Marine Pollution Bulletin 109 (2016) 490–494

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Research paper

A belt transect setting strategy for mark-recapture experiments to evaluate the 1D diffusion coefficient of beached litter in the cross-shore direction

Hirofumi Hinata [a],*, Tomoya Kataoka [b]

[a] Department of Civil and Environmental Engineering, Faculty of Engineering, Ehime University, 3 Bunkyo-cho, Matsuyama, Ehime 790-8577, Japan
[b] Coastal Zone Systems Division, Coastal, Marine and Disaster Prevention Department, National Institute for Land and Infrastructure Management, 3-1-1 Nagase, Yokosuka, Kanagawa 239-0826, Japan

ARTICLE INFO

Article history:
Received 13 April 2016
Received in revised form 3 May 2016
Accepted 4 May 2016
Available online 2 June 2016

Keywords:
Residence time
Diffusion coefficient
Nearshore current
Mark-recapture experiment
Backwash flux

ABSTRACT

We propose a belt transect setting strategy for mark-recapture experiments (MREs) to evaluate the time-independent 1D diffusion coefficient ($\langle D_{p0} \rangle$) of marine litter in the cross-shore direction that determines the backwashing flux of the litter, based on two-year MREs for plastic floats (PFs) on Wadahama Beach, Nii-jima Island, Japan. When the alongshore width of the belt transect (L_t) was of the order of, or longer than, the length scale of wave-induced nearshore current circulation (L_c), the PFs were rarely transported alongshore across the selected transects prior to being backwashed offshore. Thus, the transect residence time became longer and showed a much weaker dependence on the transect position, in contrast to when L_t was even shorter than L_c. We therefore obtained the diffusion coefficients close to the value of ($\langle D_{p0} \rangle$) when we set L_t to the order of, or longer than, L_c.

1. Introduction

An understanding of the residence time of marine litter on a beach, namely, the temporal trend in cohort population of the beached litter, can be widely applied to the mitigation of marine plastic pollution. For example, it allows us to evaluate beach cleanup effects in terms of decreasing the total mass of toxic substances leaching from beached plastics into the beach and preventing the fragmentation of marine plastics on the beach (Kataoka and Hinata, 2015). In addition, by considering the beach as a linear input–output system, we can evaluate the accumulation rate (output) from the loading rate (input) of beached litter (and vice versa) because the decrease in population of each cohort describes the unit impulse response of the beach system in terms of linear system analysis (Kataoka et al., 2013).

The exponential cohort population decay of the plastic floats (PFs) on the entire Wadahama Beach, Japan (Fig. 1a), measured by Kataoka et al. (2013) indicates that the decay obeys a 1D diffusion equation in the cross-shore direction. That is, the backwashing flux of the PFs can be calculated by using a time-independent diffusion coefficient ($\langle D_{p0} \rangle$) and the amount of PFs on the beach. Additionally, they showed that $\langle D_{p0} \rangle$ can be estimated as B_0^2/τ_0, where B_0 and τ_0 are the average backshore width and average residence time for the entire beach, respectively. We considered the estimation of the diffusion coefficient as the most useful application of the residence time to marine litter pollution because it can be evolved to a numerical model capable of reproducing the backwash process as described below.

Kataoka et al. (2015) (hereinafter referred to as K15) clarified the backwash process of the PFs on Wadahama Beach based on two-year mark-recapture experiments (MREs). All categories of the floats (immigrant, remnant, and emigrant) concentrated in the middle and in the northern parts of the beach, where the alongshore wave-induced nearshore currents converged and rip currents occurred. Generally, the nearshore current forms a cell structure under normal wave incidence (e.g., Sonu, 1972; MacMahan et al., 2006). K15 concluded that the majority of the beached floats were trapped in the cells generated during storm events and then were backwashed offshore by the rip currents on the boundaries between the cells.

Here, we consider a numerical model of the backwashing and beaching processes of marine litter by introducing beach grid cells (width: B, length: L) (Fig. 2) into the present models in which the computational grid cells consist of ocean and land cells (e.g., Yoon et al., 2010; Maximenko et al., 2012; Lebreton et al., 2012). In the model, B is set equal to the backshore width. The backwashing litter flux is calculated using $\langle D_{p0} \rangle$ and the amount of litter in the beach cells. The alongshore flux between the beach cells is assumed to be zero; that is, L must be set so that the alongshore flux becomes negligibly small compared to the flux between the ocean and beach grid cells. How to decide L is shown later in Section 3.3. The beaching flux might be calculated using the Stokes drift velocity (U_s) and the amount of litter in the ocean cells adjacent to the beach cells.

---

* Corresponding author.
E-mail address: hinata@cee.ehime-u.ac.jp (H. Hinata).

http://dx.doi.org/10.1016/j.marpolbul.2016.05.016

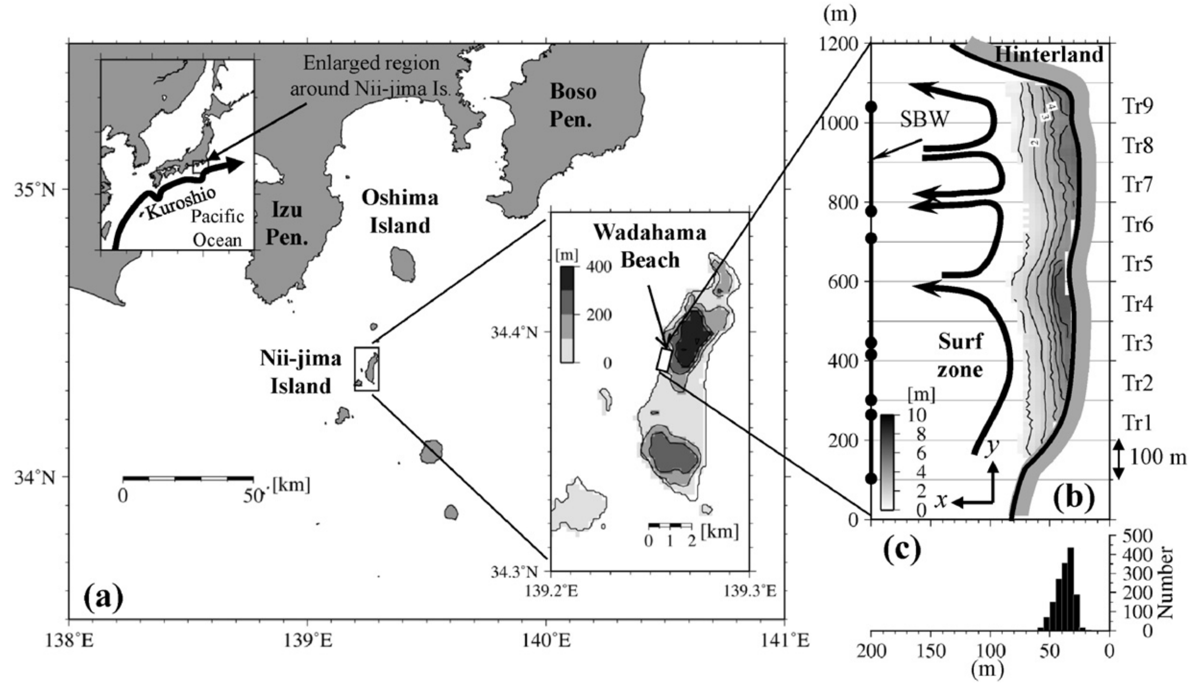

Fig. 1. (a, b) Location and topography of Wadahama Beach, Nii-jima Island, Japan. On the enlarged map, contour lines and gray-white gradation denote the altitude. (b) Black arrows represent wave-induced nearshore currents identified based on Kataoka et al. (2015). Alongshore locations of four submerged breakwaters (SBW) are represented by solid lines with circle ends. (c) Cross-shore distribution of the total amount of remnant plastic floats collected during two-year mark-recapture experiments. Almost all the floats were at an altitude higher than about 2 m (see Fig. 1b).

The diffusion coefficient of a certain target item can be obtained by measuring its residence time on the beach, which is generally measured by the MREs (Garrity and Levings, 1993; Bowman et al., 1998; Kataoka et al., 2013, 2015). The MREs for the entire beach can be regularly conducted when the beach is shorter than a few kilometers and the total number of items is less than a few hundred; otherwise, it might be difficult to continue the MREs on a regular basis (Ryan et al., 2014).

A strategy for dealing with too many items on the beach would be to randomly select several hundred items or less and to put unique identification numbers on them. On the other hand, when the beach is longer than a few kilometers, belt transects should be set on the beach and the MREs conducted within the transects; and if so, where should the transects be located? Here, we propose a strategy for the belt transect setting on a longer beach to evaluate the time-independent 1D diffusion coefficient ($\langle D_{p0} \rangle$) of marine litter in the cross-shore direction that determines the backwashing flux of the litter based on the results of two-year MREs on Wadahama Beach.

2. Data and methods

We reanalyzed the data of the MREs conducted from September 2011 to August 2013 on Wadahama Beach, Nii-jima Island, Japan (Fig. 1a), by K15. We divided the beach into nine 100-m-wide belt transects (Tr1–Tr9) as in the previous study (Fig. 1b) and estimated the average transect residence time of the PFs for various combinations of transects; that is, the residence time until the PFs disappeared from the original transects after being backwashed offshore or moved to other transects.

The nearshore current cells off Wadahama Beach generated during storm events are illustrated in Fig. 1b. The cells in the northern region (600–1100 m) were identified by K15, and the ones in the southern region (200–600 m) were inferred based on the longshore movement of the PFs (see Fig. 5 in K15). The PFs in the northern (southern) region were mainly concentrated around $y = 800$ m (600 m). In the northern region, two coupled cells with opposite rotations created a unit circulation system as described in Sonu (1972), occurring at a longshore length

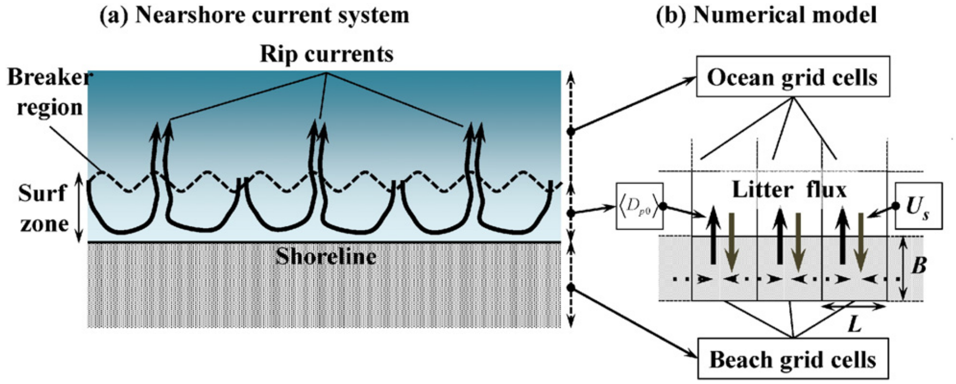

Fig. 2. Schematic image of the relationship between the nearshore current system (a) and numerical grid cells in our model (b). Backwashing flux (black arrows) of litter will be calculated by using the time-independent diffusion coefficient ($\langle D_{pt} \rangle$) determined by mark-recapture experiments, while beaching flux (grey arrows) might be calculated by Stokes drift velocity (U_s). No alongshore flux (dotted arrows) will be assumed between the beach grid cells.