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EFFECTS OF CRUDE OIL EXPOSURE ON STANDARD METABOLIC RATE OF LEACH'S STORM-PETREL[1]

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INTRODUCTION

In a previous report (Trivelpiece et al. 1984), we noted decreased survival and reduced growth rate in chicks of oil-dosed adult Leach's Storm-Petrels (*Oceanodroma leucorhoa*). It was suggested that these effects were related to impaired ability of oil-dosed adults to provide food for their young, possibly due to elevated metabolic demands following contamination. We report here the effects of oil exposure on the standard metabolic rate of adults of this species using two different experimental methods.

In the first experiment, the effects of oil exposure on adult petrels incubating eggs (20 to 40 days after laying) were assessed using a Scholander temperature-compensated respirometer. Petrels were captured in their nesting burrows during the day and were randomly assigned either to control or to one of two experimental groups. One experimental group (Internal Group) was fed 0.1 ml Prudhoe Bay crude oil (PBCO) with a stomach tube, while the other group (External Group) received an external application of 1.0 ml PBCO on breast and abdominal plumage via syringe. A gas chromatographic/mass spectroscopic analysis of PBCO has been reported previously (Peakall et al. 1982). Adults were weighed, oiled, and then maintained in artificial burrows for the duration of the experiment. The artificial burrows were 1-cm cylindrical cardboard tubes (length, 30 cm; internal diameter, 9 cm), with wire screen at one end for ventilation. Birds were maintained in a sheltered, heavily shaded area where daily temperatures ranged from 16 to 21°C. When adult petrels were placed in the respirometry jars (4-liter), they were confined in small cardboard tubes (length, 20 cm; internal diameter, 6 cm) which were screened at each end. Soda lime was used to absorb carbon dioxide in the closed system, and the change in total pressure was tracked visually with a fluid-filled manometer. Oxygen depleted from the system by the bird was replaced via a syringe during a 30-min period, and oxygen consumption per hour was corrected to 0°C and 760 torr. Measurements of oxygen consumption were made about one hr prior to dosing and 24 hr after exposure. Following the experiment, adults were released into their breeding burrows.

In the second experiment, adult petrels were captured in their burrows while they were brooding chicks (1 to 3 days of age). The petrels were maintained in cloth socks inside individual compartments in a cardboard box in a dark, cool basement (18 to 20°C) for the duration of this experiment. Birds were weighed and randomly assigned to control or experimental groups. Experimental birds were intubated with 0.1 ml of PBCO, and control birds were sham dosed without fluid. All birds were injected intraabdominally with 0.1 ml of water containing 95% atom % oxygen-18 and 98.8% atom % hydrogen-2 (deuterium) immediately after being dosed with oil. One hour after the injection, a blood sample was taken via a heparinized micro-hematocrit tube from the wing vein. Studies by Ricklefs and Williams (1984) have shown that one hr was sufficient for equilibrium to be established between the injected labeled water and the body fluids in the European Starling (*Sturnus vulgaris*). The birds were confined again, and a second blood sample was taken 24 hr later. The birds were then reweighed, sacrificed, and sexed by examination of reproductive organs.

A 5-μl blood sample was micro-distilled and hydrogen was produced by passage over uranium at 750°C. Hydrogen was collected for mass spectrometric assay by freezing onto activated charcoal at −189°C (Bigeleisen et al. 1952). Oxygen isotope measurements were made by converting blood samples directly to CO_2 gas by reaction with guanidine hydrochloride using a technique described by Boyer et al. (1961), and more recently modified by Viglino et al. (1985). D/H and O^{18}/O^{16} ratios were determined by conventional isotope ratio mass spectrometry. Rates of CO_2 production were calculated by the method of Nagy (1980).

An examination of the data from the two experiments conducted in this study revealed apparently contradictory results. The mean (±SE) 0 hr standard metabolic rate (SMR) values for a group of 9 adults (2.1 ± 0.1 ml $O_2/(g \cdot h)^{-1}$ and 24-hr values for the control group (2.4 ± 0.1 ml $O_2/(g \cdot h)^{-1}$ in the respirometry experiment did not differ significantly from SMR values obtained for the treatment groups at 24 hr in this experiment (Table 1). By contrast, the mean SMR value calculated by changes in isotopic ratios during a 24-hr period was 3.7 + 0.4 ml $CO_2/(g \cdot h)^{-1}$ for control birds, which was significantly lower than the mean value of 4.6 ± 0.3 ml $CO_2/(g \cdot h)^{-1}$ for treatment adults ($t = 5.361$, $P < 0.001$). Differences in results obtained in the two experiments may reflect basic differences in the manner by which SMR was estimated by the two methods employed. The doubly labeled water method es-

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TABLE 1. Mean (±SE) standard metabolic rate values for control and treatment groups of adult Leach's Storm-Petrels used in respirometry and doubly labeled water experiments.

	Carbon dioxide production [ml $CO_2/(g \cdot h)^{-1}$]	Oxygen consumption [ml $O_2/(g \cdot h)^{-1}$]	Conversion[e] [kJ/day]
(Respirometry)			
Control—0 hr	—	2.1 ± 0.3	45.1
Control—24 hr	—	2.4 ± 0.3	45.5
Internal PBC—24 hr	—	3.0 ± 0.8	55.1
External PBC—24 hr	—	2.5 ± 0.8	49.3
(Doubly labeled water)			
Control—24 hr	3.7 ± 0.4[a]	2.7 ± 0.1[b,c]	60.8
Internal PBC—24 hr	4.6 ± 0.3[a]	3.4 ± 0.1[d]	75.9

[a] Average RQ of 0.75 used to convert CO_2 to O_2.
[b] Lower than 0-hr controls from respirometry experiment ($t = 3.779$, $P < 0.01$).
[c] Lower than 24-hr controls from respirometry experiment ($t = 2.258$, $P < 0.05$).
[d] Lower than 24-hr controls from doubly labeled water experiment ($t = 5.360$, $P < 0.001$).
[e] Mean O_2 consumption converted to kJ/day.

timated average SMR by measuring cumulative CO_2 production over a 24-hr period, while the respirometry technique estimated SMR by measuring O_2 consumption during a 30-min period 24 hr after the birds were exposed to oil. The latter method would not be sensitive to transient increases in SMR within the 24-hr period following exposure.

Conversion of the SMR value from CO_2 produced to O_2 consumed was accomplished by multiplying the former values by a respiratory quotient (RQ) of 0.75 (Schmidt-Nielson 1975). There were no sexual differences in SMR for control groups in either experiment. Comparisons of 24-hr mean SMR values for control groups from the two experiments revealed that the doubly labeled water controls at 24 hr had higher SMR values than either the 0-hr or 24-hr controls in the respirometry experiment (Table 1). Conceivably, adults used in the doubly labeled water experiment may have been maintained under more stressful conditions than birds used in the respirometry study. The mean 0-hr and 24-hr oxygen consumption by controls in the respirometry experiment was equivalent to SMR values of 48.6 kJ/day and 45.5 kJ/day, respectively. These values are much lower than the mean control value of 60.8 kJ/day calculated for the 24-hr control group in the doubly labeled water experiment (Table 1). However the latter value is consistent with those of 55.3 kJ/day (Iverson and Krog 1972) and 61 kJ/day (Ricklefs et al. 1980) reported in the literature for this species. Apparent differences in SMR values in the literature and in the results described in the present study may be related to differences in the phase of the breeding cycle at which SMR estimates were obtained.

Leach's Storm-Petrels feed on zooplankton at the ocean's surface at considerable distances from the breeding colony. Since storm-petrels feed at the air-water interface, they are potentially at risk to exposure to floating oil. Petroleum hydrocarbons have been found in the crops of both Leach's and Fork-tailed storm-petrels (*Oceanodroma furcata*) collected in the Gulf of Alaska (Boersma, cited in Holmes 1984). Previous studies (Hartung 1967, Lambert et al. 1982) have shown that external oiling increases metabolic rate presumably to compensate for increased heat loss. Our metabolic experiment using the doubly labeled water technique suggests that internal exposure to small amounts of oil (ingested when birds preen fouled plumage, or when they consume contaminated food) may also temporarily increase adult metabolic rate. This in turn may contribute to the generally elevated metabolic rates observed in oiled birds in previous studies. However, the effects of small but significant increases in SMR on the foraging energetics or breeding success of oil-exposed adults in the wild remain speculative in the absence of more extensive data.

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