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Appendix S1

Supplementary material for:

Title:
Stream and ocean hydrodynamics mediate partial migration strategies in an amphidromous Hawaiian goby

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Contents:

Literature Cited:

Hogan, J. D., M. J. Blum, J. F. Gilliam, N. Bickford, and P. B. McIntyre. 2014. Consequences of alternative dispersal strategies in a putatively amphidromous fish. Ecology 95:2397–2408.

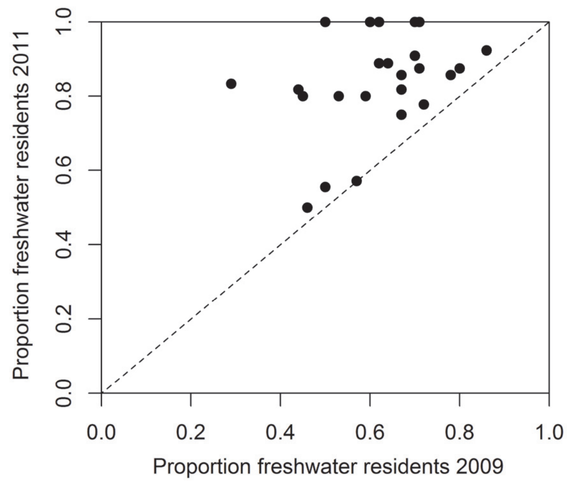

Figure S1: The proportion of *Awaous stamineus* gobies that were lifelong freshwater residents in streams (n = 4 to 19 per stream per year) sampled in both 2011 (83%, n = 274) and 2009 (62%, n = 316). The dashed line indicates parity between the axis values.

Table S1. The number (N) of *Awaous stamineus* freshwater adult otoliths taken from surveys during 2009 (Hogan et al. 2014) and 2011. Saltwater migrants (SW) are those with elevated Sr:Ca ratios of the otolith in the larval phase (~8 mmol/mol), which then quickly declines after freshwater settlement (to ~2 mmol/mol, Hogan et al. 2014). Otoliths having consistently low Sr:Ca and lacking variation between larval and adult portions of the otolith are interpreted as lifelong freshwater residents (FW). We indicated the proportion saltwater migrants (SW) and freshwater (FW) residents in each year. For hydrological analysis, we indicate the USGS gage number used in each watershed which were denoted according to the DAR Hawaiian Watershed Atlas code.

DAR	Island	Watershed	N 2009	SW 2009	FW 2009	N 2011	SW 2011	FW 2011	USGS gage
82032	Hawai‘i	Hakalau	0	n/a	n/a	9	0.00	1.00	
82056	Hawai'‘i	Honoli‘i	14	0.43	0.57	7	0.43	0.57	16717000
82049	Hawai‘i	Ka‘ie‘ie	7	0.71	0.29	12	0.17	0.83	
81013	Hawai‘i	Niuli‘i	3	0	1	11	0.00	1.00	
82061	Hawai‘i	Wailoa R.	8	0.13	0.88	0	n/a	n/a	
81044	Hawai‘i	Waipi‘o	10	0.5	0.5	9	0.44	0.56	
22001	Kaua‘i	Anahola	3	0.33	0.67	0	n/a	n/a	
21010	Kaua‘i	Hanakāpī‘ai	5	0.2	0.8	8	0.13	0.88	
21019	Kaua‘i	Hanalei	5	0.8	0.2	0	n/a	n/a	
22004	Kaua‘i	Kapa‘a	10	0.4	0.6	10	0.00	1.00	
23004	Kaua‘i	Lāwa‘i	17	0.47	0.53	10	0.20	0.80	
21034	Kaua‘i	Moloa‘a	11	0.55	0.45	10	0.20	0.80	
24004	Kaua‘i	Waimea R.	13	0.38	0.62	9	0.11	0.89	16010000
21014	Kaua‘i	Wainiha	8	0.38	0.63	2	0.00	1.00	16108000
65020	Mau‘i	‘Ālelele	9	0.22	0.78	7	0.14	0.86	
61011	Mau‘i	Honokōhau	7	0.29	0.71	8	0.00	1.00	16620000
62009	Mau‘i	'Īao	6	0.33	0.67	7	0.14	0.86	16604500
62003	Mau‘i	Kahakuloa	2	0	1	4	0.25	0.75	16618000
64011	Mau‘i	Pi'ina‘au	9	0.56	0.44	11	0.18	0.82	
61001	Mau‘i	Ukumehame	0	n/a	n/a	10	0.50	0.50	
62007	Mau‘i	Waihe‘e R.	11	0.36	0.64	9	0.11	0.89	16614000
41021	Molokai	Hālawa	18	0.33	0.67	12	0.25	0.75	16400000
42003	Molokai	Honouli Wai	17	0.41	0.59	5	0.20	0.80	
41009	Molokai	Pelekunu	17	0.29	0.71	8	0.13	0.88	
41003	Molokai	Waikolu	0	n/a	n/a	10	0.30	0.70	
41015	Molokai	Wailau	10	0.3	0.7	11	0.09	0.91	
33007	O‘ahu	Ala Wai	19	0.37	0.63	0	n/a		16240500
32007	O‘ahu	Kahalu‘u	7	0.14	0.86	13	0.08	0.92	16284200
31018	O‘ahu	Kahana	13	0.54	0.46	10	0.50	0.50	16296500
31013	O‘ahu	Kaluanui	1	1	0	12	0.25	0.75	16304200
32009	O‘ahu	Kea‘ahala	18	0.28	0.72	9	0.22	0.78	
32004	O‘ahu	Waiāhole	12	0.33	0.67	11	0.18	0.82	16294100
32002	O‘ahu	Waikāne	14	0.5	0.5	13	0.00	1.00	16294900
32015	O‘ahu	Waimānalo	10	0.3	0.7	5	0.00	1.00	
36010	O‘ahu	Waimea	2	1	0	2	0.00	1.00	16330000
		Total	316	0.38	0.62	274	0.18	0.83	

Table S2: Passive larval transport model simulated settlement rates summarized to each island (from all streams in Table S4) from 2009 to 2013. We calculated the annual percent of larvae among the 5 Islands in the Hawaiian Archipelago (in Table S3) reflecting relative island specific accessibility for amphidromous larvae. As a metric of annual variability of settlement, we calculated the mean, standard deviation (SD), and coefficient of variation (CV) in larval settlement across the 5 years for each island.

Island	2009	2010	2011	2012	2013	Mean	SD	CV
Hawai‘i	17.2	13.9	17.0	12.9	18.8	16.0	2.45	0.153
Mau‘i	22.5	18.9	19.0	18.5	22.1	20.2	1.92	0.095
Molokai	17.4	17.0	17.4	14.8	18.2	17.0	1.27	0.075
O‘ahu	21.8	24.9	20.0	22.3	17.6	21.3	2.72	0.127
Kaua‘i	21.2	25.3	26.7	31.5	23.4	25.6	3.88	0.151

Table S3: Passive larval transport model simulated settlement rates in 51 Hawaiian watersheds from 2009 to 2013. DAR = Division of Aquatic Resources (DAR) watershed code. We calculated the annual proportion of larvae among the 51 watersheds, reflecting stream specific relative accessibility for amphidromous larvae. As a metric of annual variability of settlement, we calculated the CV of larval settlement across years. We indicate (with an "X") if a watershed has overlapping USGS hydrological data and sufficient adult otolith samples to estimate freshwater residency in each stream.

DAR	Island	Watershed	Lat_dd	Lon_dd	%2009	%2010	%2011	%2012	%2013	mean	CV	USGS	Oto
82056	Hawai‘i	Honoli‘i	19.76	-155.09	0.14	0.18	0.21	0.14	0.19	0.17	0.17	X	X
81044	Hawa‘'i	Wailoa	20.12	-155.59	1.99	1.45	1.82	1.23	1.88	1.67	0.19		X
81013	Hawai‘i	Niuli‘i	20.24	-155.76	2.74	2.10	3.51	2.13	2.32	2.56	0.23		X
85003	Hawai‘i	Wai‘ula‘ula	20.01	-155.82	2.26	1.39	1.77	2.90	2.33	2.13	0.27		
82032	Hawai‘i	Hakalau	19.90	-155.13	0.66	0.43	0.52	0.33	0.33	0.46	0.31		X
83011	Hawai‘i	Hi‘onamoa	19.16	-155.44	2.49	3.25	3.40	2.58	6.58	3.66	0.46		
82061	Hawai‘i	Wailoa	19.72	-155.07	0.76	0.70	0.94	0.65	0.93	0.80	0.17		X
82044	Hawai‘i	Onomea	19.81	-155.09	0.72	0.51	0.60	0.45	0.49	0.55	0.20		
82027	Hawai‘i	Nānue	19.93	-155.16	0.94	0.66	0.77	0.47	0.53	0.67	0.28		
82033	Hawai‘i	Kolekole	19.88	-155.12	0.79	0.51	0.67	0.44	0.41	0.57	0.28		
82014	Hawai‘i	Maulua	19.95	-155.19	1.06	0.73	0.82	0.45	0.73	0.76	0.29		
82002	Hawai‘i	Ka‘awali‘i	20.01	-155.26	2.23	1.65	1.61	0.85	1.67	1.60	0.31		
82053	Hawai‘i	Kapu‘e	19.78	-155.09	0.39	0.33	0.38	0.29	0.36	0.35	0.11		
21010	Kaua‘i	Hanakāpī‘ai	22.21	-159.60	1.93	1.47	2.26	2.24	2.21	2.02	0.17		X
23004	Kaua‘i	Lāwa‘i	21.89	-159.50	2.15	2.94	3.42	3.42	2.45	2.87	0.20		X
21014	Kaua‘i	Wainiha	22.21	-159.54	0.99	0.89	1.18	1.01	0.93	1.00	0.11	X	X
24004	Kaua‘i	Waimea River	21.95	-159.67	2.11	2.44	3.03	3.30	2.62	2.70	0.17	X	X
22004	Kaua‘i	Kapa‘a	22.09	-159.31	2.22	2.71	2.04	3.61	2.23	2.56	0.25		X
22013	Kaua‘i	Nāwiliwili	21.95	-159.36	3.00	3.58	3.28	4.87	2.80	3.51	0.23		
23007	Kaua‘i	Hanapēpē	21.90	-159.59	2.24	2.97	3.75	3.58	2.85	3.08	0.20		
22008	Kaua‘i	Wailua River	22.04	-159.34	1.49	1.75	1.47	2.46	1.62	1.76	0.23		
22001	Kaua‘i	Anahola	22.15	-159.31	1.73	2.22	1.62	2.66	1.70	1.98	0.22		X
21034	Kaua‘i	Moloa‘a	22.19	-159.33	2.16	2.98	2.70	2.88	2.50	2.64	0.12		X
21019	Kaua‘i	Hanalei	22.21	-159.50	1.20	1.31	1.93	1.49	1.49	1.48	0.19	X	
62007	Mau‘i	Waihe‘e	20.95	-156.51	1.40	1.18	1.72	1.03	1.33	1.33	0.20	X	X
62009	Mau‘i	‘Īao	20.91	-156.48	0.70	0.52	0.74	0.49	0.68	0.63	0.18	X	X
61011	Mau‘i	Honokōhau	21.02	-156.61	2.74	2.80	3.57	2.53	3.31	2.99	0.14	X	X
65020	Mau‘i	‘Ālelele	20.65	-156.08	3.76	3.01	2.89	3.22	3.52	3.28	0.11		X
64011	Mau‘i	Pi‘ina‘au	20.86	-156.14	1.63	1.57	1.10	0.83	1.24	1.27	0.26		X
65013	Mau‘i	‘Ohe‘o	20.66	-156.04	4.12	3.13	2.96	3.00	3.52	3.35	0.15		
42014	Molokai	Kamalō	21.05	-156.88	2.13	2.36	2.36	2.24	2.54	2.33	0.07		
42003	Molokai	Honouli Wai	21.11	-156.75	1.87	1.89	1.99	1.88	2.28	1.98	0.09		X
41015	Molokai	Wailau	21.17	-156.83	1.96	1.42	1.78	1.22	1.64	1.60	0.18		X
41021	Molokai	Hālawa	21.16	-156.74	3.50	3.36	3.28	2.51	3.27	3.18	0.12	X	X
41009	Molokai	Pelekunu	21.16	-156.88	1.03	0.78	0.92	0.60	0.83	0.83	0.20		X
41003	Molokai	Waikolu	21.17	-156.93	0.77	0.66	0.74	0.45	0.73	0.67	0.19		X
32007	O‘ahu	Kahalu‘u	21.46	-157.84	0.50	0.55	0.46	0.43	0.44	0.48	0.10	X	X
32015	O‘ahu	Waimānalo	21.36	-157.71	4.03	4.68	2.35	2.49	2.40	3.19	0.34		X
33007	O‘ahu	Ala Wai	21.28	-157.85	4.79	5.92	7.22	7.13	3.89	5.79	0.25	X	X
32002	O‘ahu	Waikāne	21.49	-157.85	1.17	1.36	1.01	1.10	1.04	1.14	0.12	X	X
31018	O‘ahu	Kahana	21.56	-157.87	2.90	3.23	2.18	2.65	2.45	2.68	0.15	X	X
31007	O‘ahu	Kahawainui	21.65	-157.93	2.33	2.58	1.50	2.06	1.73	2.04	0.21		
31008	O‘ahu	Wailele	21.67	-157.94	3.50	3.80	2.16	2.86	2.47	2.96	0.23		
34010	O‘ahu	Waikele	21.37	-158.01	0.32	0.44	0.57	0.75	0.45	0.51	0.32	X	
36010	O‘ahu	Waimea River	21.64	-158.06	2.22	2.38	2.53	2.77	2.77	2.53	0.10	X	
42015	Molokai	Kawela	21.06	-156.95	2.47	3.40	3.08	2.89	3.19	3.00	0.12		
42004	Molokai	Waialua	21.10	-156.76	2.64	2.39	2.38	2.52	2.78	2.54	0.07		
41002	Molokai	Wai‘ale‘ia	21.17	-156.94	1.03	0.79	0.84	0.50	0.91	0.82	0.24		
61001	Mau‘i	Ukumehame	20.80	-156.59	6.87	5.28	5.00	6.63	7.51	6.26	0.17		X
64018	Mau‘i	Waiohue	20.83	-156.12	0.22	0.24	0.19	0.16	0.20	0.20	0.16		
64022	Mau‘i	Hanawī	20.83	-156.10	1.02	1.13	0.78	0.64	0.74	0.86	0.24		

Table S4: Candidate model selection through an analysis of covariance (ANCOVA) to evaluate the proportion marine migrant population of *A. stamineus* across streams several common flow metrics of the flow exceedance (Q5,Q10,Q50,Q90,Q95), flow variation (CVflow), flow stability ratio (Q90:Q10), variability ratio (Q10:Q90) and effect of collection year (2009 & 2011). The most parsimonious model with the lowest AICc score suggested the same regression slopes on CV stream discharge in 2011 and 2009 but a different intercept for each collection year (m4). The next best model greater than ΔAICc = 2 and therefore m4 is considered the most parsimonious. The indication of fit of the model with the adjusted R^2. K represents the number of parameters used in each model. To address any issue of sampling bias, we tested constrained dataset represents further restrictions for watersheds sampled in both years and a larger sample size in each stream (N = 4). In both scenarios, m4 was the top model.

Full dataset

Model	Predictors	K	AICc	ΔAICc	R^2
m1	Year	3	-22.24	2.40	0.33
m2	CVflow	3	-14.91	9.73	0.08
m3	CVflow+Year +CVflow:Year	5	-21.64	3.00	0.47
m4	**CV flow + Year**	4	-24.64	0.00	**0.47**
m5	Q10 + Year	4	-21.4	3.24	0.37
m6	Q50 + Year	4	-19.84	4.80	0.33
m7	Q90 + Year	4	-19.38	5.26	0.33
m8	Q95 + Year	4	-19.32	5.32	0.32
m9	Q5 + Year	4	-22.3	2.34	0.41
m10	Flow Stability ratio+ Year	4	-20.99	3.65	0.37
m11	Flow Variability ratio + Year	4	-20.84	3.80	0.36

Constrained dataset

Model	Predictors	K	AICc	ΔAICc	R^2
m1	Year	3	-15.62	2.11	0.27
m2	CVflow	3	-11.61	6.12	0.11
m3	CVflow+Year +CVflow:Year	5	-14.44	3.29	0.38
m4	**CV flow + Year**	4	-17.73	0.00	**0.41**
m5	Q10 + Year	4	-15.72	2.01	0.35
m6	Q50 + Year	4	-13.66	4.07	0.28
m7	Q90 + Year	4	-12.66	5.07	0.24
m8	Q95 + Year	4	-12.55	5.18	0.24
m9	Q5 + Year	4	-16.34	1.39	0.36
m10	Flow Stability ratio+ Year	4	-13.73	4.00	0.27
m11	Flow Variability ratio + Year	4	-14.02	3.71	0.29

Table S5: Candidate model selection through an analysis of covariance (ANCOVA) to evaluate the proportion marine migrant population of *A. stamineus* across mean through a joint test of mean rate of modeled marine settlement, annual variation in modeled marine settlement (CV), the effect of stream flow variation (CV) and effect of collection year (2009 & 2011). The best candidate model (lowest AICc) suggested the same regression slopes on CV stream discharge in 2011 and 2009. The indication of fit of the model with the adjusted R^2. K represents the number of parameters used in each model.

Model	Predictors	K	AICc	ΔAICc	R^2
m1	Year	2	-15.67	1.96	0.28
m2	Mean settlement	2	-8.59	9.04	0.00
m3	CV settlement	2	-8.12	9.51	0.17
m4	Mean settlement + Year	3	-13.15	4.48	0.14
m5	CV settlement + Year	3	-12.56	5.07	0.15
m6	**CV flow + Year**	**3**	**-17.63**	**0.00**	**0.41**
m7	CV settlement + CV flow +Year	4	-14.03	3.60	0.38
m8	Mean settlement +CV flow +Year	4	-14.52	3.11	0.39