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BENTHOS STUDIES IN FEEDING GROUNDS OF WESTERN GRAY WHALES OFF THE NORTHEAST COAST OF SAKHALIN ISLAND (RUSSIA), 2004-2008

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INTRODUCTION

Gray whales feed primarily on benthic and epibenthic invertebrates. The critically endangered, western population of gray whales that inhabits the northeast coast of Sakhalin Island, near the Sakhalin-1 and Sakhalin II oil and gas projects, utilizes two main feeding areas during the ice-free season: a nearshore feeding area adjacent to Piltun Bay, and an offshore area, east-northeast of Niyskiy Bay (Fig. 1). This population also utilizes an intermediate area, adjacent to Chayvo Bay, but less intensively than the other two areas. Studies of benthos food resources are essential for an adequate understanding of the ecology of the western gray whales, so that changes in their distribution and behaviour can be interpreted, and to provide information for adaptive management of mitigation and conservation programmes.

Since 2001, benthos studies have been conducted annually by an industry-sponsored research and monitoring programme offshore Sakhalin Island. These studies have focused on the Piltun and Offshore feeding areas, and on the intermediate area adjacent to Chayvo Bay (Chayvo feeding subarea), and have thus far provided a medium-term dataset of resource characteristics against which other components of the multidisciplinary programme (e.g. distribution and photo-ID surveys) can be compared.

This paper reviews the Western Gray Whales' food supply distribution patterns in feeding grounds off the Northeast coast of Sakhalin in 2004-2008. Methods of field studies and benthos distribution patterns in 2001-2003 were published earlier (Fadeev, 2007).

RESULTS AND DISCUSSION

Piltun feeding area

Benthos composition in the Piltun feeding area varies with depth. Amphipods, the main prey of gray whales, are more abundant at depths <20m. Consequently, gray whales tend to feed closer to the shore in the Piltun area. In 2008, the amphipod biomass in the overall Piltun feeding area was 36.1±9.2 g/m^2, slightly higher than in 2007 (32.1±4.8 g/m^2) and 2006 (28.5±3.8 g/m^2), but these values were less than in 2005 (38.8±7.2 g/m^2) and 2004 (47.4±7.7 g/m^2). On the other hand, amphipod biomass in shallower waters, <15m deep, was slightly lower in 2008 (65.5±11.7 g/m^2) than in 2007 (74.7±9.8 g/m^2). At this depth the amphipod biomass had the lowest values in 2006 (59.8±5.8 g/m^2), and the highest in 2004 (111.2±12.3 g/m^2). More than 90% of the amphipod abundance was due to the presence of 2 species: *Monoporeia affinis* (> 60% of total amphipod biomass) and *Eogammarus schmidti* (> 30%). Overall, the results obtained in 2008 showed that amphipod resources in the Piltun feeding area were not significantly different compared to 2004-2007.

The distribution of amphipod biomass in the Piltun feeding area showed similar trends in 2004-2008; zones of maximum biomass were associated with the shallow, and the amphipod distribution has a distinctly aggregated nature. The most notable decrease in the abundance and spatial distribution of the dominant amphipod, *Monoporeia affinis*, occurred in 2006 when sea ice persisted later in the season and lower bottom temperatures occurred.

Results of the benthos studies suggest that the sand lance *Ammodytes hexapterus* may be an occasional food source for gray whale. Sand lance aggregations in the northern part of the Piltun feeding area at the depths >20 m continued to decline in 2008; after reaching maximum frequency of occurrence there of 40-60% in 2005, sand lance were only found in 8-12% of samples in 2008. Average sand lance biomass in the overall Piltun area was lower in 2008 (12.9±5.4 g/m^2) than in 2007 (27.7±12.1 g/m^2), in 2006 (17.7±9.9 g/m^2), and in 2005 (16.3±4.4 g/m^2), although these differences are not statistically significant (Fig. 2). Compared to the sporadic, highly localized spates of sand lance abundance, a more consistent and abundant food resource in the Piltun area is offered by amphipods – the main food source of western gray whales.

Cluster analysis was used to examine differences in the composition and quantitative abundance of taxonomic groups at different locations. Three complexes were identified in the Piltun area; the Amphipods complex dominated at whale feeding sites. The Amphipods complex included 34 amphipod species, the most abundant of which were *Monoporeia affinis, Eogammarus schmidti, Eohaustorius eous eous* and *Anisogammarus pugettensis*. Amphipods (90.2 ±18.5 g/m^2) constituted 92% of the total biomass in this complex, which also included isopods and bivalve molluscs.

Chayvo feeding subarea

The distribution of benthos in the Chayvo subarea reflected the patterns in the Piltun feeding area: the biomass of amphipods decreased sharply with depth, from 76.54±11.4 g/m^2 at depths of ≤15 m to 5.4 g/m^2 at 25 m. The biomass values in 2008 were not significantly different compared to previous years. Gray whales utilize the smaller Chayvo subarea (about 30 km^2) less intensively than the main Piltun and Offshore feeding areas.

Offshore feeding area

Average biomass of ampeliscid amphipods in the Offshore area was 213.9±69.6 g/m^2 in 2008 and 173.5±58.6 g/m^2 in 2007. No major year-to-year variations were observed when comparing data for the whole Offshore area for all years between 2004 and 2008; forage benthos biomass in the Offshore feeding area was stable and differences in average amphipod biomass were not statistically different. Whales fed in a depth range of 41-53 m, in a zone of high abundance of amphipod *Ampelisca eschrichti.* In contrast to the dominant amphipod species in the Piltun area, the ampeliscids live in tubes attached to the substrate in areas with strong bottom currents.

The spatial distribution of benthos biomass in the Offshore area was similar in 2004-2008; the proportion of amphipod biomass in total benthos biomass of the Offshore feeding area increased with distance from shore toward deeper waters; distribution of ampeliscid amphipod biomass (g/m^2) in the Offshore area during is shown in the Figure 3. This pattern also reflected a gradual increase in the proportion of silt-pelite fractions in the seabed. Other groups (sea anemones, bivalve molluscs, cumaceans and sand dollars) that made up the remainder of the biomass had patchy distribution; higher-biomass patches of these groups were found on the edge of the amphipod complex zone.

Cluster analysis of biota in the Offshore feeding area identified four complexes. A complex dominated by the amphipod *Ampelisca eschrichti*, occurring in the eastern part of the Offshore area, had an average biomass of 644±145 g/m^2, of which 79% (or 510 g/m^2) comprised biomass of the dominant group – amphipods. The complex comprised 35 amphipod species, of which 14 species were found only in the Offshore area. *A. eschrichti* was distinctly dominant in regard to frequency of occurrence, colony density and biomass. The ampeliscid colony density and biomass in the area are comparable to, and in some cases exceed, those of other highly productive areas of the North Pacific. This complex dominated at western gray whale feeding sites; other complexes had less importance as food sources.

Trophodynamic Studies

The factors that regulate or influence the production (growth) of forage benthos on the northeast Sakhalin shelf are comparatively poorly understood. It is essential to improve our knowledge of the trophodynamics and the environmental factors driving these processes. Obtaining more insight in the temporal and spatial changes of gray whale food resources will provide us with a better understanding of whale distribution and behavior. This again would make management and conservation effort aimed at protection of the gray whale population more efficient.

Amphipods obtain their food by filtering particulate organic material (POM) from the water column. Until now, the origin of this POM was unclear. In 2008, further studies – building on 2006-2007 work – were conducted using stable isotopes and molecular biomarkers to examine the trophodynamics of key prey species, collected from whale feeding areas, and for comparison, from inside Piltun Bay. Ratios of stable carbon and nitrogen isotopes and molecular biomarkers (fatty acid composition) indicated that phytoplankton and microphytobenthos are the main sources of organic material for mass zoobenthos production in the Piltun and Offshore feeding areas; filter- and seston-feeders collected from inside Piltun Bay reflected similar results.

Year-to-year changes in forage benthos in the Piltun and Offshore feeding areas

The purpose of this section is not a detailed, cross-spectrum analysis of the relationships between benthos and foraging whales. That exercise would require special analysis. Rather, our task here is to

compare the most notable trends in year-to-year changes in the distribution of foraging whales and forage benthos.

Principal trends in the distribution of whales in 2004-2008:

(1). 2004-2005 – whales fed primarily in the Piltun area; the number of photo-identified whales in the Offshore area was low– 8 (2004) and 7 (2005) individuals; whales fed in the Piltun area generally in the shallows at depths of ≤ 20 m, while in the northern part of the area, some whales (up to 40%) fed at depths greater than 20 m.

(2). 2006 – whales fed in both the Piltun and Offshore areas; the number of photo-identified whales in the Offshore area increased to 33 individuals; whales in the Piltun area fed along the entire coastline; the number of foraging whales declined sharply in the southern part of the area, as did the proportion of whales feeding at depths >20 m in the north. A small number of foraging whales appeared in the Chayvo Bay area.

(3). 2007-2008 – whales fed in both areas; the number of photo-identified whales in the Offshore area increased to 70; the number of foraging whales in the southern Piltun area increased relative to 2006, while the number of whales feeding at depths > 20 m in the northern part of the area was very low. The Chayvo Bay area had a small number of foraging whales.

Principal trends in variation of forage benthos abundance in 2004-2008:

Offshore area: Biomass of forage benthos was stable, and no major year-to-year variations were observed; whales fed in a depth range of 41-53 m every year in a zone of high abundance of major prey: amphipods *Ampelisca eschrichti.*

Piltun area:

(1). 2004-2005 – areas with elevated amphipod biomass occur in the shallower-water part of the southern and northern Piltun area; *Monoporeia affinis* is dominant in biomass; there is an increase in the frequency of occurrence (to 40-60%) and biomass of the sand lance *Ammodytes hexapterus* in the northern part of the area.

The appearance of the sand lance coincided with a decrease in the number of whales in the Offshore area, and the appearance of foraging whales in the northern Piltun area at depths greater than 20 m.

(2). 2006 – the proportion of the amphipod *M. affinis* in the total biomass of forage benthos in the shallow-water zone decreased, and the biomass of this species at shallow-water stations in the southern part of the Piltun Feeding area declined by 50% from the 2005 level; in the northern part of the Piltun Feeding area, the frequency of occurrence of the sand lance decreased from 40-60% to 20-25%.

The decrease in abundance of amphipods and the sand lance coincided with the appearance of foraging whales in the Chayvo subarea and an increase in the number of whales in the Offshore area. It is notable that whales began feeding in the Chayvo subarea at sites with biomass of about 40 g/m^2 when the biomass of amphipods in the southern Piltun area dropped to this level.

(3). 2007-2008 – amphipod biomass increased in the shallow-water zone of the Piltun area; *M. affinis* was dominant in the southern part of the area; its biomass there in 2007-2008 was higher than in 2006 but did not reach the maximum levels of previous years; sand lance abundance in at deeper-water sites in the northern part of the area remained at the low level of 2006.

An increase in the abundance of the amphipod *M. affinis* in the south coincided with shore- and vessel-based observations of increases in the number of foraging whales in the southern section of the area; solitary foraging whales were observed in deeper waters of the northern section.

During the period from 2004 to 2008, the most notable variations (i.e. lowest biomass levels) in the abundance and spatial distribution of the dominant amphipod species – *Monoporeia affinis* – were observed in 2006 and partially (in the northern part of the area) in 2007-2008.

Changes in hydrology and sea ice cover in the Piltun area:

An analysis of the year-to-year dynamics of the hydrological regime in the Piltun area showed that the lowest bottom temperatures for the period 2004-2008 occurred in 2006-2008. Temperature is expected to affect amphipod breeding, growth, and feeding, resulting in changes to their life cycle duration. For example, the dominant species in the Piltun area, *Monoporeia affinis*, has a two-year life cycle in cold waters and a one-year life cycle in warmer waters (Segestrale, 1967). The amphipod *Ampelisca macrocephala*, which inhabits the Offshore area, lives for 5-6 years in the cold waters of the Bering Sea, but for only 2-3 years in the temperate waters of Denmark (Kannewoff, 1969; Highsmith and Coyle, 1991). The effect of hydrological features on the life cycle of mass amphipod species on the Sakhalin north-east shelf will be further assessed once current morphometric analysis of the 2007-2008 amphipod collections is completed.

Climate-forcing parameters such as sea ice dynamics can also impact coastal biota. Ice conditions varied substantially in the Piltun area during 2004-2008. Figure 4 indicates the position of the ice edge during the first ten days of June each year. According to these satellite monitoring data, the northeastern Sakhalin coastal zone was free of ice in June 2004 and 2005. However, the area was covered in 10-point solid ice field almost to the mouth of the Piltun lagoon in early June 2006. In June 2007-2008, ice remained near the Chayvo lagoon, but there was open coastal water from the Piltun lagoon northward.

Ice cover could affect the abundance of *Monoporeia affinis* through influence on hydrological processes and on primary production. Settled phytoplankton and detritus of phytoplanktonic origin have been reported to play an important role in the diet of this species (Sarvala, 1991; Van de Bund *et al.,* 2001). In an environment with an ice regime, such as the northeast Sakhalin shelf and associated coastal bays and lagoons, the intensity and duration of spring bloom of phytoplankton may, as in similar environments, be influenced in part by light conditions when the water surface is free of ice (Schell *et al.*, 1982); persistence of ice conditions could delay the spring bloom of phytoplankton, and this in turn could affect zooplankton productivity and fish that feed on plankton (Boytsov and Orlova, 2004), as well as benthos (Fleeger *et. al*., 1989). A sharp increase in growth rates of *M. affinis* has been shown to follow the spring bloom of phytoplankton in the Baltic Sea, where food supply affected growth to a greater degree than temperature (Lehtonen and Andersin, 1998).

The lowest abundance of *M. affinis*, the most likely principal component of gray whale diet in the Piltun Feeding Area, occurred in 2006. The distinguishing features of the hydrological and climatic conditions in 2006 were: (a) a decrease in the summer temperature of bottom waters, and (b) an anomalous ice cover duration (Fig. 4). We note that the two phenomena may be related. There are available data on the observed cooling of the climate of the Sea of Okhotsk (Volvenko, 2004). Unfortunately, no data are available for phytoplankton productivity. A slight and not statistically significant increase in *M. affinis* biomass in 2007-2008 coincided with an earlier clearing of ice cover.

CONCLUSION

Whale distribution and photo-ID studies registered change of abundance gray whales in the Piltun and Offshore feeding areas in 2004-2008 (Vladimirov *et. al*., 2007, 2008; Yakovlev *et. al*., 2007, 2009). To explain these year-to-year differences, it is tempting to look for potential correlations in benthos data.

In the Piltun feeding area, the most notable changes in the abundance and spatial distribution of the dominant amphipod species, *Monoporeia affinis*, occurred in 2006 when the lowest biomass levels were observed. Although sand lance abundance in the north of the Piltun area continued to decline, this possible food source has been declining for several years, and is sporadic compared to the consistent, rich amphipod complex that provides the main food source of gray whale. Hydrological and climatic conditions in summer 2006 were characterized by lower bottom temperatures compared to 2004-2005, and the anomalous duration of the ice cover.

Forage benthos biomass in the Offshore feeding area was stable during 2004-2008, and no major year-to-year variations were observed; whales fed in a depth range of 41-53 m during all those years in a zone of high abundance of amphipods *Ampelisca eschrichti*.

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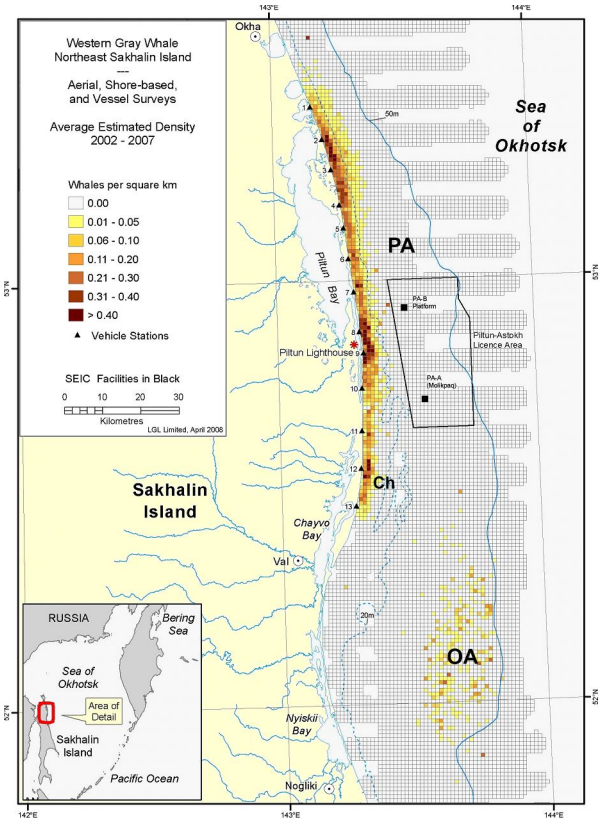

Fig 1. Locating of a feeding grounds of western gray whales off the northeast coast of Sakhalin Island. PA – Piltun Feeding Area, OA – Offshore Feeding Area, Ch – Chayvo Feeding Subarea.

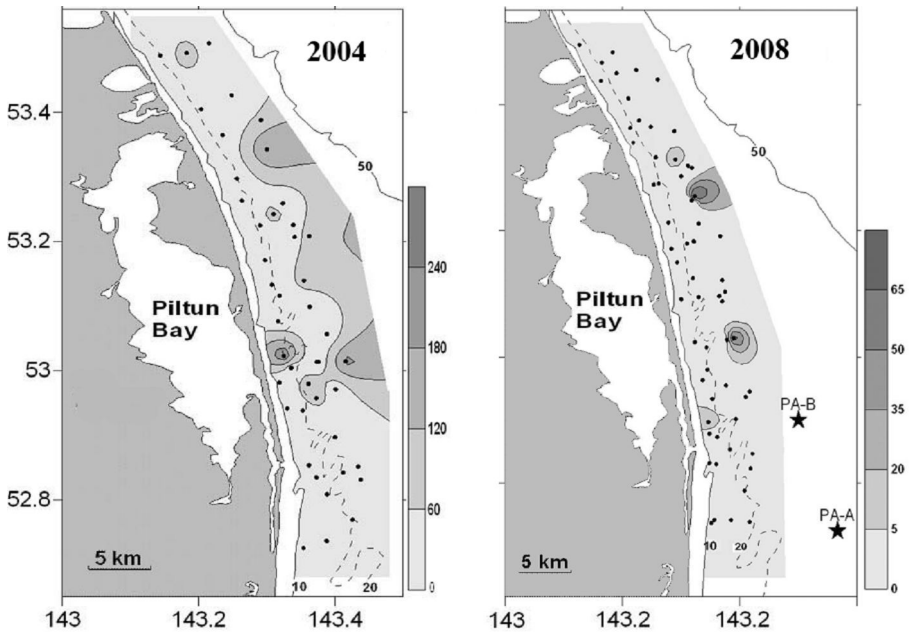

Fig. 2. Sand lance *Ammodytes hexapterus* biomass distribution in the Piltun area in 2004 and 2008.

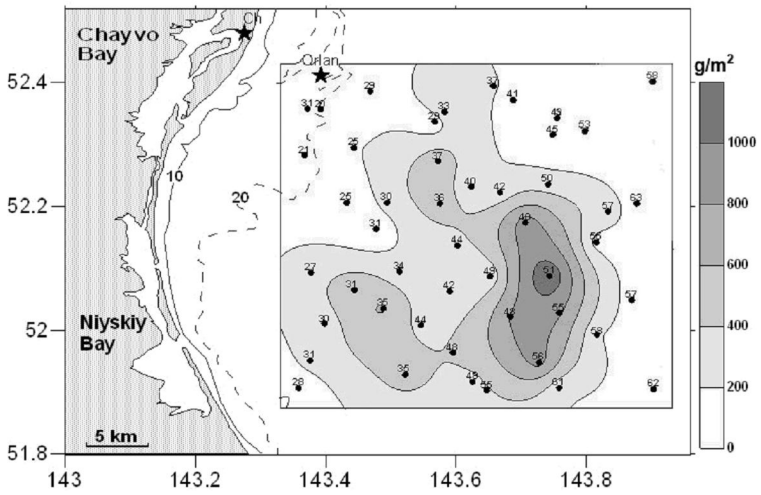

Fig. 3. Amphipod *Ampelisca eschrichti* biomass distribution (g/m^2) in the Offshore area in 2004-2008. Numbers indicate stations depth.

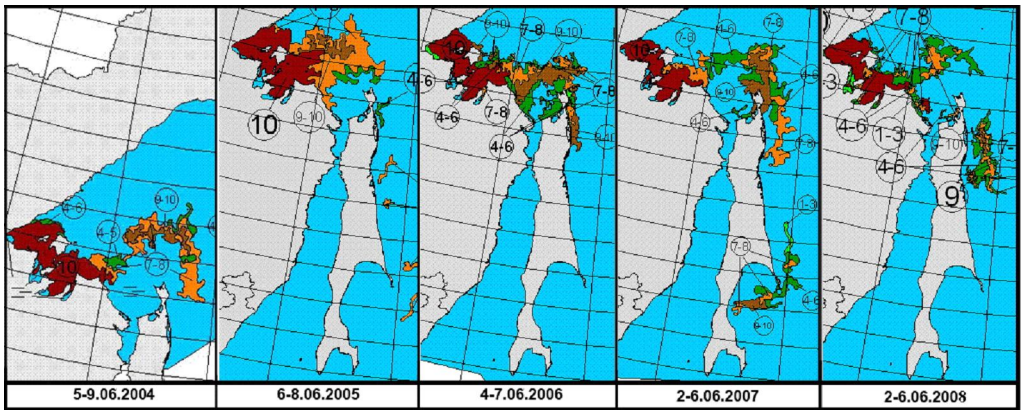

Fig. 4. Locations of ice fields according to satellite monitoring data during the first ten days of June 2004-2008 of northeastern Sakhalin (http://www.aari.nw.ru).