MEMORANDUM

DATE: January 12, 2009
TO: Habitat, MPA and Ecosystems Committee
FROM: Chad Demarest
SUBJECT: Atlantic wolffish EFH

The Groundfish Ctte passed a motion recommending the Council add Atlantic wolffish to the Northeast Multispecies management unit. If the Council were to adopt this motion, the MSA requires the Council to designate EFH for wolffish, presumably at the same time it is added to the multispecies Fishery Management Plan in groundfish Amendment 16 (A16). The EFH designation in A16 should meet all MSA requirements and cover areas appropriate for the species, perhaps with an emphasis on inclusiveness rather than refinement. In the future, the Council may choose to refined the designations at a later date if necessary in the Omnibus 2 Amendment (e.g., consistent with the four broad Alternatives in the Phase 1 document).

Essential Fish Habitat – Atlantic wolffish (*Anarhichas lupus*)

*Background Information*

**Geographic Range**

Atlantic wolffish (*Anarhichas lupus*) can be found in northern latitudes of the eastern and western North Atlantic Ocean. In the north and eastern Atlantic they range from eastern Greenland to Iceland, along northern Europe and the Scandinavian coast extending north and west to the Barents and White Sea’s. In the northwest Atlantic they are found from Davis Straits off of western Greenland, along Newfoundland and Labrador and continue southward through the Canadian Maritime Provinces to Cape Cod, USA. They are found infrequently in southern New England to New Jersey (Collete and Klein-MacPhee 2002). Northeast Fishery Science Centers Bottom Trawl surveys have only encountered 1 fish southwest of Martha’s Vineyard, Massachusetts since 1963.

**Habitats**
Atlantic wolffish are a demersal species which prefer complex habitats with large stones and rocks which provide shelter and nesting sites (Pavlov and Novikov 1993). They are occasionally seen in soft sediments such as sand or mud substrate and likely forage for food sources in these habitats (Collete and Klein-MacPhee 2002; Falk-Petersen and Hansen 1991). They are believed to be relatively sedentary and populations localized. Tagging studies from Newfoundland, Greenland and Iceland indicate that most individuals were recaptured within short distances, ~8km, of the original tagging sites (Templeman 1984; Riget and Messtorff 1988; Jonsson 1982). Three significantly longer migrations were reported in Newfoundland ranging from 338 – 853 km (Templeman 1984).

Atlantic wolffish occupy varying depth ranges across its geographic range. In the Gulf of Maine they inhabit depths of 40 – 240 m, in Greenland and Newfoundland 0 – 600 m, in Iceland 8 – 450 m and in Norway and the Barents Sea from 10 – 215 m (Riget and Messtorff 1988; Albikovskaya 1982; Templeman 1984; Jonsson 1982; Falk-Petersen and Hansen 1991). In U.S. waters, abundance appears to be highest in the southwestern portion of the Gulf of Maine, from Jefferies Ledge to the Great South Channel, corresponding to the 100 m depth contour (Nelson and Ross 1992). Similarly, abundance is highest in the Browns Bank, Scotian shelf and northeast peak of Georges Bank areas in the Canadian portion of the Gulf of Maine (Nelson and Ross 1992). Atlantic wolffish in Newfoundland and Icelandic waters were identified as most abundant in depths 101 – 350 m and 40 - 180 m, respectively (Albikovskaya 1982; Jonsson 1982).

Temperature ranges where Atlantic wolffish occurs also deviate slightly with geographic region. Historically in the Gulf of Maine they have been associated with temperatures ranging from 0 – 11.1°C (Bigelow and Schroeder 1953). Bottom temperatures collected from NEFSC bottom trawl surveys where wolffish were encountered range from 0 – 10°C in spring and 0 – 14.3°C in fall. In Newfoundland wolffish thermal habitat ranged from -1.9 – 11.0 °C, Norway from -1.3 - 11 °C and in Iceland and Northern Europe -1.3 – 10.2 °C (Collete and Klein-MacPhee 2002; Falk-Petersen and Hansen 1991; Jonsson 1982). Laboratory studies indicate wolffish can survive a wide span of temperatures -1.7 – 17.0°C and that feeding is negatively correlated with the higher temperature extremes (Hagen and Mann 1992; King et al. 1989).

**Reproduction**

In general Atlantic wolffish are solitary in habit, except during mating season when bonded pairs form in spring/summer depending on geographic location (Collete and Klein-MacPhee 2002; Keats et al. 1985; Pavlov and Novikov 1993). Spawning is believed to occur in September through October in the Gulf of Maine but is likely to depend on temperature and possibly photoperiod (Collete and Klein-MacPhee 2002; Pavlov and Moksness 1994). Spawning is reported to occur from August – September in Nova
Scotia, during autumn in Newfoundland, September – October in Iceland, July – October in Norway, and late summer – early autumn in the White Sea (Keats et al. 1985; Templeman 1986; Jonsson 1982; Falk-Petersen and Hansen 1991; Pavlov and Novikov 1993). In the Gulf of Maine there is weak indication of a seasonal migration as wolfish may travel from shallow to deep in autumn and then deep to shallow in spring (Nelson and Ross 1992). Similar migrations occur in Iceland and the White Sea where wolfish migrate to colder temperatures before the spawning season (Pavlov and Novikov 1993; Jonsson 1982). Atlantic wolfish have the lowest fecundity compared to their relatives, the spotted wolfish (*Anarhichas minor*) and the northern wolfish (*Anarhichas denticulus*). Fecundity is related to fish size and body mass in this species and increases exponentially with length. Newfoundland mean fecundity estimates, combined from several NAFO statistical areas, range from 2,440 eggs at 40 cm to 35,320 eggs at 120 cm (Templeman 1986). In Norway a female at 60 cm produces approximately 5,000 eggs while a female 80-90 cm will lay 12,000 eggs (Falk-Petersen and Hansen 1991). Potential fecundity of wolfish in Iceland was measured between 400 and 16,000 eggs for fish at lengths of 25 and 83 cm respectively (Gunnarsson et al. 2006). Mature eggs are large measuring 5.5 – 6.8 mm in diameter (Colette and Klein-MacPhee 2002). Male Atlantic wolfish have small testes and produce small amounts of sperm peaking during late summer and autumn. These data along with morphological development of a papilla on the urogenital pore during spawning suggest internal fertilization (Pavlov and Novikov 1993; Pavlov and Moksness 1994, Johannessen et al. 1993). Males have been observed guarding egg clusters for several months but it is not certain if they continue until hatching (Keats et al. 1985; Collete and Klein-MacPhee 2002). Hatching may take 3 to 9 months depending on temperature (Collete and Klein-MacPhee 2002).

**Food Habits**
The diet of Gulf of Maine and Georges Bank wolfish consist primarily of bivalves, gastropods, decapods and echinoderms (Nelson and Ross 1992). Wolfish possess specialized teeth, including protruding canine tusks (hence its name) and large rounded molars, which allow for removal of organisms from the sea floor and crushing of hard shelled prey (Collete and Klein-MacPhee 2002). Due to diet teeth are replaced annually (Albikovskaya 1983; Collete and Klein-MacPhee 2002). Fish have also been reported as an important food source in other regions along with amphipods and euphausiids shrimp for smaller individuals, 1 – 10 cm (Collete and Klein-MacPhee 2002; Albikovskaya 1983; Bowman et al. 2000). Travel between shelters and feeding grounds occurs during feeding periods as evidenced by crushed shells and debris observed in the vicinity of occupied shelters (Collete and Klein-MacPhee 2002; Pavlov and Novikov 1993). Fasting does occur for several months while replacing teeth, spawning and nest guarding occurs (Collete and Klein-MacPhee 2002).

**Size**
In the Gulf of Maine and Georges Bank regions individuals may attain lengths of 150 cm and weights of 18 kg (Goode 1884; Idoine 1998). Northeast Fishery Science Center
bottom trawl surveys have captured animals ranging in size from 3 – 137 cm in spring and 4 – 120 cm in fall and with a maximum weight of 11.77 kg.

Age and Growth
Mean length at age for Atlantic wolffish in the Gulf of Maine was determined to be 22 years at 98 cm and 0 years at 4 cm (Nelson and Ross 1992). Fish over 100 cm were not sampled extensively in this study, 10 fish from 100-118 cm. Ages in the Gulf of Maine are comparable to wolffish ages in other regions, such as 21 years in east Iceland and 23 years in Norway (Gunnarsson et al. 2006; Falk-Petersen and Hansen 1991). Age 0 fish grow quickly in Icelandic waters and may reach 10.5 cm in the first year (Jonsson 1982). Gulf of Maine wolffish have faster growth rates than fish in Iceland but grow fastest in the North Sea region (Nelson and Ross 1992; Liao and Lucas 2000). Growth in the Gulf of Maine for both male and female wolffish was best estimated using a Gompertz growth function, \( L = 98.9 \text{ cm, } K = 0.22 \text{ and } t_0 = 4.74 \) (Nelson and Ross 1992). Female growth from Iceland has been modeled using a logistic growth function and coefficients estimated using non-linear optimization (Gauss-Newton method), results from the east and west regions were: \( L = 90.919, K = 0.230 \text{ and } t_0 = 8.837 \text{ and } L = 70.046, K = 0.378 \text{ and } t_0 = 4.691 \), respectively (Gunnarsson et al. 2006). Von Bertalanffy growth parameters for the North Sea population of wolffish were \( L = 111.2, K = 0.12 \text{ and } t_0 = -0.43 \text{ and } L = 115.1, K = 0.11 \text{ and } t_0 = -0.39 \), for males and females respectively (Liao and Lucas 2000).

Maturity
In the Gulf of Maine individuals are believed to reach maturity by age 5-6 when they reach approximately 47 cm total length (Nelson and Ross 1992; Templeman 1986). Size at fifty percent maturity \( (L_{50}) \) of females varies latitudinally which is likely due to the effects of temperature. Templeman (1986) showed that northern fish mature at smaller sizes than faster growing southern fish in Newfoundland. \( L_{50} \) was reported as 51.4 cm in the northern area, 61.0 cm in the intermediate region and 68.2 cm in the south. In a study somewhat contradictory to Templeman 1986, Atlantic wolffish in east Iceland, where water temperatures are colder, had larger \( L_{50} \) values than fish in the relatively warmer waters of east Iceland (Gunnarsson et al. 2006). Authors indicate that maturity may be difficult to determine using visual methods in females because of large eggs size in this species. Second generation eggs are visible in young, immature fish when the reach the cortical alveolus stage but they may not be able to spawn for several more years (Gunnarsson et al. 2006; Templeman 1986).

A logistic maturity ogive was developed for female Atlantic wolffish based on spring and fall NEFSC survey. \( L_{50} \) was estimated at approximately 35 cm from these data. This \( L_{50} \) for female wolffish is lower than estimates reported in Newfoundland and Iceland where females containing second generation eggs were considered immature (Templeman 1986; Gunnarsson et al. 2006). NEFSC maturity data is based on visual inspection of the reproductive organs. Fish are classified into 1 of 7 stages of maturity (Burnett et al 1989). Fish classifications for females include immature, developing, ripe,
eyed (unique for redfish), ripe and running, spent and resting. This analysis considered fish that were in the developing through resting stages as a mature and immature were those fish that contained no visible eggs. Size at maturity may be difficult to interpret for wolfish from these data as they may have an additional developing stage, or a set of second generation eggs which may last for several years, where fish are reproductively immature (Gunnarsson et al. 2006). These immature fish would likely be classified as developing in NEFSC surveys and were considered mature in the ogive thereby reducing the size at 50% mature.

**Options for designating Essential Fish Habitat**

The EFH Final Rule states that “FMPs must describe and identify EFH in text that clearly states the habitats or habitat types determined to be EFH for each life stage of the managed species. FMPs should explain the physical, biological, and chemical characteristics of EFH and, if known, how these characteristics influence the use of EFH by the species/life stage. FMPs must identify the specific geographic location or extent of habitats described as EFH. FMPs must include maps of the geographic locations of EFH or the geographic boundaries within which EFH for each species and life stage is found.” Life stages are unique developmental periods and for the purposes of this action are defined as follows:

1. **Egg stage** – The life history stage of an animal that occurs after reproduction and refers to the developing embryo, its food store, and sometimes jelly or albumen, all surrounded by an outer shell or membrane. Occurs before the larval or juvenile stage.

2. **Larval stage** – The first stage of development after hatching from the egg for many fishes and invertebrates. This life stage looks fundamentally different than the juvenile and adult stages, and is incapable of reproduction; it must undergo metamorphosis into the juvenile or adult shape or form.

3. **Juvenile stage** – The life history stage of an animal that comes between the egg or larval stage and the adult stage; juveniles are considered immature in the sense that they are not yet capable of reproducing, yet they differ from the larval stage because they look like smaller versions of the adults. Young-of-the-year juveniles are juveniles less than one year old.

4. **Adult stage** – In vertebrates, the life history stage where the animal is capable of reproducing. Spawning adults are adults that are currently producing eggs.
EFH Option 1 – Omnibus Amendment 1 Method
Text descriptions and maps for five life stages would be consistent with methods employed in the Omnibus EFH Amendment 1 (1998), as described in Appendix A of the Omnibus EFH Amendment II (attached).

Notes:
1. The spawning adult lifestage would be designated if sufficient information was available
2. 1963-1997 trawl survey would be used for juvenile, adult and adult spawning lifestages, and 1977-1987 MARMAP data would be used for egg and larvae life stages
3. Four survey presence thresholds could be explored for mapping the spatial extent of EFH: 50%, 75%, 90% and 100%

EFH Option 2 – NOAA Trawl Survey Presence
Text descriptions would be consistent with that described above, and maps for the five life stages would be based on presence in the NOAA trawl survey.

Notes:
1. This Option could use spring and fall surveys of varying time periods:
   a. 1963–1997 (consistent with Option 1)
   b. 1967-2005 (consistent with Alternative 2 in the Omnibus 2 document)
   c. More recent data, such as 1967 – 2007
2. MARMAP data (1977-1987) would be used for egg and larvae life stages
3. Four survey presence thresholds could be explored for mapping the spatial extent of EFH: 50%, 75%, 90% and 100%
References


