

Competing effects of seasonal hydrodynamics and temperature-dependent development shape marine larval dispersal

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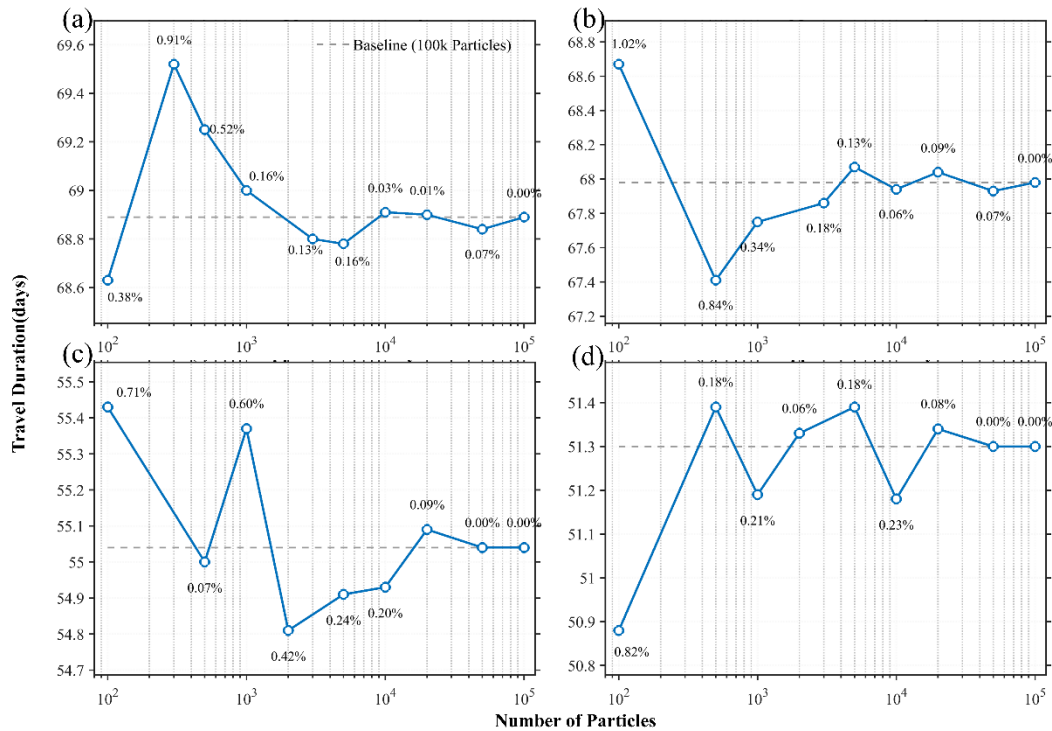


Figure S1. Sensitivity analysis of the Lagrangian particle tracking model to variations in number of particles. (a) OGT approach at May 1st 2013, (b) GDD approach at May 1st 2013, (c) GDD approach at May 15th 2013, and (d) OGT approach at May 15th 2014.

15 **Comparison with Previous Satellite-Tracked Drifters and Field Observations**

16 Our simulated larval dispersal patterns (Fig. S2), in which particles were released from
17 34°N, differed partly from the trajectories of satellite-tracked drifters reported by Yuan et al.
18 (2017). Specifically, our simulated particles were not transported toward the southern coast of
19 the Shandong Peninsula, whereas the satellite-tracked drifters reached the coast (Fig. 11 in Yuan
20 et al., 2017). Nevertheless, the northward transport direction and overall trajectories were
21 broadly consistent between the simulations and observations. This discrepancy is likely
22 attributable to differences in the simulation period, as Yuan et al. (2017) released drifters in
23 2009, whereas our simulations covered 2013–2018. Notably, our simulated dispersal patterns
24 for 2016 were consistent with those reported by Xing et al. (2020), who simulated particle
25 trajectories for the same year (black dots in Fig. S2). These supports the ability of our particle-
26 tracking model to realistically reproduce the regional transport pathways of passive particles.

27 However, comparisons with field observations showed that the simulated larval
28 distributions were only partially consistent with observed patterns, agreeing with some surveys
29 but differing from others. For example, Wan et al. (2002) reported that Japanese anchovy larval
30 abundance decreased along a survey transect extending from approximately 120.6°E, 35.9°N
31 to 125.8°E, 33.0°N, with peak abundance occurring near 121°E, 35.5°N. This distribution
32 agrees well with the centroid locations predicted using the temperature-dependent travel
33 durations (Fig. 5). Similarly, surveys conducted between 2000 and 2004 within 120–124°E and
34 33°30'–37°N recorded larvae throughout the study area, although their spatial distribution was
35 highly patchy (Wan et al., 2008). In contrast, surveys conducted during 2016–2018 from

approximately 122.8°E, 37.0°N to 119.2°E, 32.0°N found relatively few larvae between 35°N and 36°N, with most individuals occurring in nearshore waters around 34°N, south of Haizhou Bay (Zhang et al., 2025).

The discrepancy with field surveys reported by Zhang et al. (2025) may reflect the existence of additional spawning grounds that were not considered in the present study to provide those larvae around 34°N, or the simplifying assumption of passive larval transport. Incorporating active larval behaviors, such as directional swimming or rheotaxis, although these behaviors remain poorly understood, may modify dispersal and settlement patterns and improve agreement between model predictions and field observations. These possibilities are quite interesting and warrant further investigation.

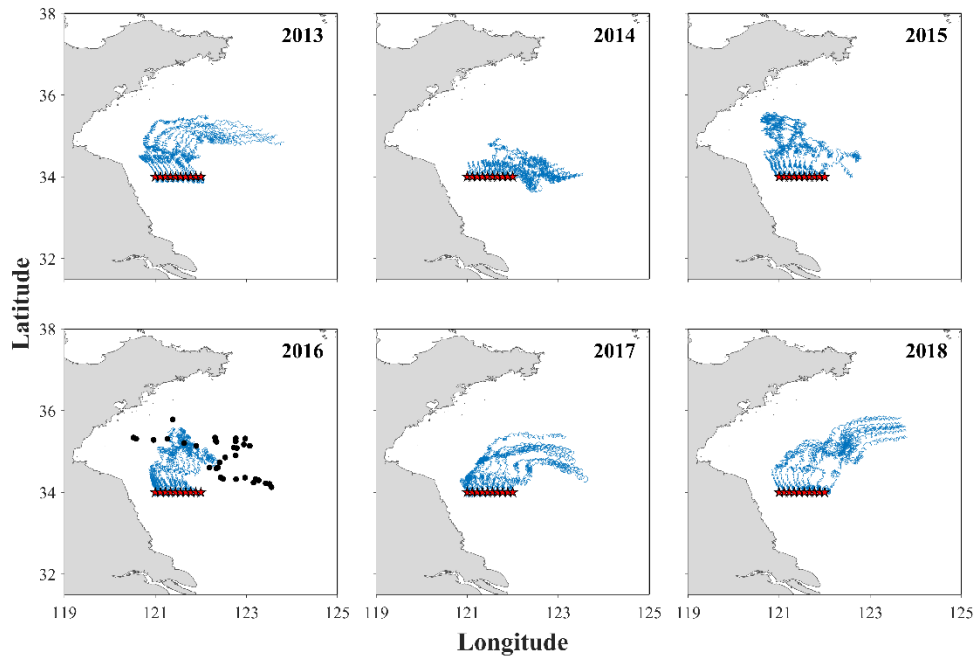


Figure S2. Blue lines indicate simulated larval trajectories for particles released along the 34°N transect (red stars) on May 28 and tracked until July 19. Black dots indicate the settlement locations of particles released from 121–122°E along the 34°N transect on June 1 2016 and tracked until July 20, as reported by Xing et al. (2020).

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52 **Table S1.** Results of the two-way ANOVA testing the effects of release year (excluding 2017 and
 53 all years) and release date on the mean water temperatures experienced by simulated Japanese
 54 anchovy (*Engraulis japonicus*) larvae under the OGT and GDD approaches.

Approach	Source	Sum Sq.	d.f.	Mean Sq.	F	p-value
OGT	Release Year (excluding 2017)	2.90	4	0.73	3.566	>0.01
	Release Date	305.53	5	61.11	300.523	<0.01
	Error	4.07	20	0.20		
GDD	Release Year (excluding 2017)	2.07	4	0.52	2.909	>0.01
	Release Date	231.89	5	46.38	261.131	<0.01
	Error	3.55	20	0.18		

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Approach	Source	Sum Sq.	d.f.	Mean Sq.	F	p-value
OGT	Release Year (all years)	9.90	5	1.98	8.912	<0.01
	Release Date	361.14	5	72.23	325.175	<0.01
	Error	5.55	25	0.22		
GDD	Release Year (all years)	12.18	5	2.44	14.029	<0.01
	Error					

	Release Date	289.67	5	57.93	333.779	<0.01
	Error	4.34	25	0.17		

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57 **Table S2.** The median-dispersal distance and long-distance dispersal values, values are presented
58 as the median dispersal distance with long-distance dispersal (LDD) values in parentheses.

Pathway	Release Date	2013	2014	2015	2016	2017	2018
GDD	May 1	268.9 (340.8)	172.5 (230.4)	199.4 (289.0)	217.0 (273.6)	213.6 (293.3)	287.8 (350.1)
	May 15	228.9 (309.9)	143.2 (216.7)	196.1 (294.2)	209.1 (275.1)	239.0 (322.3)	277.0 (332.9)
	June 1	235.3 (326.0)	136.3 (206.6)	143.4 (198.6)	203.8 (277.6)	236.2 (317.1)	310.6 (397.7)
	June 15	218.8 (307.9)	172.2 (267.6)	92.8 (175.4)	147.4 (234.1)	221.2 (346.0)	235.9 (356.7)
	July 1	184.7 (317.5)	150.0 (240.2)	93.4 (144.5)	188.5 (254.6)	152.3 (258.6)	203.9 (330.8)
	July 15	144.5 (280.0)	96.6 (172.3)	152.1 (214.7)	169.5 (261.9)	161.0 (250.1)	201.2 (285.9)
OGT	May 1	275.5 (343.9)	174.2 (228.8)	198.1 (284.4)	211.3 (272.1)	213.4 (289.8)	289.6 (355.1)
	May 15	230.4 (313.4)	145.2 (214.9)	191.3 (291.7)	206.3 (272.7)	237.1 (316.6)	276.2 (337.0)
	June 1	258.3 (365.2)	143.8 (215.9)	143.3 (194.5)	201.1 (272.2)	320.1 (371.8)	330.8 (397.5)
	June 15	241.9 (341.3)	184.2 (273.1)	112.8 (212.7)	239.5 (315.8)	346.7 (468.0)	267.4 (423.1)
	July 1	294.7 (425.1)	122.0 (205.2)	134.6 (198.6)	134.0 (238.5)	207.4 (443.2)	158.5 (436.5)
	July 15	229.1 (385.9)	100.4 (188.7)	94.8 (222.0)	189.5 (273.8)	120.5 (253.4)	145.3 (401.1)
30day	May 1	128.9 (184.8)	149.7 (223.6)	128.6 (175.6)	86.4 (149.5)	164.2 (230.3)	111.5 (186.3)
	May 15	104.8 (165.6)	92.3 (170.0)	178.4 (262.1)	110.4 (185.0)	178.5 (248.8)	180.9 (245.0)
	June 1	151.6 (231.3)	84.1 (157.1)	138.9 (220.8)	159.1 (231.2)	169.3 (272.3)	210.6 (307.4)
	June 15	189.3 (259.7)	109.5 (197.3)	83.9 (171.9)	151.1 (240.2)	220.5 (344.5)	200.7 (287.5)

	July 1	183.8 (322.4)	147.2 (256.4)	86.9 (140.7)	191.8 (255.6)	149.4 (263.5)	202.6 (333.8)
	July 15	181.3 (329.1)	98.0 (168.1)	150.9 (214.9)	182.9 (268.3)	180.3 (250.8)	219.5 (332.6)

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60 References

61 Yuan D, Yao L, Wang B, et al., 2017. Coastal Circulation in the Southwestern Yellow Sea in the

62 Summers of 2008 and 2009[J]. Continental Shelf Research, 143.

63 Zhang W, Ye Z, Jiang Y, et al., 2025. Early Growth Pattern of Japanese Anchovy *Engraulis*

64 *japonicus* in the Coastal Yellow Sea and Its Influencing Factors[J]. Fisheries Oceanography,

65 34(5): 1-16.

66 Wan R, Huang D, Zhang J, 2002. Abundance and distribution of eggs and larvae of *Engraulis*

67 *japonica* in the Northern part of East China Sea and the Southern part of Yellow Sea and its

68 relationship with environmental conditions[J]. Journal of Fisheries of China(4): 321-330.

69 Wan R, Wei H, Sun S, et al., 2008. Spawning ecology of the anchovy *Engraulis japonica* in the

70 spawning ground of the Southern Shandong PeninsulaI. Abundance and distribution characters

71 of anchovy eggs and larvae[J]. Acta Zoologica Sinica(5): 785-797.

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