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David GRÉMILLET

Institut für Meereskunde, Abteilung Meereszoologie, Düsternbrooker Weg 20, D-24105 Kiel,  
Germany

STOMACH TEMPERATURE PROBES IN CORMORANTS  
*PHALACROCORAX CARBO*:  
A MEASUREMENT OF THE DAILY FOOD INTAKE  
IN FREE-LIVING INDIVIDUALS

**ABSTRACT:** The method of determination of the amount of food ingested from the cormorant stomach temperature measurements is described. Two different units were used to record stomach temperature of free-living and captive cormorants: the Eink-

naliger Automatischer Temperatur Logger (EATL) and the Single Channel Unit Processor (SICUP). The weight of taken food was determined with a mean accuracy of 80%.

**KEY WORDS:** cormorant, daily food intake, stomach temperature

## 1. INTRODUCTION

As fish predators, cormorants *Phalacrocorax carbo* often enter into competition with man. Thus, a field considered important to research is diet. Cormorants, like most seabirds, are rarely observed capturing prey, so investigators generally

study pellets or stomach contents to learn about their diet. However, it has been shown that both of these methods have serious drawbacks (Duffy and Laurenson 1983, Grémillet 1993, Zijlstra and van Eerden 1995).

## 2. METHOD

In 1992, Wilson et al. (1992) suggested a method for the direct measurement of food intake in seabirds. This method is based on the fact that the intake of cold food in homeotherms leads to a drop in stomach temperature, followed by an exponential warming (Fig. 1). The area under the temperature asymptote (the

hatched zone in Fig. 1) can be related to the energy the bird must invest to warm its prey to body temperature. This energy is a function of the temperature difference between predator and prey (water temperature), the specific heat capacity of the prey (which is taken to be the specific heat capacity of water) and its mass.

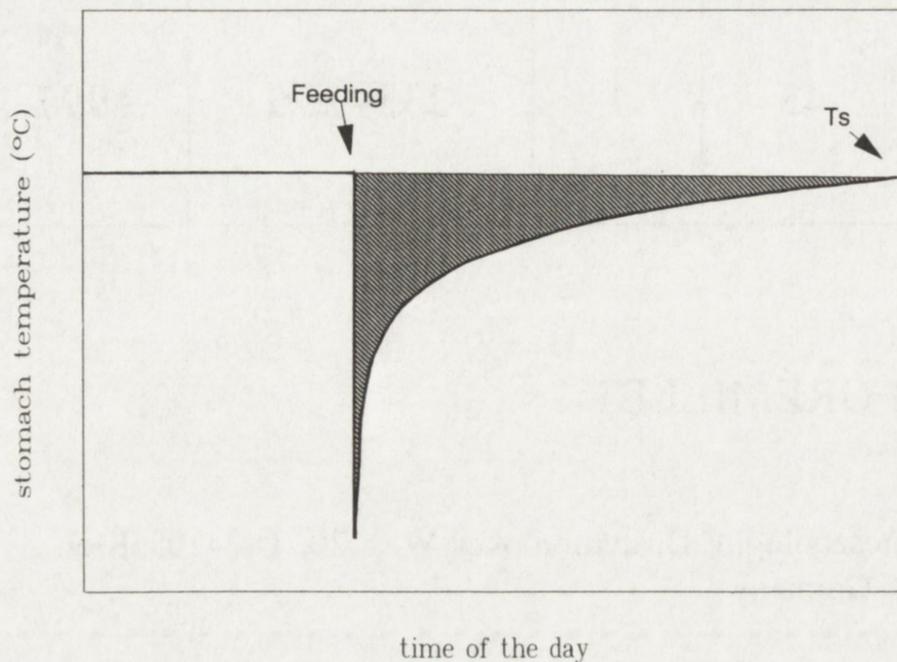


Fig. 1. Idealized prey ingestion event as recorded by a stomach temperature sensor. An initial sharp drop in temperature due to the appearance of cold prey in the stomach is followed by an exponential temperature rise as the prey is warmed to body temperature ( $T_s$ )

If the rate at which birds can supply energy to their ingesta is determined by feeding cormorants fish of known mass, the amount of food eaten by a free-living bird can be subsequently determined by simply recording its stomach temperature (see Grémillet 1993).

Two different units have been developed to record stomach temperature of free-living seabirds, with masses of 80 and 17 g respectively: the Einkanaliger Automatischer Temperatur Logger (EATL; Elcutec GmbH) and the Single Channel Unit Processor (SICUP; Driesen and Kern GmbH). These units essentially consist of a RAM-chip, a quartz clock, a temperature sensor and a lithium battery.

The electronics fit in a water-tight, titanium housing and the temperature of the surface of the housing is recorded and stored once every 16 seconds. An interface is used to allow the units to communicate with a computer via which they may be programmed and data accessed.

I utilised these units both in captive cormorants *Phalacrocorax carbo sinensis* and free-ranging bank cormorants *P. neglectus*. The devices were administered in a fish and rejected by the birds as a pellet after a maximum period of 24 hours. The weights of 42 different fish fed to the birds were back-calculated with a mean accuracy of 80%.

### 3. RESULTS

The daily amount of food eaten by captive cormorants was similar for birds equipped with temperature sensors (309 g,  $s = 120$ ,  $n = 16$ ) and for controls (336 g,  $s = 98$ ,  $n = 16$ ), which indicates that the units do not inhibit feeding. The intake of 62 prey-items by 7 free-living bank cormorants during 18 foraging trips was recorded (see e.g. Fig. 2) and the mean daily food intake of these birds determined to be 282 g ( $s = 150$ ,  $n = 5$ , range = 193–547 g; bank cormorants weigh ca 2000 g (Cooper 1984).

Five bank cormorants regurgitated their temperature sensors together with indigestible prey remains in the form of pellets. I compared the amounts of prey determined from the pellet-contents with the results of the temperature recordings. Stomach temperature changes indicate a total of 42 prey-items ingested whereas the pellets contained the remains of only 8 prey.

Although the deployment of stomach temperature loggers in free-living cormorants results in some loss of units due to regurgitation away from breeding

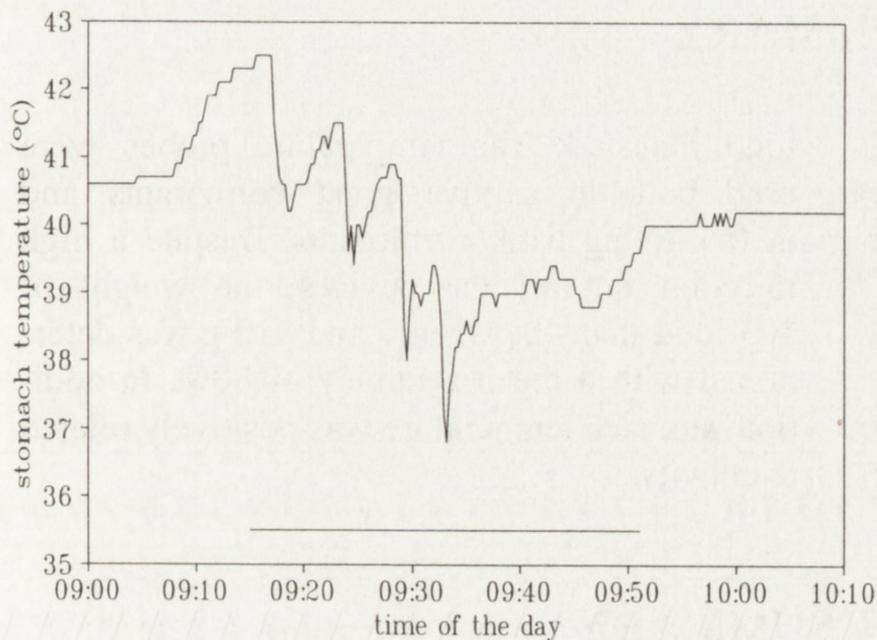


Fig. 2. Stomach temperature changes recorded in a free-living bank cormorant showing rapid drops coinciding with the ingestion of prey. The horizontal bar shows the time the bird was at sea

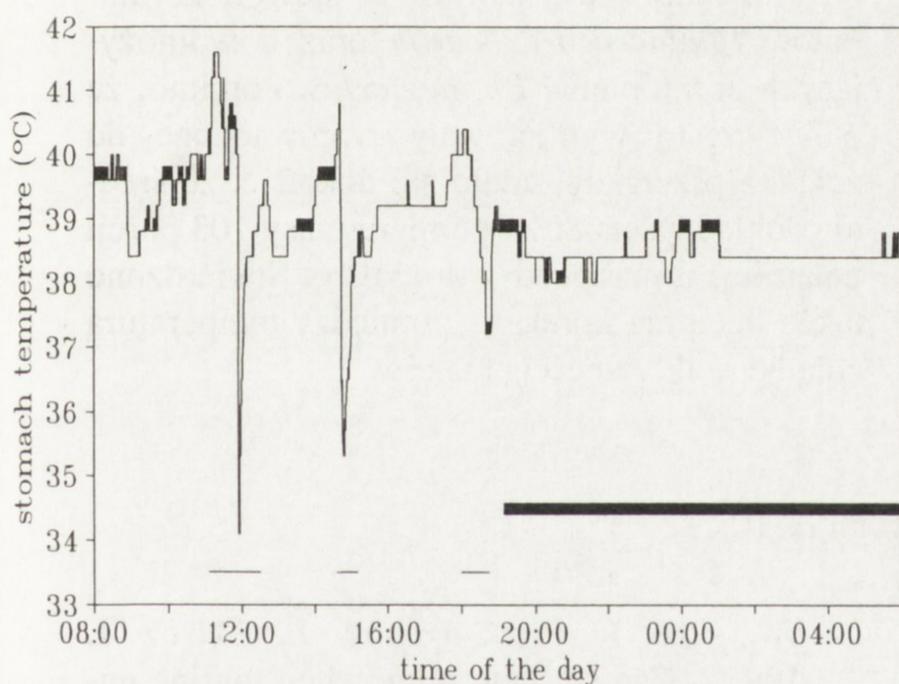


Fig. 3. Stomach temperature changes in a free-living bank cormorant over 22 hours. Thin horizontal bars indicate periods when the bird was at sea. The thick horizontal bar indicates darkness

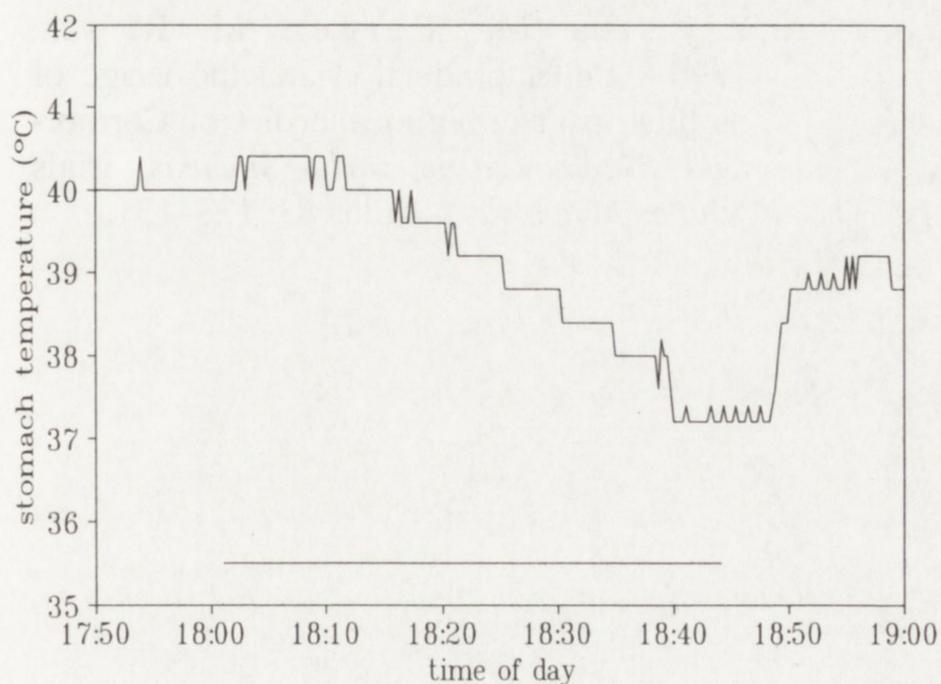


Fig. 4. Changes in stomach temperature in a free-living bank cormorant during a foraging trip when no prey were ingested demonstrating the cooling effect of the water. The horizontal bar shows the time the bird was at sea

colonies (in my study the losses of 38% occurred), this new method appears promising in dietary studies. In addition, stomach temperature data enable one to examine bird activity and energetics (Figs 3 and 4; see also Grémillet 1993).

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#### 4. SUMMARY

Two different units were used to record stomach temperature of free-living and captive cormorants: the Einkanaliger Automatischer Temperatur Logger (EATL) and the Single Channel Unit Processor (SICUP). Stomach temperature fluctuates when cold food is eaten, and when such changes are recorded they can be analysed so as to determine the amount of

food ingested. The temperature probes were used both in captive great cormorants and in free-living bank cormorants. Despite a high rejection rate of the devices, the weight of 103 food items between 7 and 310 g was determined with a mean accuracy of 80%. In addition, stomach temperature was positively related to activity.

#### 5. POLISH SUMMARY

Do pomiaru temperatury żołądka, zarówno wolnożyjących jak i trzymanyh w niewoli kormoranów, stosowano dwa rodzaje przyrządów: Einkanaliger Automatischer Temperatur Logger (EATL) oraz Single Channel Unit Processor (SICUP). Temperatura żołądka ulega zmianie w momencie zjadania zimnego pokarmu i analiza zapisu takich zmian pozwala na ocenę masy połkniętej zdobyczy. Zapis temperatury żołądka

prowadzono u trzymanyh w niewoli kormoranów *Phalacrocorax carbo* oraz u wolnożyjących kormoranów *Ph. neglectus*. Pomimo, że ptaki często wymiotowały wprowadzone do żołądka przyrządy, udało się dokonać, ze średnią dokładnością 80%, pomiaru masy 103 porcji pokarmu, o masie od 7 do 310 g. Stwierdzono także dodatnią korelację pomiędzy temperaturą żołądka a aktywnością ptaków.

#### 6. REFERENCES

1. Cooper J. 1984 – Biology of the Bank Cormorant, Part 2; Morphometrics, plumage, bare parts and moult – *Ostrich* 56: 79-85.
2. Duffy D., Laurensen L. J. B. 1983 – Pellets of Cape Cormorants as indicators of diet – *Condor* 85: 305-307.
3. Grémillet D. 1993 – Methodische Untersuchungen zur Nahrungsökologie von Seevögeln am Beispiel des Kormorans – Diplomarbeit. Institut für Meereskunde an der Universität Kiel.
4. Wilson R. P., Cooper J., Plötz J. 1992 – Can we determine when marine endotherms feed? A case study with seabirds – *J. Exp. Biol.* 167: 267-275.
5. Zijlstra M., Eerden M. R. van. 1995 – Pellet production and the usage of otoliths in determining the diet of Cormorants *Phalacrocorax carbo sinensis*: trials with captive birds – *Ardea* 83: 123-131.