estuaries sustain the vulnerable early developmental life stages of many fish species...Herring spawn their eggs in areas of reduced salinities, salmon early life stages use both stream and estuary for much of the first year of life, and the juveniles of many marine species use the estuaries for nursery grounds. The very qualities of these natal and rearing habitats that provide

protection from predators also make both the habitat and, by extension, the species vulnerable to pollution. The sediments of salmon streams and many nearshore estuaries are capable of harboring oil for extended periods with slow release.

- Habitats used by demersally spawning fish such as salmon, herring, and capelin are particularly vulnerable to the effects of oil coming ashore on beaches and the spawning gravels of streams.
- Fish natal and rearing habitats are clearly vulnerable to oil poisoning from chronic discharges under the current regulatory framework. Oil discharges into these habitats are covered by water quality standards based on acute LC50 results for more tolerant life stages, which may seriously underestimate cumulative adverse effects, even when presumably conservative safety factors of 0.01 are applied. These water quality standards need to be revised if we are to protect these habitats.
- Chronic pollution seldom results in floating fish carcasses. Instead, there is continued habitat contamination, erosion of populations, and when coupled over time with other events such as hard winters, other habitat loss, increased in predators or fishing, decreases in food availability at a critical life stage, etc. may eventually result in population extinctions in high impact environments. Species with life history strategies that rely on streams or estuaries for reproduction are most vulnerable.
- In the absence of further laboratory study with other fish species, we (Short et al.) suggest a toxicity threshold of approximately 1 ng/L of aqueous PAHs for habitats where fish eggs and larvae rear, derived from studies on sensitive early life stages of pink salmon and Pacific herring. We (Short et al.) recommend that government standards for dissolved aromatic hydrocarbons should be revised to reflect this threshold for protection of critical life stages and habitats of fish.

Peterson et al. (2003) recently describe the long-term ecosystem response to the *Exxon Valdez* oil spill. Peterson et al. (2003) state:

> The ecosystem response to the 1989 spill of oil from the Exxon Valdez into Prince William Sound, Alaska, shows that current practices for assessing ecological risks of oil in the oceans and, by extension, other toxic sources should be changed. Previously, it was assumed that impacts to populations derive almost exclusively from acute mortality. However, in the Alaskan coastal ecosystem, unexpected persistence of toxic sub-surface oil and chronic exposures, even at sublethal levels, have continued to affect wildlife. Delayed population reductions and cascades of indirect effects postponed recovery. Development of ecosystem-based toxicology is required to understand and ultimately predict chronic, delayed, and indirect long-term risks and impacts.
>
> ...uncertainties do little to diminish the general conclusions: oil persisted beyond a decade in surprising amounts and in toxic forms, was sufficiently bioavailable to induce chronic biological exposures, and had long-term impacts at the population level. Three major pathways of induction of long-term impacts emerge: (i) chronic persistence of oil, biological exposures, and population impacts to species closely associated with shallow sediments; (ii) delayed population impacts of sublethal doses compromising health, growth, and reproduction; and (iii) indirect effects of trophic and interaction cascades, all of which transmit impacts well beyond the acute-phase mortality.

Peterson et al. (2003) describe long-term responses of a variety of wildlife and fish resources impacted by the Exxon Valdez oil spill; those specifically pertinent to fish resources are quoted below:
Chronic exposures of sediment-affiliated species:

- Chronic exposures enhanced mortality for years;
- After the spill, fish embryos and larvae were chronically exposed to partially weathered oil in dispersed forms...(citing Murphy et al., 1999)
- Laboratory experiments showed that these multiringed polycyclic aromatic hydrocarbons (PAHs) from partially weathered oil at concentrations as low as 1 ppb are toxic to pink salmon eggs exposed for the months of development and to herring eggs exposed for 16 days (citing Marty et al., 1997; Heintz et al. 2001)
- This process explains the elevated mortality of incubating pink salmon eggs in oiled rearing streams for at least 4 years after the oil spill. (citing Bue et al., 1998)

Sublethal exposures leading to death from compromised health, growth, or reproduction:

- Oil exposure resulted in lower growth rates of salmon fry in 1989 (citing Rice et al., 2001), which in pink salmon reduce survivorship indirectly through size-dependent predation during the marine phase of their life history (citing Willette et al., 2000)
- After chronic exposure as embryos in the laboratory to < 20 ppb total PAHs, which stunted their growth, the subsequently marked and released pink salmon fry survived the next 1.5 years at sea at only half the rate of control fish (citing Heintz et al., 2001)
- In addition, controlled laboratory studies showed reproductive impairment from sublethal exposure through reducing embryo survivorship in eggs of returning adult pink salmon that had previously been exposed in 1993 to weathered oil as embryos and fry (Heintz et al., 1999)
- Abnormal development occurred in herring and salmon after exposure to the Exxon Valdez oil (citing Carls et al., 2001; Marty et al., 1997)

Cascades of indirect effects:

- Indirect effects can be as important as direct trophic interactions in structuring communities (citing Schoener, 1993)
- Cascading indirect effects are delayed in operation because they are mediated through changes in an intermediary.
- Perhaps the two generally most influential types of indirect interactions are (i) trophic cascades in which predators reduce abundance of their prey, which in turn releases the prey's food species from control (citing Estes et al., 1995) and (ii) provision of biogenic habitat by organisms that serve as or create important physical structure in the environment (citing Jones et al., 1994)
- Current risk assessment models used for projecting biological injury to marine communities ignore indirect effects, treating species populations as independent of one another (citing Peterson 2001; Rice et al., 2001)
- Indirect interactions lengthened the recovery process on rocky shorelines for a decade or more (citing Peterson 2001)
- Expectations of rapid recovery based on short generation times of most intertidal plants and animals are naive and must be replaced by a generalized concept of how interspecific interactions will lead to a sequence of delayed indirect effects over a decade or longer (citing Peterson 2001)
- Indirect interactions are not restricted to trophic cascades or to intertidal benthos. Interaction cascades defined broadly include loss of key individuals in socially organized populations, which then suffer subsequently enhanced mortality or depressed reproduction.
- Ecologists have long acknowledged the potential importance of interaction cascades of indirect effects. Now synthesis of 14 years of Exxon Valdez oil spill studies documents the contributions of delayed, chronic, and indirect effects of petroleum contamination in the marine environment (Table 1 of old and new paradigms).
- Old paradigm in oil ecotoxicology – oil toxicity to fish: oil effects solely through short-term (~4 day) exposure to water-soluble fraction (1- to 2-ringed aromatics dominate) through acute narcosis mortality at parts per million concentrations.
- New paradigm in oil ecotoxicology – oil toxicity to fish: long-term exposure of fish embryos to weathered oil (3- to 5- ringed PAHs) at ppb concentrations has population consequences through indirect effects on growth, deformities, and behavior with long-term consequences on mortality and reproduction.

Carls et al. (2005) studied cytochrome P4501A (CYP1A) induction pink salmon embryos exposed to crude oil and linked adverse effects at the cellular, organism, and population levels. Their study found that CYP1A induction indicates that long-term damage is probable, leading to reduced survival. In similar exposures to PAH with pink salmon embryos, earlier studies found both short- and long-term effects, including poor adult returns when embryos were exposed to similar dose levels (citing Marty et al. 1997; Heintz et al. 1999, 2000). Specifically, depressed fry growth and significantly reduced marine survival were observed after exposure of pink salmon embryos to $<5.2 \mu g\ 1^{-1}$ aqueous TPAH concentrations (citing Heintz et al. 2000). Tests confirm that long-term consequences can be expected from low exposure doses to embryos. Theirs and other studies demonstrate that CYP1A induction in embryos is linked to reduced marine survival, and ergo population-level effects.

Reduced growth potential in the marine environment, caused by toxic action in oil-exposed embryos, is probably the key functional change that leads to the distinct survival disadvantage and fewer returning adult spawners (Carls et al. 2005). Rapid fry growth after emigration to the marine environment is important to escape mortality from size-selective predation (Carls et al. 2005 citing Parker 1971, Healey 1982, Hargreaves and LeBrasseur 1985), thus placing oil-exposed fish at a disadvantage. In oil exposure tests with pink salmon embryos followed by released fry, reduced marine survival of pink salmon adults has been directly observed in 3 different brood years (1993, 1995, and 1998; citing Heintz et al. 2000). Depressed marine survival was consistently correlated with depressed growth rate 4 to 10 months after emergence, and was a more sensitive measure of significant response in 1995 fish than growth rate.

Carls et al. (2005) determined that the model of activity demonstrated by their study is consistent with a similar cascade of effects described in Prince William Sound after the Exxon Valdez oil spill. In juvenile pink salmon in marine water, CYP1A was induced by oil, and growth slowed (citing Carls et al 1996, Wertheimer and Celewycz 1996, Willette 1996). Geiger et al (1996; as cited by Carls et al 2005) estimated that approximately 1.9 million wild pink salmon failed to return as adults in 1990 because poor growth, reduced survival (about 28% of the potential wild-stock production in the SW portion of Prince William Sound). Pink salmon embryos incubating in the intertidal reaches of streams were exposed to PAH from oil-coated intertidal sediment; CYP1A was induced and survival was significantly reduced through 1993 (citing Bue et al. 1996, 1998, Wiedmer et al. 1996, Craig et al. 2002, Carls et al. 2003). Gieger et al (1996, as cited by Carls et al. 2005) estimated that 60,000 to 70,000 pink salmon failed to return as adults in 1991 and 1992, respectively, as a result of toxic exposure. Hence, the laboratory study is consistent with these field data.

Exposure to PAH during the earliest stages of development may significantly increase the risk of damage to developing embryos, consistent with the general observation that early life stages are highly vulnerable to pollutants (Carls et al. 2005, citing e.g. Moore and Dwyer 1974)...leading to immediate, secondary, and delayed effects. Carls et al. (2005) reported some macroscopic abnormalities that were positively correlated with TPAH exposure. Abnormalities that were positively correlated with exposure were ascites, bulging eyes, malformed head, short opercular plates, external hemorrhaging, mouth or jaw malformation, and deformed caudal fin. Unusual pigmentation and tumors were negatively correlated with exposure, probably because embryos with these developmental problems were less likely to survive oil exposure (Carls et al. 2005). Permanent multiple defects are likely to have lasting consequences, such as poorer growth and marine survival (Carls et al. 2005, citing e.g. Heintz et al. 2000).

Carls et al. (2005) expect that their observations may be generalized to all fish; CYP1A induction has been observed in many species and in many of the same tissues (citing e.g. Sarasquete and Segner 2000, Stememan et al. 2001). Carls et al. (2005) concluded that (1) induction of CYP1A is statistically correlated with adverse effects at cellular, organism and population levels in pink salmon and can be used to predict these responses (2) exposure of pink salmon embryos and larvae to oil caused a variety of lethal and sublethal effects; and (3) the combined results from a series of embryo-larval exposure experiments spanning 5 brood years are consistent, and demonstrate that CYP1A induction is related to a variety of lethal and sublethal effects, including abnormalities, reduced growth and diminished marine survival.

Based on the information presented above, we reviewed the recovery status of injured fish resources tracked by the Exxon Valdez Oil Spill Trustee Council (EVOSTC). The EVOSTC considers recovery to be essentially “a return to conditions that would have existed had the spill not occurred” and is considered herein to equate to a return of the affected population(s) to their former status. Pacific herring, as of 2005, are not recovering; this equates to eight generations since the EVOS (i.e., spring 1989). Pink salmon were listed as “not recovering” until 1997, at which time they were regarded as “recovering.” Pink salmon were listed as “recovered” as of 2002, as were also sockeye salmon. Consequently, 6.5 generations passed since the EVOS before pink salmon were recovered. This information further supports the long-term effects of crude oil spills upon herring and salmon described by Carls et al. (2002); Short et al. (2003); and Peterson et al. (2003), as well as capturing the lingering and indirect effects of the EVOS.

Estuaries have long been regarded as important sites for fish, both as nursery and overwintering sites, migration routes and areas which naturally support large numbers of fish (Elliott 2002; citing McHugh 1967; Haedrich 1983). Wyman and Stevenson (2001) define an estuary as "coastal waters where seawater is measurably diluted with freshwater; a marine ecosystem where freshwater enters the ocean. The term usually describes regions near the mouths of rivers and includes bays, lagoons, sounds, and marshes."

Fish use estuarine habitats for part of all of their life cycle, or migrate through estuaries between their feeding and breeding areas (Costello et al. 2002). The young of many marine fish use estuaries and shallow coastal waters as nursery grounds, and some freshwater fish use estuarine habitats as feeding areas. The concentration of cities, industry and rivers has resulted in estuaries being amongst the most polluted and threatened marine habitats.

The high food availability in estuaries-especially that leading to detritus-based food webs-makes them important for fishes and crustaceans (Elliott 2002; citing de Sylva 1975). The allochthonous and autochthonous detritus present in an estuary will fuel those food webs (Elliott 2002; citing McLusky 1989) and thus lead to the support of large populations. The central position of estuaries in the passage from freshwaters to marine areas and vice versa further contributes to their importance. This importance mainly reflects the value for diadromous fishes, such as the salmonids (e.g. salmon and trouts) and coregonids (e.g., whitefishes), anguillids (e.g. eels), as well as other estuarine/nearshore spawners and feeders that include the clupeids (e.g. herring), osmerids (e.g., capelin and rainbow smelt), and ammodytids (e.g., sand lance). Thus, any chemical (water quality) or physical (barriers) interference to that passage will have repercussions for the migratory fishes and thus their uses.

In addition to this, fish species-as with all taxa-have defined biological distributions which may be termed biogeographic regions (Costello et al. 2002). The species within areas considered here will be termed Arctic or Sub-arctic, or boundaries of these (Arctic-Subarctic. As such, they have their largest population size within optimal areas and conditions, outside which their populations decrease in abundance and biological fitness with increasing distance from those optimal conditions (Costello et al. 2002). Consequently, they will be rare or will have fragile populations at the limits of their distributions and, similarly, the populations at those extremities will be increasingly vulnerable to the effects of other stressors, whether anthropogenic or natural. In the Beaufort Sea planning area, species such as Pacific herring, capelin, rainbow smelt, Pacific salmon, and Pacific sand lance are at the northern limits of their range; they are and of small population sizes and considered rare species in the region.

Many fish species are most susceptible to stress and toxic substances during the egg and larval stages than adult stage. Intertidal areas contaminated by spilled oil may persist for years and represent a persistent source of harmful contaminants to fishes utilizing oiled estuarine or nearshore habitats. For example, capelin spawn on coastal sandy beaches along the Beaufort Sea in June, July and August and are highly specific with regard to spawning conditions. At spawning grounds, capelin segregate into schools of different sexes. The general pattern seems to be that ripe males await opportunities to spawn near the beaches, while large schools, mainly composed of relatively inactive females, remain for several weeks off the beaches in slightly deeper water (i.e., staging area). As these females ripen, individuals proceed to the beaches to spawn. Thus, most males remain in attendance near the beaches and join successive small groups of females that spawn and depart from the area. Capelin spawn at about 2 years of age and that many individuals die after spawning (mainly males; Jangaard, 1974).

Capelin eggs are demersal and attach to gravel on the beach or on the sea bottom. The incubation period varies with temperature, and hatching has been demonstrated to occur in about 55 days at 0 ˚C, 30 days at 5 ˚C, and 15 days at 10 ˚C. Newly hatched larvae soon assume a pelagic existence near the surface, where they remain until winter cooling sets in, when they move closer to the sea bottom until waters warm again in spring.

Summer is a period of intensive feeding activity in coastal waters. Feeding activity in capelin, for example, is highly seasonal. Feeding intensity increases in the prespawning season in late winter and early spring, but it declines with the onset of spawning migration. Feeding ceases altogether during spawning season.

Survivors of spawning resume feeding several weeks post-spawning and proceed at high intensity until early winter, when it ceases.

Most pink salmon spawn within a few miles of the coast and spawning within the intertidal zone or the mouth of streams is very common. Small spawning runs of pink salmon occur in the Sagvanirktok and Colville rivers, although not predictably from year to year. Available data suggest that pink salmon are more abundant in even-numbered years (for example, 1978, 1982) than in odd-numbered years (for example, 1975, 1983), as is the general pattern for this species in western Alaska (Craig and Halderson, 1986, citing Heard, 1986). This pattern may be a manifestation of the distinctive life cycle of the pink salmon (i.e., they spawn at 2 years of age and die following spawning). Among the few pink salmon collected in the Sagavanirktok River and delta were several spawned-out adults. Bendock (1979) noted pink salmon spawning near the Itkillik River and at Umiat. Two male spawners were caught near Ocean Point just north of Nuiqsut (Fechhelm and Griffiths, 2001, citing McElderry and Craig, 1981). In recent years, "substantial numbers" of pink salmon have been taken near the Itkillik River as part of a fall subsistence fishery (Fechhelm and Griffiths, 2001, citing George, pers. commun.). Pink salmon also are taken in the subsistence fisheries operating in the Chipp River and Elson Lagoon just to the east of Point Barrow (Fechhelm and Griffiths, 2001, citing George, pers. commun.). Craig and Halderson (1986) propose that pink salmon spawn successfully and maintain small but viable populations in at least some arctic drainages; continued occurrences of pink salmon in arctic drainages indicates their suggestion is credible.

Schmidt, et al., (1983) describe the life cycle of pink salmon:

> Eggs are laid in redds [nests] dug in gravel. The eggs hatch during the winter however the alevins remain in the gravel, until the yolk sac is absorbed, emerging later in spring. After emerging from the gravel, the fry begin moving downstream. They remain in the estuary for up to a month prior to moving offshore. Little is known of the movements undertaken during the 18 months the salmon spend at sea. It is likely the North Slope populations move westerly towards the Chukchi Sea and upon maturing at the age of 2 years, the salmon then return to their natal streams to spawn in the fall.

Such life history strategies as those of the capelin and pink salmon make their populations highly susceptible to an oil spill affecting their spawning, nursery, or summer feeding or migration areas. An oil spill may lead to Types I, II, III, IV, and/or V response patterns (Munkittrick and Dixon 1989) by capelin, pink salmon, or other estuarine/nearshore fish populations. The patterns represent population changes and describe responses to exploitation, recruitment failure, the presence of multiple stressors, food limitation and niche shifts. Response patterns are briefly described below.

Type I response (Exploitation): The best understood response pattern is the characteristic compensatory response of a previously unexploited fish population to adult removal (Munkittrick and Dixon 1989; citing Colby 1984). The removal of a significant number of adults results in a relative increase in the amount of food and habitat available for those surviving. This relative increase theoretically leads to an increased growth rate and fecundity, as well as an earlier age at maturation (Munkittrick and Dixon 1989; citing McFarlane and Franzin 1978; Trippel and Harvey 1987). Due to the shift in the age-structure of the population, the mean age of the population declines.

A type I response should be found whenever a sudden decrease in the population size has occurred, and not just in response to man's harvest of a standing crop. Type I responses have been documented in response to increased mortality associated with predation of fish by harbor seals (Munkittrick and Dixon 1989; citing Power and Gregoire 1978), parasitization by Ligula intestinalis (Munkittrick and Dixon 1989; citing Burrough and Kennedy 1979) and the chronic effects of atmospheric metal deposition (Munkittrick and Dixon 1989; citing McFarlane and Franzin 1978).

Type II response (Recruitment Failure): A type II response is also characterized by an increased growth rate in response to a decreased population size. The response differs from a type I pattern in that there is an increase in the mean age of the population, due to prolonged increases in egg mortality or recruitment failure (citing Colby 1984). The response can be due to deterioration of spawning or nursery habitat, or to stressor-induced spawning failures, and is typical of a population approaching extinction.

Type III response (Multiple Stressors): In the absence of contaminants, a type III response is reflective of the persistence of marginal, adverse conditions for a prolonged period of time. Food supply problems are associated with a decline in growth rate and fecundity. The increase mean age can be related to a decline in reproduction and recruitment, the size-selective mortality of young fish, or to a prolonged decline in habitat or food supply.

Type III responses have also been associated with contamination events, and are suggestive of multiple stressors. Generally, factors associated with recruitment failure are responsible for increasing the mean age, while food availability problems prevent a characteristic compensatory response.

Type IV response (Limitation): This pattern is evident where a fish population has reached the carry capacity of a system. The response is initiated by a decline in food and habitat availability, and the population does not show an increase in the mean age. The response is often associated with an increased population size due to predator removal or overstocking, or to a decline in habitat availability. A decline in food availability should result in decreased growth rate, condition factor and fecundity, and an increase in the age at maturity. The persistence of conditions will result in a gradual increase in mean age, characteristic of the type III response.

Type V response (Niche Shift): A type V response is characterized by a decline in fecundity of the fish without concomitant changes in condition or mean age. This response is typically seen when a portion of the population is eliminated and a stressor prevents the population from regaining its former abundance. It can also be seen when there is a gradual change in food availability or when the introduction of a competing species results in a niche shift.

Based on the reviewed information, an oil spill occurring and oiling intertidal or nearshore spawning or nursery habitat (e.g., capelin, pink salmon) may decimate a year-class of young, and cause additional measurable lethal and sublethal effects to the local population in successive years. Additionally, a large oil spill impacting a spawning area habitually used by capelin, pink salmon, or similar nearshore spawning fishes poses two scenarios. One scenario is that fish may not detect contaminated substrate and spawn there for successive generations. Eggs deposited in the proximity of the contaminated substrate over a series of years may be exposed to PAHs retained in the substrate, subsequently leading to lethal and sublethal effects to those offspring as described by Carls et al. (2002, 2005); Peterson et al. (2003); and Short et al. (2003). A second scenario is that the capelin, pink salmon or other fishes detect oil at the spawning site and choose not to spawn there. It is not known what such a behavioral response may have upon the dynamics of the population, however, the oiled spawning site(s) would likely be unavailable for use for multiple generations, depending on the sensitivity of the fish to detecting contaminated substrates and how long the oil persists in the habitat. Also unknown are the distribution and abundance of spawning sites used by capelin and other fishes in the Alaskan arctic.

For purposes of analysis, one large spill was assumed to occur and was analyzed in the Beaufort multiple-sale EIS, Sale 195 EA and this EA. The chance of one or more large spills total is 21% for the Proposed Action and alternatives based on the mean spill rate over the life of the project (Figure C-5 through C-9). Table C-9 shows the chance of one or more large spills total for the Proposed Action and alternatives using spill rates at the 95% confidence interval. For the Proposed Action and alternatives, the percent chance of one or more large spills occurring total ranges from 14-29% using the spill rates at the 95% confidence interval over the life of the project.

Appendix A-1 of the Multisale EIS (MMS 2003) describes the many facets of oil spill assessment appertaining to the proposed leasing actions. Maps A-3a and A-3b show the location of the 66 land segments dividing the Beaufort Sea coastline for analytical purposes. Land segment identification numbers (ID) and the geographic place names within the land segment are shown in Table A.1-2b. Conditional probabilities of one large spill contacting any of the various land segments are reported in a suite of tables contained in Appendix A-1 of the Multisale EIS. There are numerous instances whereby oil may contact estuarine or intertidal habitats; the probabilities vary but are underestimates as the model does not account for such phenomena as oil smearing along the coast.

Based on the information reviewed (e.g., Carls et al. 2002; 2005; Peterson et al. 2003; and Short et al. 2003), a large oil spill impacting estuarine or intertidal habitats utilized by capelin or other fishes is likely to result in significant adverse effects on local populations requiring three or more generations to recover to their former status. A large oil spill impacting essential fish habitat utilized by early life history stages of pink salmon is likely to result in significant adverse effects on local populations requiring three or more generations to recover to their former status. Furthermore, locally significant adverse effects may adversely effect adjacent population units depending on metapopulation structure and interactions among and between large marine ecosystems, the magnitude of which is unknown due to the lack of information regarding metapopulations. Additionally, other leasing related activities associated with the proposed action (e.g., seismic surveys, exploratory drilling, construction and operation of production facilities and infrastructure, vessel traffic, permitted discharges, and small chemical spills, including oil) all can contribute additive and/or synergistic lethal and sublethal impacts that remove individuals (mainly early life history stages) from the population, and depress recruitment to the breeding age cohorts, pre- and post-occurrence of a large oil spill impacting fish resources (e.g., capelin, pink salmon) of the Beaufort Sea.

Lethal effects, or sublethal effects reducing reproductive fitness or survival, of rare and/or highly aggregated species (e.g. Pacific herring, capelin, pink salmon) may be more consequential to their respective populations via Allee effects. The Allee effect is a phenomenon in biology used to describe the positive relation between population density and the *per capita* growth rate. In other words, for smaller populations, the reproduction and survival of individuals decreases. This effect usually saturates or disappears as populations get larger. The effect may be due to any number of causes. In some species, reproduction—finding a mate in particular—may be increasingly difficult as the population density decreases. Less fish reproduction lends to further decrease populations. Other species may use strategies (such as schooling in fish) that are more effective for larger populations, but also make them potentially more susceptible to greater impacts as individuals are concentrated. Continuance of leasing-related exploration and development activities in the years (e.g., seismic surveys or additional small oil spills) following a large oil spill impacting fish resources (e.g., capelin or pink salmon) would likely contribute to the Allee effect and delay the recovery of affected populations to their former status well past the three generation threshold for recovery. Additional indirect effects that may also delay recovery of affected populations include the potential influence of a disease or parasite loads, as evident from the Exxon Valdez oil spill case.

Conclusions: Based on the information reviewed (e.g., Carls et al. 2002; 2005; Peterson et al. 2003; and Short et al. 2003), a large oil spill impacting estuarine or intertidal habitats utilized by capelin or other fishes is likely to result in significant adverse effects on local populations requiring three or more generations to recover to their former status. A large oil spill impacting essential fish habitat utilized by early life history stages of pink salmon is likely to result in significant adverse effects on local populations requiring three or more generations to recover to their former status.

Updated Effects from Routine, Permitted Operations

3. BENEFITS OF THE STANDARD MITIGATION

Tom: Let's talk about this on Monday as it is extremely problematic relative to the Seismic and invasive species mitigations I proposed for the PEA.

4. OVERALL CONCLUSION—THE MITIGATED EFFECT

Tom: Let's talk about this on Monday as it is extremely problematic relative to the Seismic and invasive species mitigations I proposed for the PEA.