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Experimental Support for a New Drift Block Design to Assess Seabird Mortality from Oil Pollution

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ABSTRACT.—Seabird mortality from large oil spills and chronic oil pollution is often significant. Total mortality estimates are derived from counts of dead birds that wash ashore and are corrected for numbers lost at sea. Past attempts to estimate proportion of birds that die at sea and wash ashore have included several experiments using carcasses and different types of wooden drift blocks. Results varied greatly depending on environmental conditions and distance from shore where blocks or carcasses were released. Wind seemed to be the predominant factor determining movement over large distances, whereas tidal currents influenced deposition on specific beaches. Determining timing and location of arrival of dead birds on beaches are crucial for accurate mortality estimates. Drift experiments using beached birds that have already drifted at sea for an undetermined length of time are inaccurate due to natural buoyancy loss and decomposition. To determine accuracy of drift block designs used in the past, we compared drift characteristics and patterns between four drift block designs and fresh murre (*Uria* spp.) carcasses. Our experiments showed that drift blocks used in the past have none of the drift characteristics of dead seabirds, because they have much larger areas exposed to wind and hence drift much faster and farther than murre carcasses. Past mortality estimates using those blocks are therefore doubtful. The drift block design that most accurately mim-

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TABLE 1. Summary of carcass-drift and drift-block experiment results conducted in Europe and North America (adapted from Piatt et al. 1990)

Location	Distance off-shore released	Bird species	Drift block type (cm)	*n*	% recovered
England[a]	?	shag	—	?	25%
English Channel[b]	?	gulls	—	144	20%
Irish Sea[c]	<100 km	alcids	—	400	20%
Irish Sea[d]	<100 km	gulls	—	347	59%
				300	11%
				305	44%
Irish Sea[e]	?	alcids, gulls	—	?	7.5%
North Sea[f]	10 km-?	gulls	—	600	9.8%
North Sea[g]	?	gulls	—	?	40.8%
	?	gulls	—	?	11.3%
Alaska[h]	10 km	murres	—	100	3%
Alaska[i]	6 km	—	9 × 9 × 20	302	0.7–61%
California[j]	?	alcids	—	63	0%
	?	gulls, alcids	—	186	29.9%
British Columbia[k]	1–2 km	—	4 × 9 × 10/20/40	300	43–53%
	35–56 km	—	4 × 9 × 10/20/40	150	18.6%
	86–116 km	—	4 × 9 × 10/20/40	150	0.6%
		Newfoundland			
St. John's to Hibernia[l]	10–500 km	murres	—	115	0%
		—	10 × 10 × 20	400	0%
Cape Race to Sable Island[l]	?	alcids	—	129	0%
		—	10 × 10 × 20	600	24%
Off Cape St. Mary's[m]	50 km	—	10 × 10 × 20	100	30–66%
Placentia Bay[n]	5 km	—	10 × 10 × 20	120	7%

References: [a] Coulson et al. 1968, [b] Hope-Jones et al. 1978, [c] Hope-Jones et al. 1970, [d] Bibby and Lloyd 1977, [e] Lloyd et al. 1974, [f] Bibby 1981, [g] Stowe 1982, [h] Piatt et al. 1990, [i] Flint and Fowler 1998, [j] Page et al. 1982, [k] Hlady and Burger 1993, [l] Threlfall and Piatt 1982, [m] Piatt et al. 1985, [n] Chardine and Pelly 1994.

icked murre carcass drift during our experiments was a 9 × 9 × 14.5 cm wooden block with a 450 gram steel weight that adjusts buoyancy and area exposed to the wind. We propose that in areas where murres are predominant victims of oil spills, that block design be used for all future estimates of oiled seabird mortality.

The effect of chronic oil pollution and large oil spills on seabirds is frequently significant (e.g. Piatt et al. 1990) and usually assessed by counting dead oiled birds that wash up on shore. Birds that die at sea may sink, drift away from shore, get scavenged, decompose at sea, or may be overlooked after they wash ashore on beaches (Ford et al. 1987, Page et al. 1990, Hlady and Burger 1993). Estimates of proportion of birds that actually die at sea and that both reach the shore and are retrieved during beach surveys (Proportion of Dead Birds Retrieved, PDBR) are necessary to quantify total number of birds killed by oil. That is true regardless of whether the seabird mortality event resulted from a large catastrophic accidental oil spill or from a small deliberate or accidental dumping of oil at sea. Attempts to estimate PDBR have included several experiments using carcasses (Coulson et al. 1968, Hope-Jones et al. 1970, 1978; Lloyd et al. 1974, Bibby and Lloyd 1977, Bibby 1981, Stowe 1982, Threlfall and Piatt 1982, Page et al. 1982, Piatt et al. 1990) and wooden drift blocks (Threlfall and Piatt 1982, Piatt et al. 1985, Hlady and Burger 1993, Chardine and Pelly 1994, Flint and Fowler 1998). Those experiments were conducted with different bird species and block types, from different distances from shore, in varying environmental conditions (ocean currents, sea and air temperatures, wind speeds), seasons, and geographical regions. Consequently, results for onshore recoveries varied from 0–59% and 0–66%, for carcasses and drift blocks, respectively (Table 1) and can not easily be directly compared. Generally consistent conclusions stated in the existing literature were (1) wind seems to be the principal factor determining carcass and block drift movement (2.2–4% of wind velocity), and (2) currents, especially tidal currents, may influence deposition on specific beaches once the drifting carcass or block approaches the shore.

The greatest uncertainty in estimating number of birds killed by oil arises from not knowing what proportion of birds oiled actually reach shore and are recovered (Piatt et al. 1985). Although drift block experiments may provide biased estimates of seabirds

TABLE 2. Comparison of relevant physical characteristics of murre carcasses and different drift block designs.

Physical characteristic	Murre carcasses	9 × 9 × 20 cm (block Y)	9 × 9 × 15.5 cm (block S)	4 × 9 × 30 cm (block L)	9 × 9 × 14.5 cm (block W)
Mass (g)	650	1000	695	380	1000
Density (g cm^{-3})	0.76	0.50	0.50	0.50	0.85
ED (cm^2)	90	78	60.45	60	101.5
Area in water (cm^2)	150	130	100.75	60	101.5
Area in air (cm^2)	50	130	100.75	60	29

that drift ashore (e.g. increased detectability, passive drift vs. birds flying to land), they are crucial for estimating PDBR. Use of drift blocks has been criticized in the past because they produce poor estimates of mortality by not taking into account number of oiled birds that actively fly or swim to shore, and because they do not mimic bird-drift appropriately (Hlady and Burger 1993). Ford et al. (1987) outlined a method for taking the former into account in mortality estimates after oil spills. Hlady and Burger (1993) varied length of softwood drift blocks to mimic different species of alcids, and Burger (1991) conducted a buoyancy experiment of oiled carcasses and determined that most alcid carcasses sank within two weeks. Nevertheless, relevant drift characteristics of birds and drift blocks have never been compared and lack of drift similarities between seabird carcasses and previously used drift blocks have never been addressed experimentally. It is sometimes assumed, without supporting evidence, that 10% of seabirds that die at sea as a result of an oil spill reach the shore (Tanis and Morzer Bruijns 1969, Bourne 1970, National Research Council 1985, Canadian Coast Guard 1998), and so beach bird-survey results taken after oil spills have sometimes been multiplied by that PDBR factor. We concur with Burger (1993), who pointed out that the 10% PDBR figure is rarely likely to be correct due to the high degree of weather dependence and distance from shore at the time of the pollution event, buoyancy loss mentioned above, and because drift blocks used in the past had none of the drift characteristics of a seabird carcass. The aim of our study was to experimentally compare drift properties of different block designs to seabird carcasses at sea and thus develop a drift block with appropriate properties for useful estimation of PDBR.

Methods.—For two bodies to float and drift equally through a medium under the same circumstances, several physical characteristics such as drag, density, mass, and projected areas exposed to wind and ocean currents need consideration. We used murres (*Uria* spp.) as a comparison for drift block design, because they are the most vulnerable known seabird species to oil pollution in the northern hemisphere (Camphuysen 1989, Wiese 1999, Wiese and Ryan 1999) and represented over 63% of all birds found dead on Newfoundland shores between 1984 and 1997 (Wiese 1999, Wiese and Ryan 1999). Murres are ~37 cm long from bill tip to tail tip and 10 cm wide at their widest point on the back. Dead, but not decomposed, oiled murres collected during beached-bird surveys had an average mass of 650 g, a density of 0.76 g cm^{-3}, and exposed 150 and 50 cm^2 to water and wind, respectively. A commonly used drift block in the past (Y block) measures 9 × 9 × 20 cm (or 10 × 10 × 20cm), weighs ~1,000 g, has a density of 0.5 g cm^{-3}, and exposes 130 cm^2 to the water and wind (Table 2).

Drag (resistant force exerted on a body parallel but contrary to its movement; Kundu 1990) is essential when comparing drift velocity of two bodies. The general equation for drag is:

$$\text{Drag} = \Omega \times c_d \times A \times \rho \times u^2$$

where c_d is the drag coefficient, A the projected area exposed to the flow, ρ the density of the medium (water and air) and u the fluid velocity (water current; Streeter 1981). Because medium density and fluid velocity are equal for all bodies, the relevance lies in differences between the drag coefficient (which is particular to shape and surface texture) and projected area to the water flow. In the case of a murre, whose shape can be approximated by a cylinder ($c_d = 1.2$; Streeter 1981) with a length of 25 cm, a diameter of 8 cm, and a projected area to the water flow of 150 cm^2 (25 × 6 cm), that effective drag (ED) equals 90 cm^2, where ED is the drag on the portion of the body immersed in water, without taking into consideration ρ or u, because they are equal to all.

Because Y blocks float with the waterline along their diagonal axis, they are also most closely approximated by a cylinder, but of different size ($A = 130$ cm^2), resulting in an ED of 78 cm^2. The main difference between murres and Y blocks seemed therefore not to be ED, but mass and area exposed to wind (Table 2).

Past studies suggested wind force to be the most important factor for block drift (Bibby and Lloyd 1977, Bibby 1981, Hlady and Burger 1993, Flint and Fowler 1998). As denser types of wood are not readily available locally in Newfoundland, we chose to shorten the Y block to approximate wind exposed area and mass, while keeping ED within two-thirds of murres. This new shorter block (S) was 15.5 cm

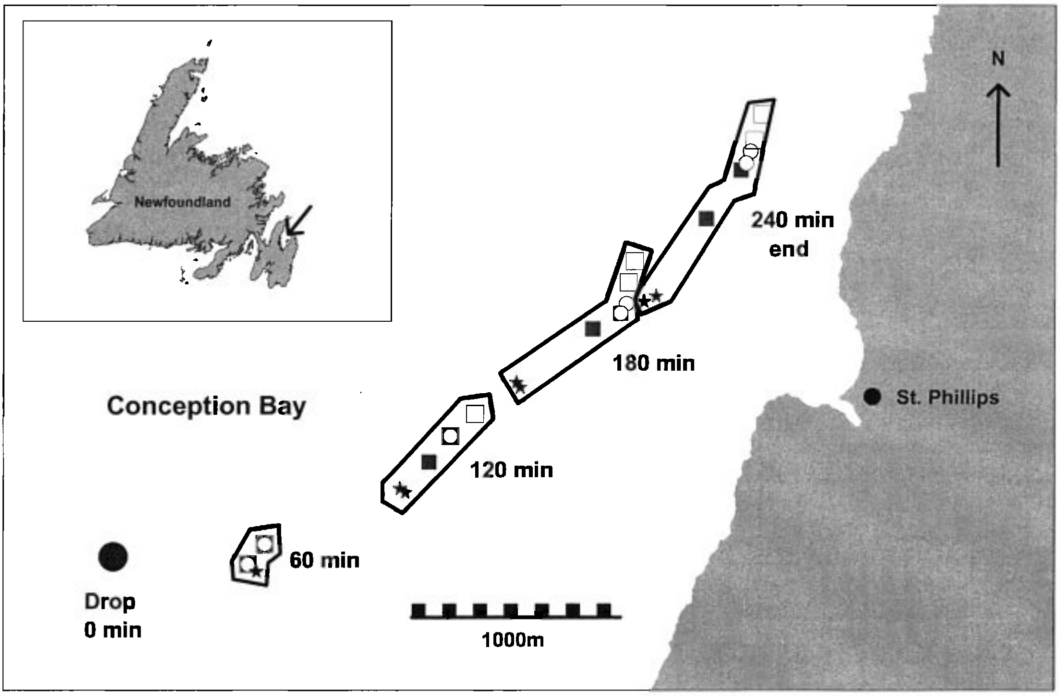

FIG. 1. Study area in Newfoundland, Canada. Comparison of drift between Y blocks (open circle), S blocks (solid square), L blocks (open square), and murres (stars), 11 September 1999. Thirty-three blocks and six murres were dropped. Positions are shown every hour. Points for blocks represent the extremes of their spread. Four murres were lost after 30 min, so only two were tracked the entire time.

long (Table 2). Another way to reduce the wind-exposed area while keeping ED within two-thirds of murres was a 4 × 9 cm softwood block (L block). It was found that a 30 cm long L block achieved that (Table 2), because they float flat in the water as a rectangle, changing drag coefficient (c_d) to 2 (Streeter 1981). As a result, each of the three block types approximated the physical characteristics of a dead murre in one or more ways (Table 2).

We tested 11 blocks of each type (Y, S, L) in the field against six murre carcasses that were freshly dead when collected, had been immediately frozen, and thawed the night before use. All 33 blocks were uniquely marked and dropped simultaneously with the murres from an inflatable boat in Conception Bay, Newfoundland, between Bell Island and the town of St. Phillips on 11 September, 1999 (Fig. 1). Every 15 min, position of the birds and different blocks types were recorded with a hand-held GPS (Garmin GPS III, Garmin, Olathe, Kansas), as was wind speed and direction. Separation and spread was determined. "Separation" was defined as distance separating blocks of different types and carcasses, whereas "spread" was distance separating blocks or carcasses of the same type. After 4 h, the experiment was stopped and the blocks and birds collected. A second similar field experiment was performed on 6 December, 1999, using an additional modified block design based on results of the first experiment. This new block (W block) was weighted down with 450 g of steel (1.25 × 5 × 8.75 cm) attached to one side of the block with a zinc-coated screw. That addition of extra mass resulted in a block with 2 cm of the block exposed to wind and made them float flat ($c_d = 2$; Streeter 1981). Both drag and mass increased as a result, so we shortened the block to 14.5 cm to partially compensate for that (Table 2).

Results.—Birds and blocks drifted in the direction of the wind, but at different speeds. During the first experiment, block types started to separate from each other (separation) after ~30 min, and a clear pattern of separation became apparent after 75 min. Birds moved slowest, whereas especially the L blocks drifted very quickly (Fig. 1). Despite initial use of six murre carcasses, it was only possible to follow two for a longer period of time. Birds floated very low in the water, mostly with their dark-colored backs up, making them very hard to detect again after a 15 min period. After 4 h, the L blocks were furthest away from the birds, followed by the Y blocks. S blocks clearly approximated murre carcass drift the closest (Table 3, Fig. 1). They stayed within 360–600 m of the birds, whereas the Y and the L blocks were at much greater distances (690–740 m and 780–850, respectively).

TABLE 3. Movement (distance in meters) from the drop point for murre carcasses and different drift-block types. Distance ranges reflect the spread within each block type. No range means no spread or just one bird.

Time after drop min	Murres	Y blocks	S blocks	L blocks
60	810	630–740	630–740	630–740
105	1280–1400	1970	1790–1830	1820–1970
120	1500	1790	1630–1750	1780–1920
180	2250	2780–2790	2670–2740	2900–2960
240	3020	3710–3760	3380–3620	3800–3870

Observations during the experiment clearly confirmed that the predominant factor driving movement of drift blocks was wind, and hence area of the block exposed to it. Although L blocks accounted for that, they seemed too light, so the experiment was repeated replacing L blocks with the new W blocks (Table 4, Fig. 2).

During that second trial, W blocks clearly showed closest proximity to the birds because several blocks drifted among them throughout the experiment. Y and S blocks separated from birds after only 30 min and behaved the same way as previously. Winds during both experiments were southwest, yet wind speeds varied (9–20 km h^{-1} and 15–25 km h^{-1} in the first and second trial). Unfortunately, the second experiment had to be ended after 105 min due to bad weather and increasing separation between birds and blocks, making it difficult to track the objects. After 105 min, separation of the W blocks from the carcasses was 20–80 m, whereas the S and Y blocks were at 170–250 m and 330–370 m, respectively.

Discussion.—To quantitatively evaluate the effect of chronic or large oil spills on seabirds, it is essential to quantify number of oiled birds that die at sea. One method to estimate PDBR involves use of wooden drift blocks. Previously collected oiled carcasses are not suitable for that purpose, because they have already been exposed to variable periods of drift, begun to decompose, and therefore no longer have the same buoyancy as a seabird recently killed by exposure to oil (Burger 1991, F. K. Wiese unpubl. data).

To minimize error in drift times and path induced by using a wooden block rather than a bird, we designed a drift block type that closely mimicked murre carcass drift. Several relevant physical characteristics of murre carcasses and drift blocks were examined and empirically compared to each other. Both trials showed a clearly different drift behaviour between blocks and birds. Y blocks used in the past, which approximated ED and area exposed to the water, were found at 690–740 m from the birds in the first trial after 240 min and at 330–370 m after 105 min in the second trial. Extrapolated over a two week drift period (less than the recovery time of blocks usually included in results of past studies) assuming constant wind direction and speed, they would be located between 58–71 km from the murre carcasses. Such a distance could clearly subject birds and blocks to different weather and tidal regimes and puts relevance of past studies using that block type in serious doubt. S blocks, a shorter unweighted version of Y blocks, approximated murre mass and were intermediate between areas exposed to wind and water of murre carcasses. Although that did result in smaller distances to birds than Y blocks, extrapolated again over two weeks assuming constant wind speed and direction, they would be located 30–48 km away from birds and hence be similarly inaccurate. The reason for that difference between carcasses and S blocks appeared to be substantial difference in surface area exposed to wind, a physical characteristic that, together with their minimal mass, seemed to be the most relevant factor in approximating drift of blocks and carcasses. That seemed to be substantiated by L blocks, which did approximate wind exposed area, but were very light, resulting in greatest distance from the murres of all block types tested.

W blocks met the right criteria. They approximated murres in ED, had a small wind-exposed area, and were heavy enough. Most of them stayed with carcasses throughout the experiment or at a maximum

TABLE 4. Results of the second drift block calibration experiment. Movement (distance in meters) from drop point for murre carcasses and different drift block types. Distance ranges reflect the spread within each block type. No range means no spread.

Time after drop min	Murres	Y blocks	S blocks	W blocks
15	180–230	250–270	230	200–220
45	570–710	730–760	640–720	600–630
75	910–1250	1130–1200	1030–1110	970–1010
105	1370–1410	1700–1780	1540–1660	1390–1490

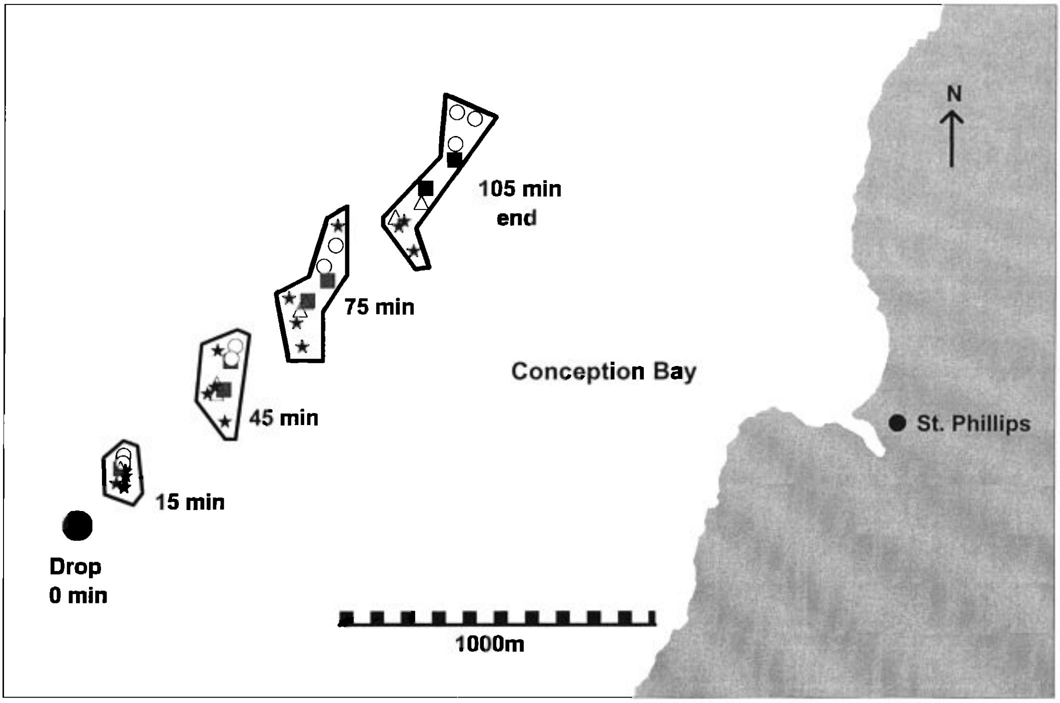

FIG. 2. Comparison of drift between Y blocks (open circle), S blocks (solid square), W blocks (triangles), and murres (stars), 6 December 1999. Thirty blocks and 5 murres were dropped. Positions are shown only at set intervals for clarity. Points for blocks represent extremes of their spread. One murre was lost after 75 min, and one after 90 min.

distance of 80 m. Again translated over a two week period, they would mostly be with the carcasses or a maximum of 15 km away. Given a spread of 100 m among the seabird carcasses over the same time period, we believe that separation was acceptable.

Drift-block experiments are a useful tool in assessing proportion of seabirds that die at sea and drift to shore. They are an important component in estimation of overall avian mortality caused by an oil spill incident or through chronic oil pollution throughout the year. We found that blocks used in the past drifted significantly faster than seabird carcasses, so past results may have misinterpreted drift times of bird carcasses and possibly provided misleading estimates of mortality and drift patterns. Because drifting carcasses are subjected to buoyancy loss through water-logging and scavenging, and may not stay afloat longer than two weeks (Burger 1991), accuracy of drift-time estimates is essential. Using W blocks as described here is not only likely to accomplish that, but may also allow modification of mathematical models for carcass drifts. That would result in the description of more accurate carcass drift-paths for forecasts and to determine the possible origin of the oil retrospectivly. We strongly recommend that all future drift-block studies carried out in areas where murres are a dominant victim of oil pollution use the W block. In areas where other seabird species are predominate victims of oil pollution, similar experiments to ours should be carried out to design drift blocks that match relevant physical drift properties of the species involved.

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