A NOTE ON STOMACH CONTENTS ANALYSIS FROM JARPA

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ABSTRACT

The diurnal variation of weight of stomach contents of Antarctic minke whales taken under JARPA in the Southern Ocean have been used to estimate mean daily prey consumption (Tamura and Konishi, 2006). They estimated mean daily consumption of krill of 4.39-4.95% of whale body mass. These estimates are particularly sensitive to assumptions about digestion rates for which few data are available. They are also complicated by the lack of night time data between 22:00 and 03:00 which may include the peak feeding period. The diurnal patterns in stomach weight contents reported by Tamura and Konishi (2006) would appear consistent with no feeding during the period 03:00 to 18:00 or alternatively a prey consumption of 2.8% of whale body mass over the same period if it is assumed that 20% of prey remains undigested after four hours. The resulting range of estimates for mean daily consumption is around 1.5% – 7%. This range covers what might be considered the plausible range of values. However, despite large sample sizes (6777 whales), the current data set does not appear able to narrow this range.

INTRODUCTION

Tamura and Konishi (2006) give estimates for daily prey consumption by Antarctic minke whales (*Balaenoptera bonaerensis*) based on analyses of weight of stomach contents and assumptions regarding digestion rates. Given the paucity of data on digestion rates, this note examines the sensitivity of the results to the assumptions made. The assumption made in Tamura and Konishi (2006) is that either 20% or 30% of prey remain undigested after four hours. The reference given for the four hour figure is to Bushuev (1986) but in fact no actual data on digestion rates are given in that paper. A paper by Nordøy *et al.* (1993) is also cited (but not in the reference list). Nordøy *et al.* (1993) do not give estimates of digestion times either but investigated *in vitro* dry matter disappearance after 12 and 24 hours. They note that about 70% of the dry matter of the substrate disappeared into solution by bacterial degradation within 12 hours. It is possible that this process happened quicker initially, but there is no basis in the data of Nordøy *et al.* (1993) to assume that this level of digestion would have occurred within the first 4 hours of the twelve hour study period, as assumed in Tamura and Konishi (2006). Other estimates relating to the passage of the prey through the gut in baleen whales include Vikingsson (1997) who estimated a mean passage time in fin whales from the forestomach to the fundic chamber of 3-6 hours (although notes a caveat of small sample size). The data in Tamura and Konishi (2006) are for the forestomach and fundus combined so it is not clear how this would relate to the estimate of Vikingsson (1997).

Most studies to date have investigated relative rates of digestion to examine potential biases in stomach content analysis. Absolute rates are clearly more difficult to simulate under laboratory conditions. Jackson *et al.* (1987) found that crustacean muscle was slower to digest than fish or squid, taking about 17 hours to be fully digested with a mean of 25% digested after 4.35 hours. However, this study may not have fully replicated the bacterial content of the stomach of baleen whales.

METHODS

Values for the daily change in mean stomach contents (forestomach and fundus) as a proportion of whale body mass were read from Tamura and Konishi (2006) Figure 7 and shown in Figure 1 of this paper. These show an exponential decrease from the first data at 03:00 until 18:00. Some evidence of feeding is seen in the period 18:00 to 21:00 and there are no data given between 21:00 and 02:00. The initial shape of the plot between 03:00 and 05:00 and the large variance of the measurements for this period may also suggest some feeding.

Tamura and Konishi (2006) give estimates of daily consumption based on exponential decay of prey. If S is the proportion of prey remaining undigested after one hour then, in the absence of feeding, the stomach contents V at time t after a feed of mass C would be

$$V = CS^t$$

For t=4, if S=0.67 then V=0.2C, and if S=0.74, V=0.3C.

The daily variation in combined mean proportion of fresh and lightly digested prey in the forestomach was also read from Figure 6 and shown in Figure 2 of this paper. This also shows an exponential decrease between 05:00 and 18:00 with evidence of feeding between before 05:00 and after 18:00.

RESULTS

The crosses in Figure 1 represent the mean estimated hourly quantity of prey consumed during the period 03:00 to 18:00 based on the assumption of S = 0.67 (20% of prey remaining undigested after four hours). Thus the area under these points represents the total consumption during this period. For values of S=0.67 and S=0.74 respectively this gives a total of 2.8% and 2.1% of whale body mass. These compare to the equivalent estimates of mean total daily consumption in Tamura and Konishi (2006) of 4.95% and 4.36%.

The sensitivity of the estimates of prey consumption to estimates of digestion rate is shown in Figure 3. It can be seen that if it is assumed that there is essentially no feeding between 03:00 and 18:00 then this would give S=0.94 resulting in around 80% of prey being undigested after four hours.

The data in Figure 6 of Tamura and Konishi (2006) were also examined to investigate whether they were consistent with the possibility of no feeding throughout the day. Figure 2 of this paper shows the trend in mean combined fresh and lightly digested proportion of stomach contents for the period 05:00-18:00. The exponential rate of change is very similar to that of total stomach contents and is consistent with around 80% of prey being undigested (fresh or lightly digested) after four hours. However, Figure 6 of Tamura and Konishi (2006) does indicate suggest some feeding activity between 03:00 and 04:00.

DISCUSSION

Estimating mean daily consumption prey for minke whales based on the stomach contents data in Tamura and Konishi (2006) is problematic for two main reasons. The estimates are particularly sensitive to assumptions about digestion time, and what appears likely to be the peak feeding period from 21:00-02:00 is not covered by the dataset. Given that the mean stomach content at 03:00 of just over 1% body mass is considerably smaller than the maximum stomach contents observed of 3-4% body mass, the time of peak feeding will have a large impact on estimates, particularly if digestion rates are assumed to be rapid.

The data themselves appear to be consistent with the possibility that there is no feeding between 05:00 and 18:00. This would imply around 80% of prey undigested after four hours which is also consistent with the results of Jackson *et al.* (1987) for crustacean muscle. If it were assumed that no daytime feeding occurs, and Figure 1 was extrapolated to the beginning of the unsampled period around 22:00 then this would suggest a mean daily consumption of around 1.5% of body mass, or around one third of the estimates of Tamura and Konishi (2006).

At the other end of the range of values, if S=0.67 and all whales had full stomachs of 3.5% of body mass at midnight, then this could still be reconciled with the data. This would result in an estimate of mean daily consumption of around 7% of body mass. This is greater than the estimate in Tamura and Konishi (2006) because of different assumptions about what happens during the period for which there are no data.

Thus if digestion is assumed to be rapid there will still be considerable uncertainty due to the unsampled period of the day. If digestion is slower then the unsampled period is less critical but consumption estimates might be considered rather low compared to estimates based on energy requirements, depending on the assumptions made about the length of the feeding season. The range of estimates here 1.5%-7% of body mass cover the range of what might be considered plausible values, but there seems limited scope for refining these despite the large sample sizes (6777 whales).

As identified in the JARPA review report (SC/59/Rep1), estimates of total consumption by minke whales in Antarctic waters also require data on the duration of the feeding period. This note only addresses the issue of mean daily consumption.

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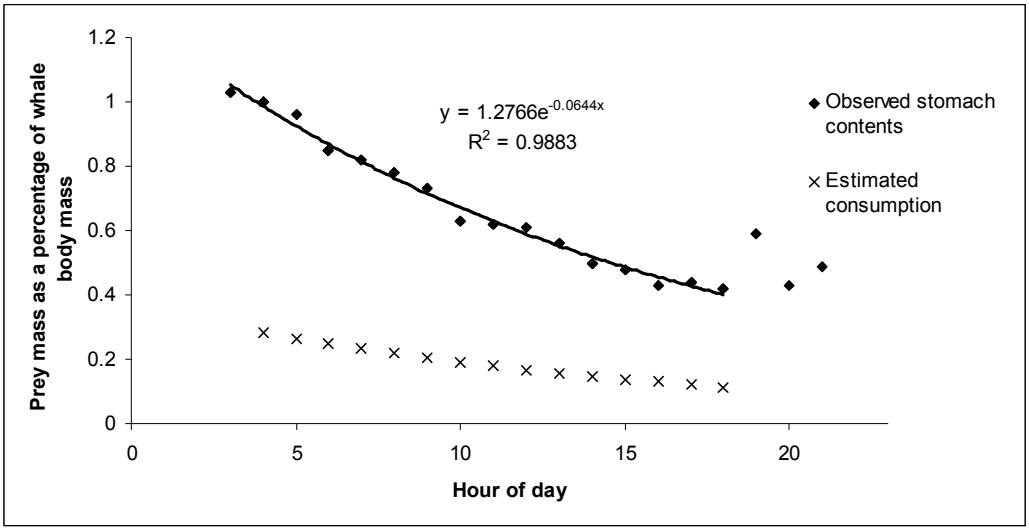

Figure 1. Diurnal variation in mean stomach contents as a percentage of whale body mass taken from Figure 7 of Tamura and Konishi (2006). Fitted curve is to data from 03:00 to 18:00. Crosses indicate estimates of hourly prey consumption as a proportion of whale body mass assuming S=0.67

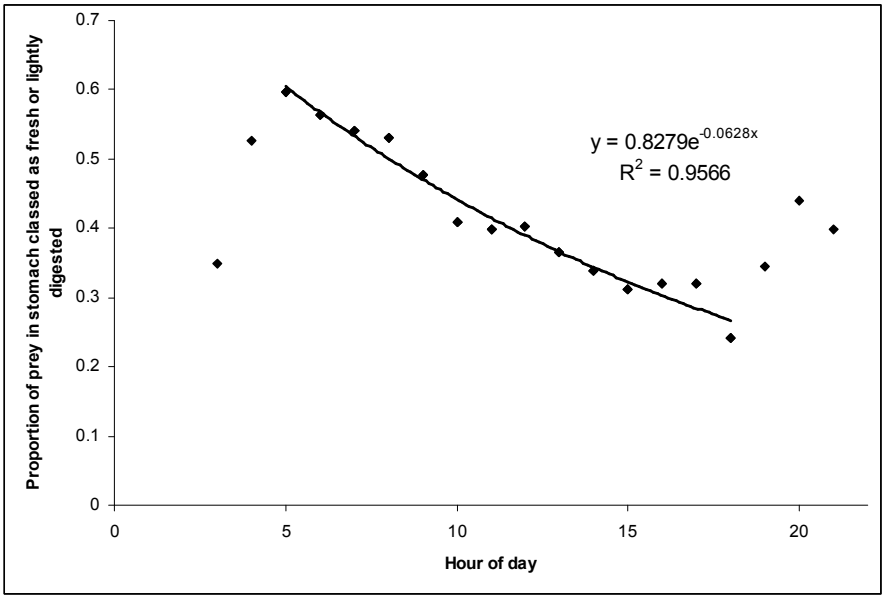

Figure 2. Diurnal variation in mean combined proportion of fresh or lightly digested stomach contents taken from Figure 6 of Tamura and Konishi (2006). Fitted curve is to data from 05:00-18:00

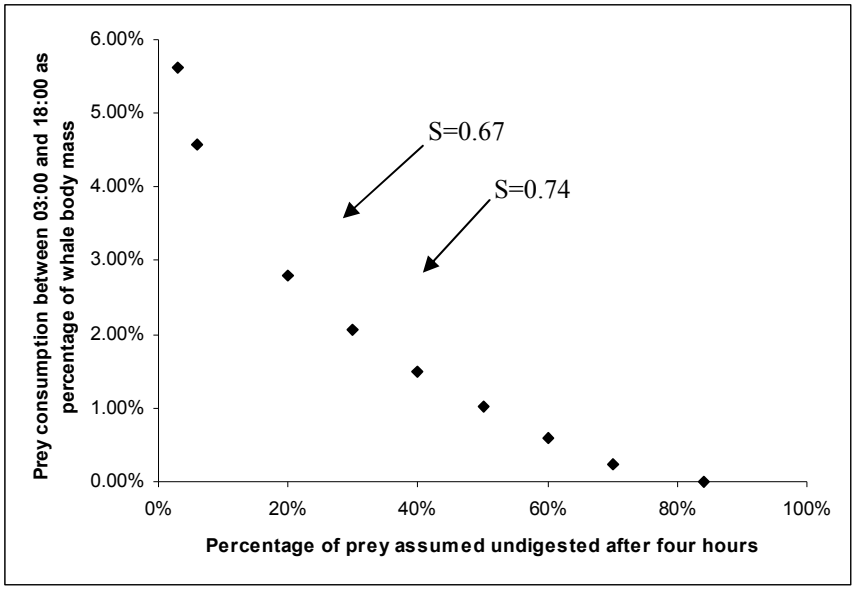

Figure 3. Sensitivity of estimates of consumption between 03:00 and 18:00 as a percentage of whale body mass to estimates of digestion rates.