17. Baleen Whales and Odontocetes

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Background

Cetaceans (whales, dolphins and porpoises) inhabiting the EMAX study ecoregions migrate between the four regions and also go outside them. A general description of the distribution and habit of cetaceans in the North Atlantic is found in Waring and Palka (2002). More detailed descriptions for each species are found in Waring *et al.* (2004). Cetaceans that have teeth (odontocetes) that utilize at least one of the EMAX ecoregions for some part of the year include: bottlenose dolphins (*Tursiops truncatus*), common dolphins (*Delphinus delphis*), beaked whales (*Ziphius* or *Mesoplodon* spp.), Risso's dolphins (*Grampus griseus*), harbor porpoise (*Phocena phocena*), dwarf sperm or pygmy sperm whale (*Kogia* spp.), long-fin and short-fin pilot whales (*Globicephala* spp.), sperm whales (*Physeter macrocephalus)*, spotted dolphins (*Stenella frontalis)*, striped dolphins (*S. coeruleoalba)*, and white-sided dolphins (*Lagenorhynchus acutus)*. Cetaceans with baleen that utilize some part of the EMAX ecoregions for some part of the year include: fin whales (*Balaenoptera physalus)*, sei whales (*B. borealis)*, humpback whales (*Megaptera novaeangliae)*, minke whales (*B. acutorostrata*), and right whales (*Eubalaena glacialis*).

Data Sources

The biomass data are based on abundance shipboard and aerial sighting surveys conducted by the NMFS/NEFSC during the summers of 1998 and 1999. The 1999 survey was used to estimate abundance within the Gulf of Maine ecoregion, while the 1998 survey covered the other ecoregions (Figure 17.1). The 1998 shipboard survey was conducted from 6 July to 6 September, and two teams of observers searched for marine mammals using line transect field data collection methods. These data were analyzed using the direct duplicate line transect analysis method (Palka 1995; Palka 2005a). The 1998 aerial survey was conducted from 18 July to 21 August using standard 1-team line transect methods (Palka 2005b). The 1999 shipboard and aerial surveys were conducted during 28 July to 31 August using methods similar to those used in the 1998 surveys (Palka 2000).

Quantitative Approach for Biomass Estimates

Biomass (in metric tons) of baleen whales and odontocetes within an ecoregion was calculated as the sum of the seasonally averaged biomass of each baleen or odontocetes species within that ecoregion. Biomass per area (in g m^{-2}) was calculated as biomass (in metric tons) per area of the region (in km^2; Table 1.1). The seasonally averaged biomass of species *k* within ecoregion *i* was calculated as the product of the seasonal average abundance estimate for species *k* in ecoregion *i* and the average weight (in kg; Table 17.1) of an individual of species *k*:

(EQ. 17.1) $$Average\ Biomass_{ki} = \frac{\sum_{season}(seasonal\ \ abundance_{ki})}{4} \bullet \frac{avg\ weight_{k}}{1000}.$$

The seasonal average abundance estimate was defined as the average of the abundance for each season weighted by the length of the season. The seasons were defined as summer (June to August), fall (September to November), winter (December to February), and spring (March to May). Average weights of individuals were based on values in Trites and Pauly (1998) and Kenney *et al.* (1997).

Abundance estimates were derived from shipboard and aerial line transect surveys conducted by the NEFSC in the summers (July and August) of 1998 and 1999 (Figure 17.1). The EMAX Gulf of Maine abundance estimate was derived from the 1999 survey data and the abundance estimates for the rest of the ecoregions were derived from the 1998 data. Shipboard and aerial abundance estimates within an EMAX ecoregion were derived from the length of track lines (L), number of sightings (n), and average group size ($\bar{s}$) within each EMAX region and the estimates of the effective strip width (esw) and g(0) derived from the entire survey. Thus, the abundance for a species *k* within ecoregion *i* on platform *j* (ship or plane) was:

(EQ. 17.2) $$Abundance_{kij} = \frac{n_{kij} \bullet \bar{s}_{kij}}{2 \bullet L_{ij} \bullet esw_{kj} \bullet g(0)_{kj}} \bullet A_{ij},$$

where A_{ij} was the area within EMAX ecoregion *i* that was surveyed by platform *j*. The total abundance for species *k* within a region was the sum of the aerial and shipboard abundance estimates for that species.

Abundance estimates from these surveys represent the summer season. Since each species migrates up and down the U.S. Atlantic coast in different ways and at different times, a seasonal abundance estimate for each species within each EMAX ecoregion was calculated separately. That is, the seasonal abundance estimate within each ecoregion was defined as a proportion of the summer population within that region using expert opinion and general patterns documented in the Cetacean and Turtle Assessment Program (CETAP) (1982) and Department of Navy (2005).

Note that the estimate of *g(0)*, the probability of detecting a group on the track line, was defined as 1.0 for these aerial surveys, while *g(0)* was estimated for the shipboard data. This means the abundance estimates presented here are negatively biased, because not all whales and dolphins were seen on the track line from an airplane flying at 600 ft altitude as was assumed when *g(0)*=1. During 2004, methods developed to estimate g*(0)* for aerial survey data indicate *g(0)* for large whales as about 0.2 and for smaller cetaceans about 0.6 to 0.7 (Palka 2005). Consequentially, if *g(0)* was included in the calculation, the abundance estimates would be 50-500% higher than what is presented here, depending on the species.

Quantitative Approach for Production Estimates

Net production biomass (in metric tons) within an ecoregion was calculated as the sum of the net production of species found in that region. Net production biomass per area (in g m^{-2}) was calculated as biomass (in metric tons) per area of the ecoregion (in km^2; Table 1.1). Net production biomass of species *k* within ecoregion *i* was calculated as the product of the seasonally averaged biomass of species *k* (eq. 17.1) within ecoregion *i* and the net production rate for species *k*:

(EQ. 17.3) $$net\ production\ \ biomass_{ki} = (seasonal\ \ avg\ biomass_{ki} \bullet net\ production\ rate_k)/1000.$$

The net production rate of cetaceans is poorly understood because only a few studies have calculated a species-specific rate. However, a value of 4% is recognized as a default value for both baleen and odontocetes. This is based on theoretical modeling showing that cetacean populations may not grow at rates much greater than 4% given the constraints of their reproductive history (Barlow *et al.* 1995). Thus, 4% was used as the net production rate for all baleen and odontocetes, except if there was a species-specific estimate available. The only species-specific estimate of the net reproductive rate that was available and differed from 4% was for right whales (0%; Fujiwara and Caswell 2001).

Quantitative Approach for Consumption Estimates

Consumption biomass (in metric tons) within an EMAX region was calculated as the sum of the annual consumption biomass of species found in that region. Consumption biomass per area (in g m^{-2}) was calculated as consumption biomass (in metric tons) per area of the region (in km^2; Table 1.1). The annual consumption biomass (in metric ton) for species k within ecoregion i was estimated by:

(EQ. 17.4)
$$Consumption\ biomass_{ik} = \frac{\sum_{season\ s} \sum_{days\ in\ s} daily\ feeding\ rate_{ks} \bullet (biomass / day)_{iks}}{1000}$$

where the $(\text{daily feeding rate})_{ks}$ (in kg day^{-1}) is the daily feeding rate of species k for season s and the $(\text{biomass day}^{-1})_{iks}$ (in kg) is the biomass of species k within ecoregion i and within season s. The feeding rate per individual per day is defined as a percentage of its biomass.

There is an inverse relationship between feeding rate and body weight (Sargeant 1969). Thus, for large whales (baleen whales and sperm whales) the daily feeding rate (in kg day^{-1}) for species i was estimated using (Innes *et al.* 1987):

(EQ. 17.5)
$$Daily\ feeding\ rate_i = \frac{0.042 \bullet avg\ wt_i^{\ 0.67}}{avg\ wt_i}.$$

Because baleen whales do not feed while migrating and mating in the winter, it was assumed the daily feeding rate for baleen whales in winter was 0%; all other seasons followed Equation 17.5.

The range of daily feeding rates for odontocetes is 4-11% (Table 17.2). For this study it was assumed the daily feeding rate for harbor porpoises was 8.3% of body weight, and for other odontocetes (excluding sperm whales) it was assumed to be 4.2% of body weight.

Example Results

Biomass Estimates

The seasonal distribution of baleen and odontocetes varies greatly by species (Table 17.3). Cetacean biomass per area (in g m^{-2}) is dominated by baleen whales, even though there are fewer species of baleen whales than odontocetes (Figure 17.2). The cetacean biomass per area is highest in the Gulf of Maine and Georges Bank, and the lowest in the Mid-Atlantic Bight.

Among the baleen whales, the most common species are fin and humpback whales (Figure 17.2A). Within the odontocetes, most of the biomass is from pilot whales (long and short fin), common dolphins, and white-sided dolphins (Figure 17.2B). The Gulf of Maine region has the lowest number of species but the most biomass. The Georges Bank and Southern New England regions have the most diverse composition of species. Note that all the species found in the ecoregions south of the Gulf of Maine are also found offshore of the EMAX ecoregions. For some species, the abundance offshore is much greater than that estimated for the EMAX regions.

Production Estimates

Little is known about cetacean reproduction rates, so the default value of 4% annual reproduction rate was used for all species except right whales (0%). Thus the patterns of production (g m^{-2} yr^{-1}) are the same as those for biomass (Figure 17.2). The magnitude, however, is 4% of the biomass.

Consumption Estimates

Using equation 17.5, the daily feeding rate of baleen whales during seasons other than winter ranged from 1.2% of a fin or sei whale's body weight to 2.3% of a minke whale's body weight. It was assumed baleen whales did not eat during winter (January to March). It was also assumed the daily feeding rate of harbor porpoises was 8.3% of its body weight, odontocetes (except sperm whales) were 4.2% of their body weight, and sperm whales (using equation 17.5) was 1.6% of its body weight.

The consumption rate per area (g m^{-2} yr^{-1}) is the highest in the Gulf of Maine and lowest in the Mid-Atlantic Bight (Figure 17.3). Baleen whales consume more than the odontocetes. Of the odontocetes, those on Georges Bank contribute the most biomass (Figure 17.2) and the most consumption biomass (Figure 17.3).

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Table 17.1. Weights (in kg) of an average animal of each species. W. = whale, D. = Dolphin. spp. = multiple species.

Baleen	Weight	Odontocete	Weight	Odontocete	Weight
Fin/Sei W.	50,000	Beaked W. spp.	826	Pilot W. spp.	851
Humpback W.	30,408	Bottlenose D.	188	Sperm W.	18,519
Minke W.	6,566	Common D.	80	Spotted D.	66
Right W.	23,383	Grampus	224	Striped D.	116
Sei W.	16,811	Harbor porpoise	31	Whitesided D.	92
Unid W.	24,000	Kogia spp.	139	Unid D.	136

Table 17.2. Daily feeding rates from the literature for various species.

Species	Area	Daily feeding rate (% of body weight)	Source
Pilot whale	Pacific	4	Sargeant 1969
Pilot whale	S. Atlantic	4.7	Sargeant 1969
Harbor porpoise	Pacific	11	Sargeant 1969
Harbor porpoise	S. Atlantic	8.3	Sargeant 1969
Killer whale	Pacific	3.6	Sargeant 1969
False killer whale	Pacific	4.7	Sargeant 1969
Bottlenose dolphin	S. Atlantic	4.2	Sargeant 1969
Bottlenose dolphin	Atlantic	4 - 6	San Miguel 1977
Bottlenose dolphin	Captive	5.2	Cheal & Gales 1991
Dall's porpoise	Japan	5.04	Ohizumi & Miyazaki 1998

Table 17.3. Seasonally-weighted average abundance estimates of cetacean species found in the EMAX regions. A. Baleen whales. B. Odontocetes. W. indicates whale, D. indicates dolphin. Spp. indicates species group.

A. Baleen whales.

Species	Region	Summer Abundance Estimate	% of Population in Region by Season				Seasonally Weighted Average Abundance
			Winter	Spring	Summer	Fall	
Fin or Sei W.	GB	183.96	0.2	1.3	1	0.4	133.37
	GOM	1343.82	0.1	0.9	1	0.7	907.08
	MAB	78.82	0.21	1	1	0.2	47.29
	SNE	463.05	0.1	0.8	1	0.3	254.68
Humpback W.	GB	100.14	0.1	1.2	1	0.2	62.59
	GOM	516.38	0.1	1	1	0.3	309.83
	MAB	100.00	0.2	1	0	1	55.00
	SNE	100.00	0.1	1	0	1	52.50
Minke W.	GB	64.17	0	1.3	1	0.1	38.50
	GOM	753.25	0.05	0.8	1	0.2	386.04
	MAB	100.00	0	2	1	0	75.00
	SNE	117.18	0	1.5	1	0.1	76.17
Right W.	GB	325.00	0.2	0.4	0.2	0.3	89.38
	GOM	325.00	0	0.1	0.7	0.5	105.63
	MAB	325.00	0.3	0.3	0.1	0.1	65.00
	SNE	325.00	0	0.2	0	0.1	24.38
Sei W.	GB	350.00	1	1	0.5	1	306.25
	GOM	350.00	0.5	1	0.5	0.5	218.75
	MAB	350.00	1	1	0	0.5	218.75
	SNE	350.00	0.2	0.5	0	0.1	70.00
Unid W.	GB	136.77	0.2	0.7	1	0.7	88.9
	GOM	369.21	0.1	0.5	1	0.5	193.84
	SNE	98.82	0.2	0.7	1	0.7	64.23

B. Odontocetes whales.

Species	Region	Summer Abundance Estimate	% of Population in Region by Season				Seasonally weighted average abundance
			Winter	Spring	Summer	Fall	
Beaked spp. W.	GB	88.62	1	1	1	1	88.62
Bottlenose D.	GB	741.95	0.05	1	1	0.2	417.34
	MAB	8491.67	0.05	1	1	0.7	5838.03
	SNE	6232.96	0.05	1	1	0.5	3817.69
Common D.	GB	10739.24	2	1.5	1	2	17451.27
	GOM	9369.25	0.7	0.7	1	1.5	9135.02
	MAB	2634.32	2	2	1	0.2	3424.62
	SNE	5862.25	2	2	1	2	10258.93
Risso D.	GB	2295.93	0	0.4	1	0.2	918.37
	MAB	1312.10	0.1	0.8	1	0.3	721.55
	SNE	3730.70	0	0.6	1	0.1	1585.55
Harbor P.	GB	30607.50	0.05	0.6	0	0.3	7269.28
	GOM	30607.5	0.4	0.4	0	0.3	8417.06
	MAB	30607.50	0.4	0.4	0	0.3	8417.06
	SNE	30607.50	0.3	0.4	0	0.3	7651.88
Kogia spp. W.	GB	25.36	0	0	1	0.5	9.51
	SNE	14.94	0	0	1	0.5	5.6
Pilot spp W.	GB	2488.99	0.1	2	1	0.3	2115.39
	GOM	2610.00	0.1	0.8	1	0.5	1566.00
	MAB	174.68	0.3	1	1	1	144.11
	SNE	1076.31	0.1	2	1	0.3	914.86
Sperm W.	GB	74.79	0.2	1	1	0.5	50.48
	SNE	12.59	0.1	1	1	0.5	8.19
Spotted D.	GB	1152.90	0	1	1	0.5	62.50
	MAB	100.00	0	1	0.5	1	62.50
Striped D.	GB	1526.79	0	0.7	1	0.2	725.23
	MAB	100.00	2	3	0	1	150.00
	SNE	13.04	0	1	1	1	9.78
Unid D.	GB	4769.9	0.1	0.7	1	0.7	2981.79
	GOM	2011.22	0.1	0.5	1	0.5	1055.89
	MAB	251.94	0.2	1	1	1	201.55
	SNE	6056.97	0.2	0.7	1	0.7	3937.03
Whiteside D.	GB	709.99	0.3	2	1	1	763.24
	GOM	20767.04	0.2	0.7	1	0.7	13498.58
	SNE	1317.21	0	2	1	0.5	1152.56

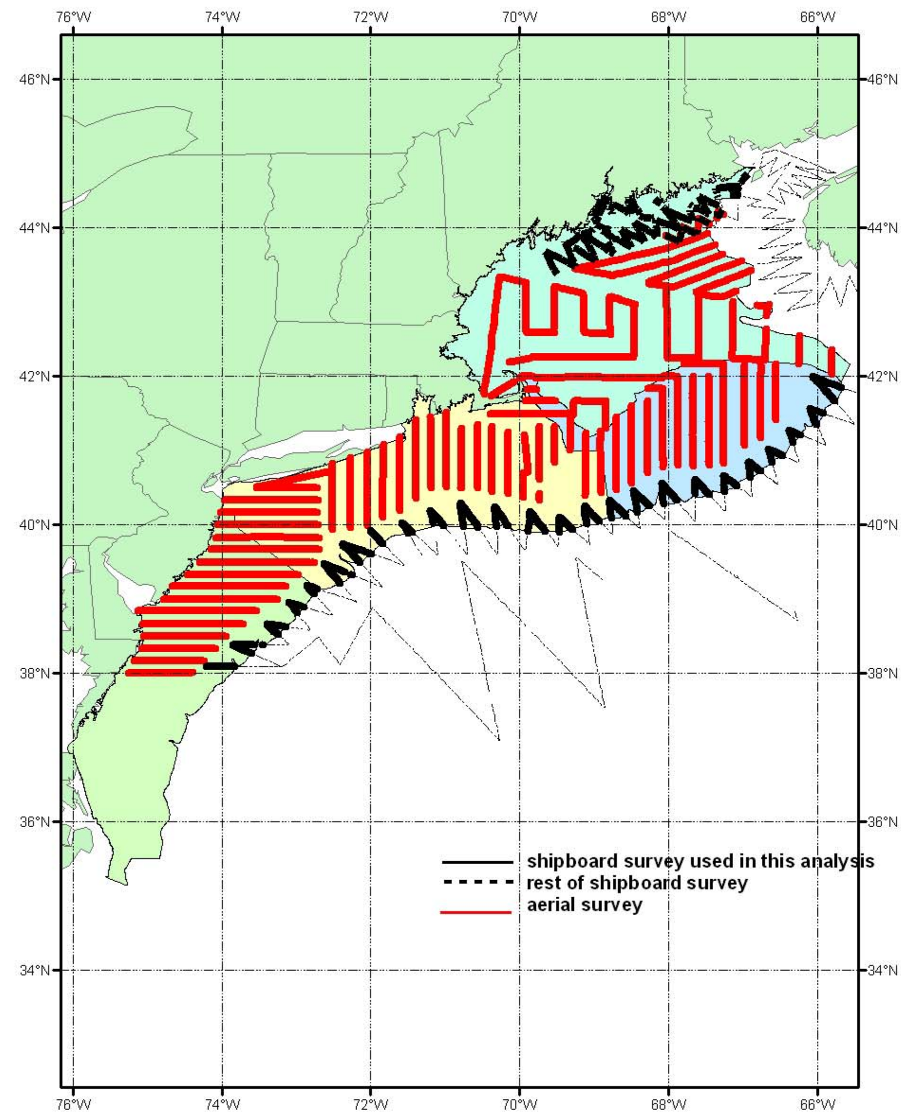
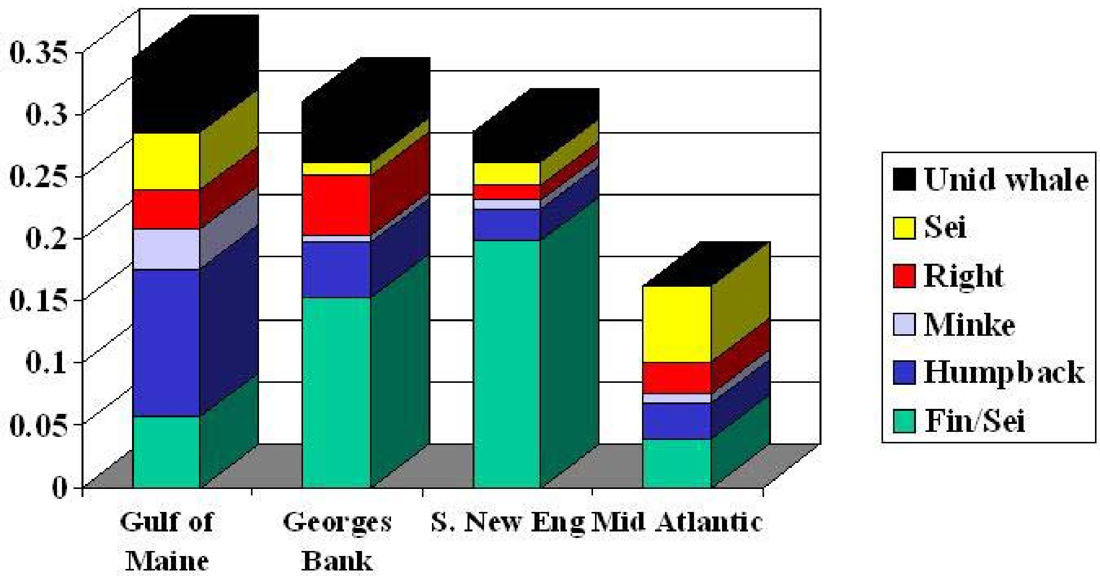


Figure 17.1. Shipboard and aerial track lines from the 1998 and 1999 marine mammal abundance surveys used to estimate abundance within the four EMAX ecoregions. Abundance from the Gulf of Maine ecoregion used 1999 data, while the other regions used 1998 data. Black track lines are from shipboard surveys, red track lines are from aerial surveys, and light gray track lines are track lines conducted in the surveys but are not part of the EMAX ecoregions.

A. Baleen



B. Odontocetes

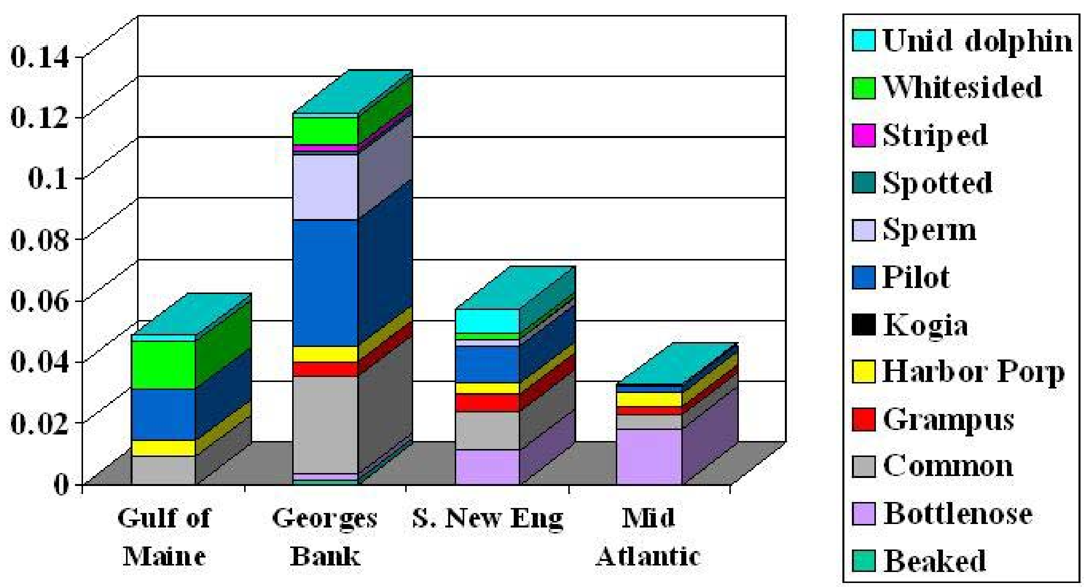
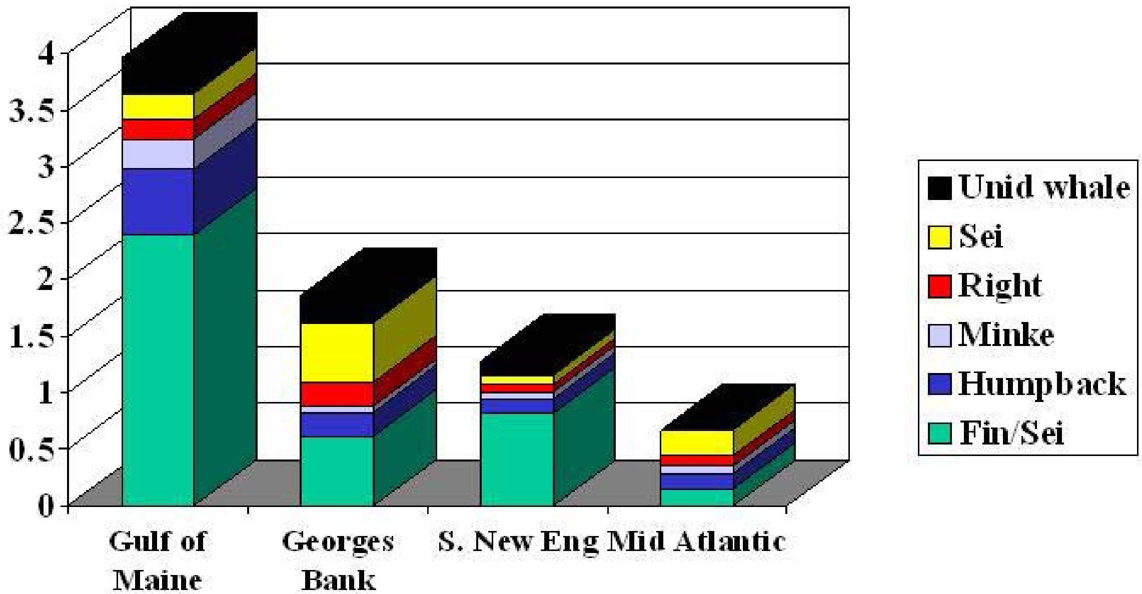


Figure 17.2. For each region, biomass per area (in g m^{-2}) of species that make up the baleen (A) and odontocetes (B) nodes.

A. Baleen



B. Odontocetes

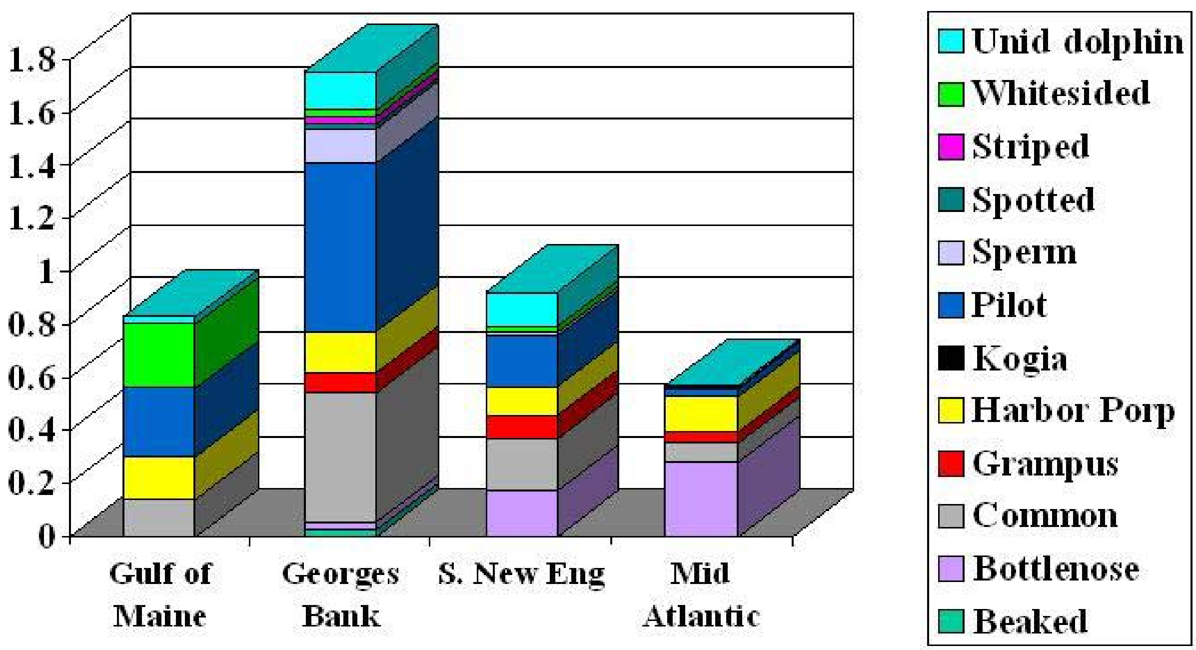


Figure 17.3. For each region, consumption biomass per area (in g m^{-2}) of species that make up the baleen (A) and odontocetes (B) nodes. The daily feeding rates of odontocetes was assumed to be 4.2% of the biomass for all species except harbor porpoises, which was assumed to be 8.3%.