Food, Stress, and Mating: Tall Choices in the Life of a Small Damselfish

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Living in Social Groups

- Benefits
  - Safety
    - Dilution effect
    - Early detection
  - Better access
    - Food
    - Mates
- Costs
  - Increased competition
    - Food
    - Shelter
    - Mates

Living in Social Groups

- Choosing a Group Size
  - Balance costs / benefits
  - Optimal strategy
    - Maximize lifetime fitness

Optimal Group Size
Is there one?

Coral Reef Fishes

- Complex Life History
  - Pelagic
    - Larval Stage
  - Demersal
    - Juvenile / Adult Stage

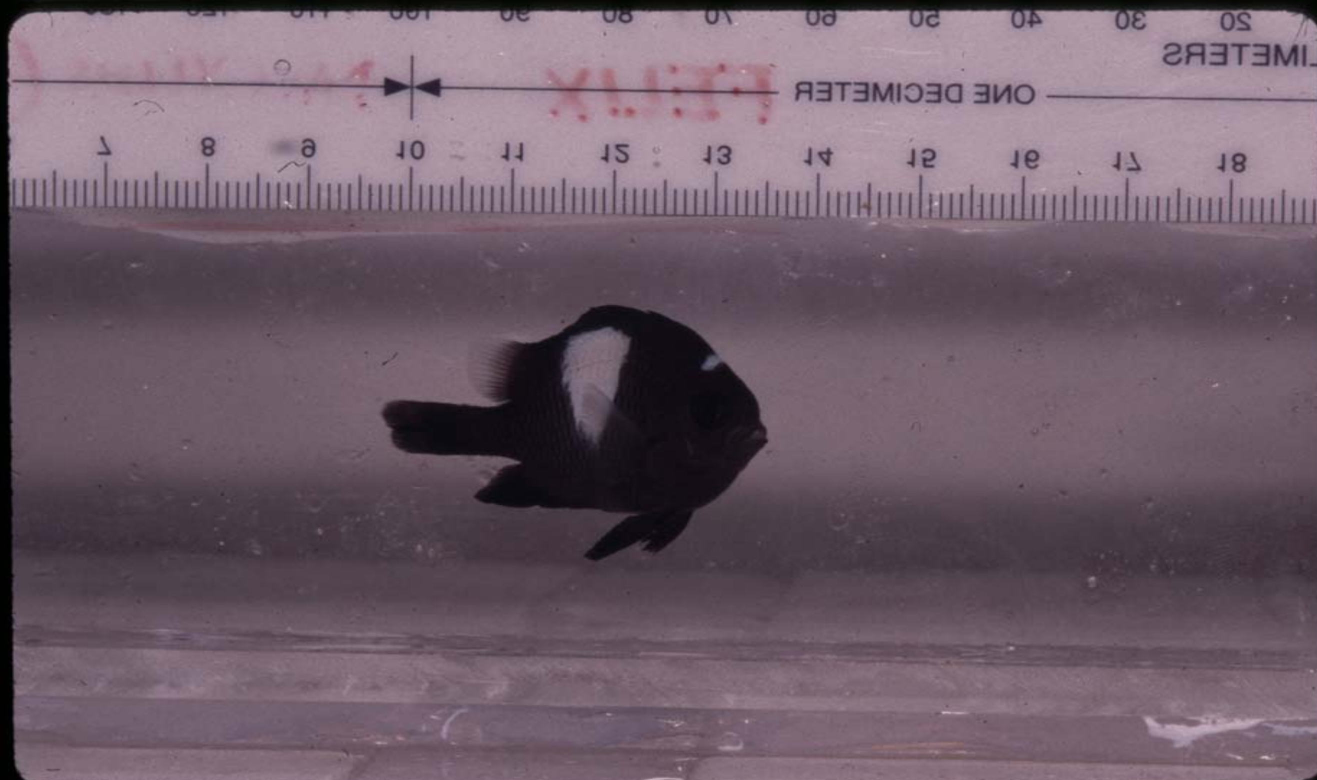
Coral Reef Fishes

- Transition b/n phases
  - Choose where to settle
- Site-attached social groups
  - Limited Post-settlement Movement
    - Disappearance = Mortality
    - Decision has implication on lifetime fitness

Hawaiian Domino Damselfish (*Dascyllus albisella*)

- Endemic planktivore
- Juvenile only groups
- Settle at 10 - 16 mm
- Mature at ~ 65 mm

Hawaiian Domino Damselfish
(*Dascyllus albisella*)



Post Settlement Juvenile Dynamics

- Group size
  - 1 to > 10 individuals

- Growth / survival trade off

↑ Group size ↓ Growth

↑ Group size ↑ Survival

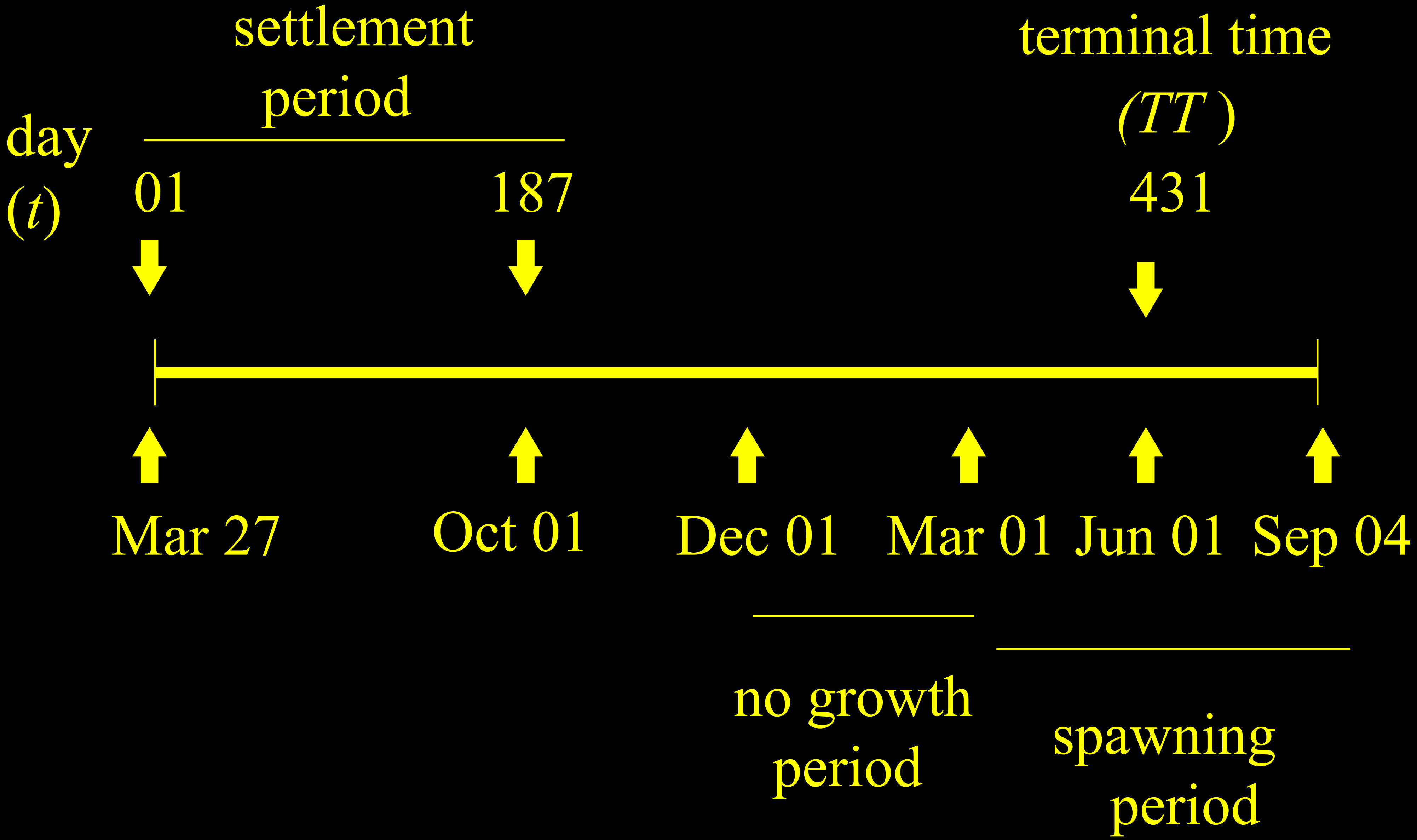
Variability in Group Size

- Habitat heterogeneity
- Multiple acceptable group sizes
  - at any given time
  - throughout the settlement period

Dynamic Programming Model

- Assumptions
  - Arrive at 10 - 16 mm / mature at 70 mm
  - Energy reserve to search up to 6 days
  - Encounter only one group each day
  - No movement after settling

Timeline


settlement period
day (t)
01
187
terminal time (TT)
431
Mar 27
Oct 01
Dec 01
Mar 01
Jun 01
Sep 04
no growth period
spawning period

Arrive at reef on day *t*

encounter group size *i*

settle

search

grow
survive
reproduce

Expected fitness

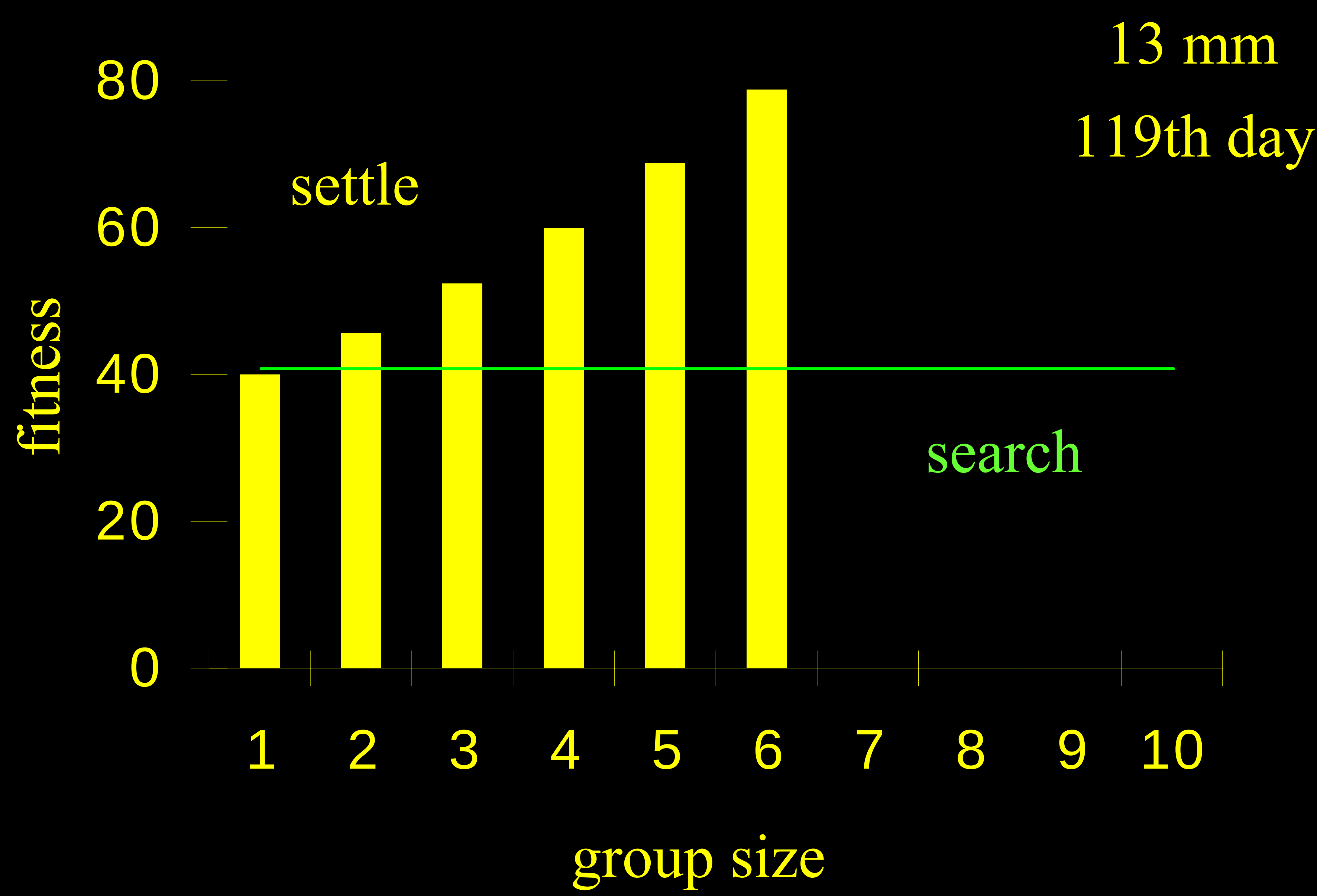
- Settle in group size *i* on day *t*
  - Pr (surv from *t* to *TT* | GS = *i*) * E{# eggs | GS = *i*}
- Continuing to search on day *t*
  - Pr (surv 1 day of search) * Pr (encounter GS = *i*) * E{fitness | optimal decision at GS = *i*)

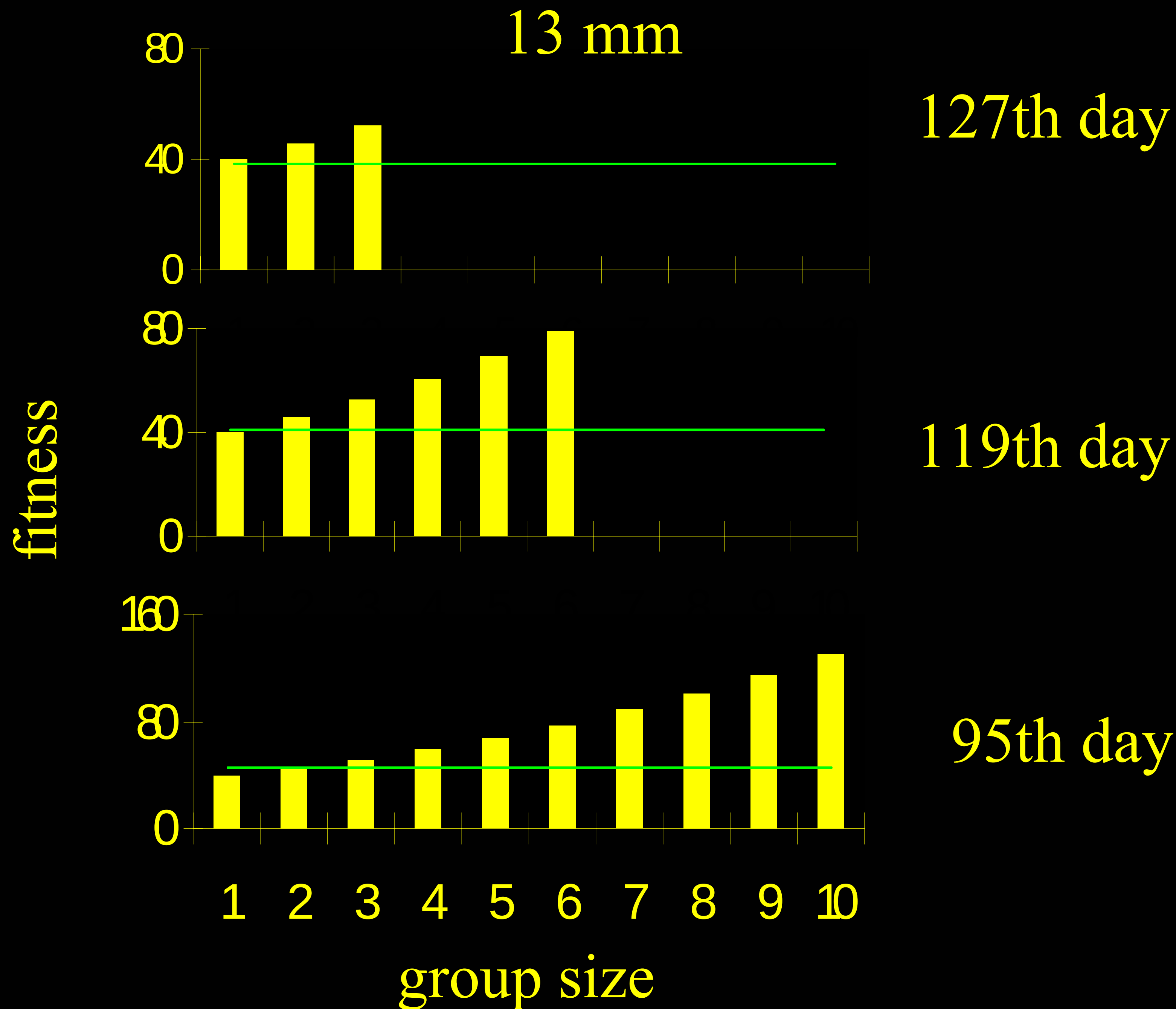
Optimal decision

- Prob. of encountering specific group sizes in the future
- Fitness value of settling in those group sizes
- Risk of not encountering an acceptable group size within 5 days

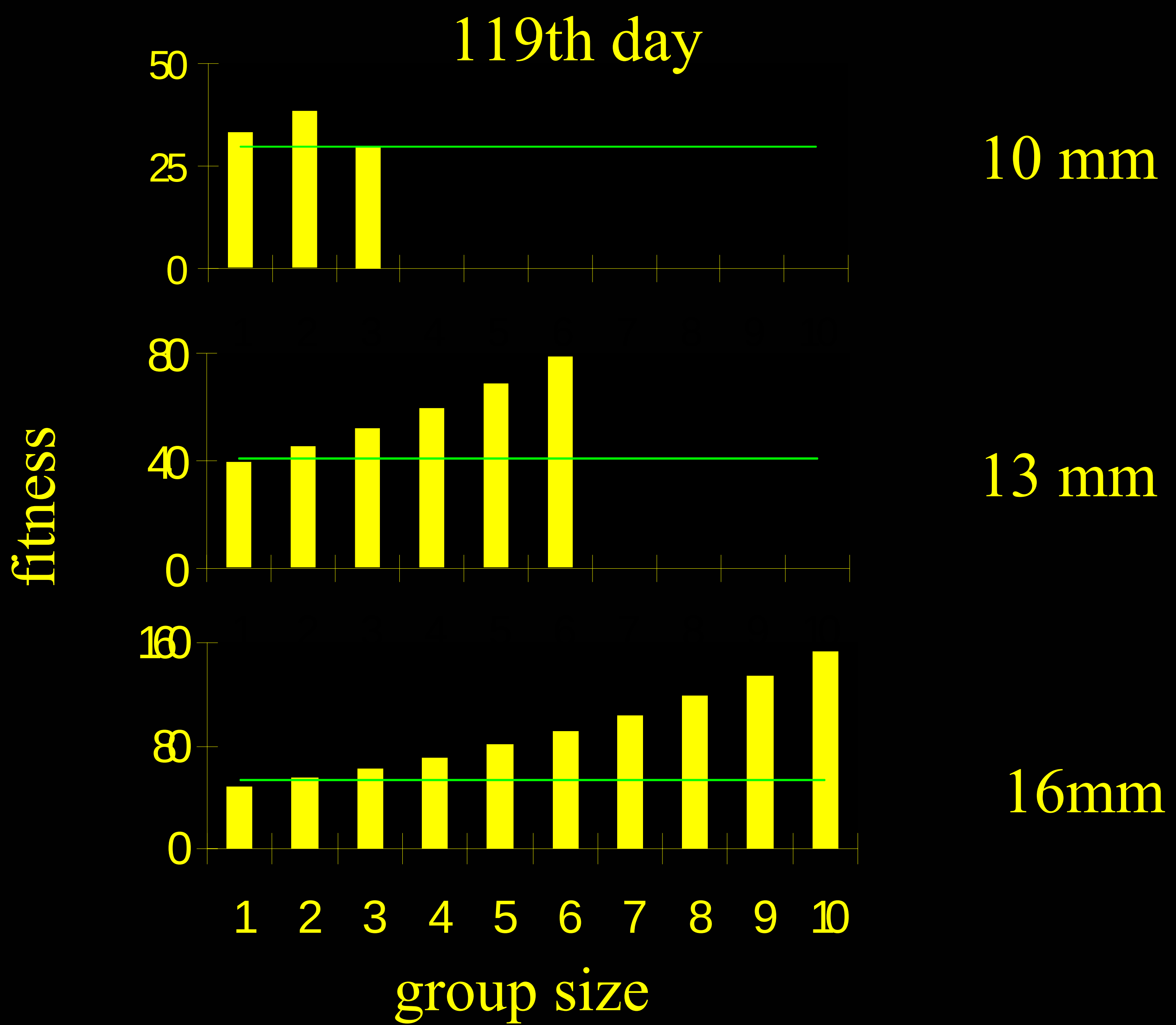
Model Parameters

• Arrival at reef	day 1 - 187
• Initial larval size	10 - 16 mm
• Condition factor	determined by number of days searching (0 - 5 days)
• Group sizes	1 - 10 fish Poisson distribution, mean = 5

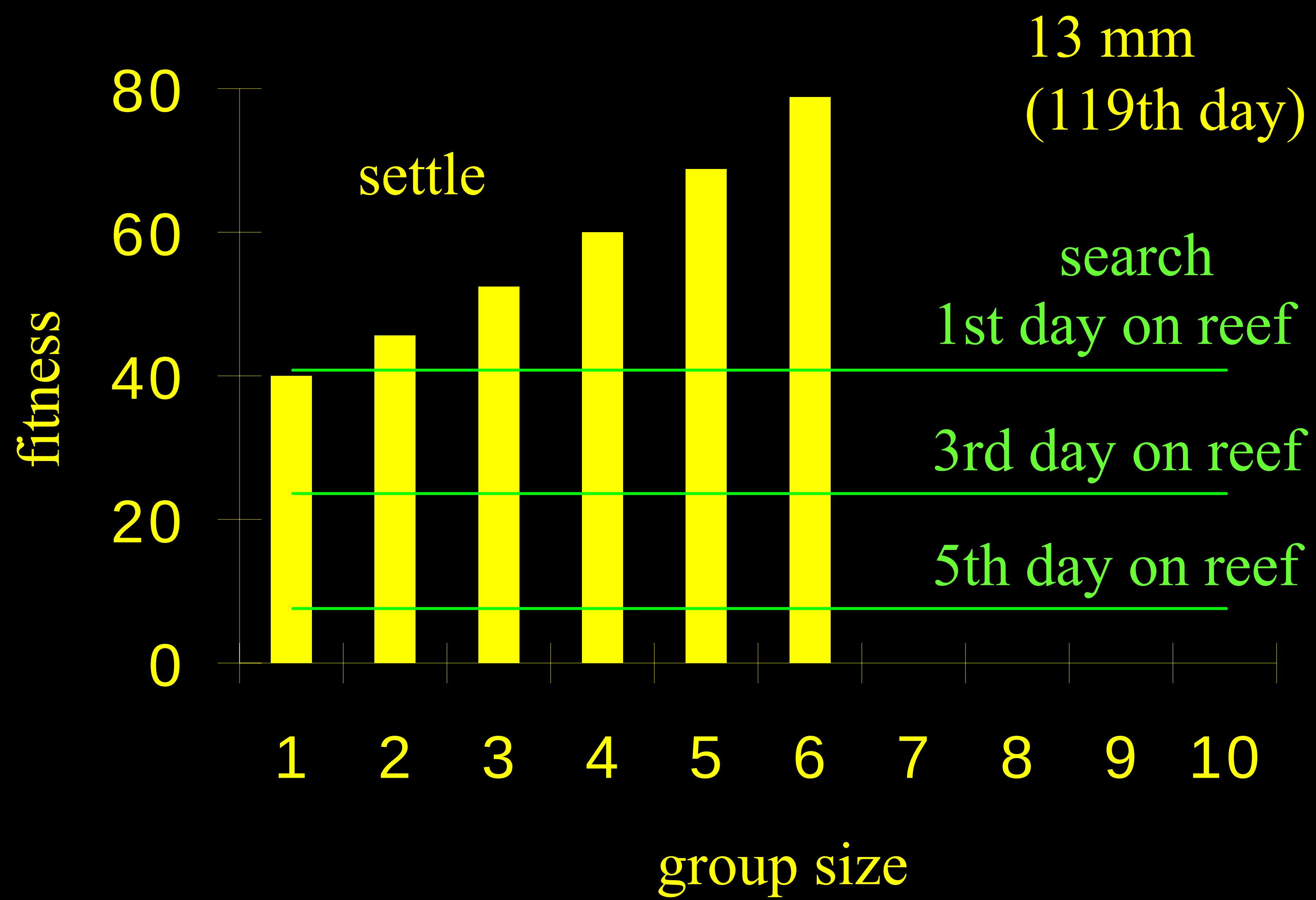

13 mm
119th day
settle
search
fitness
group size
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10

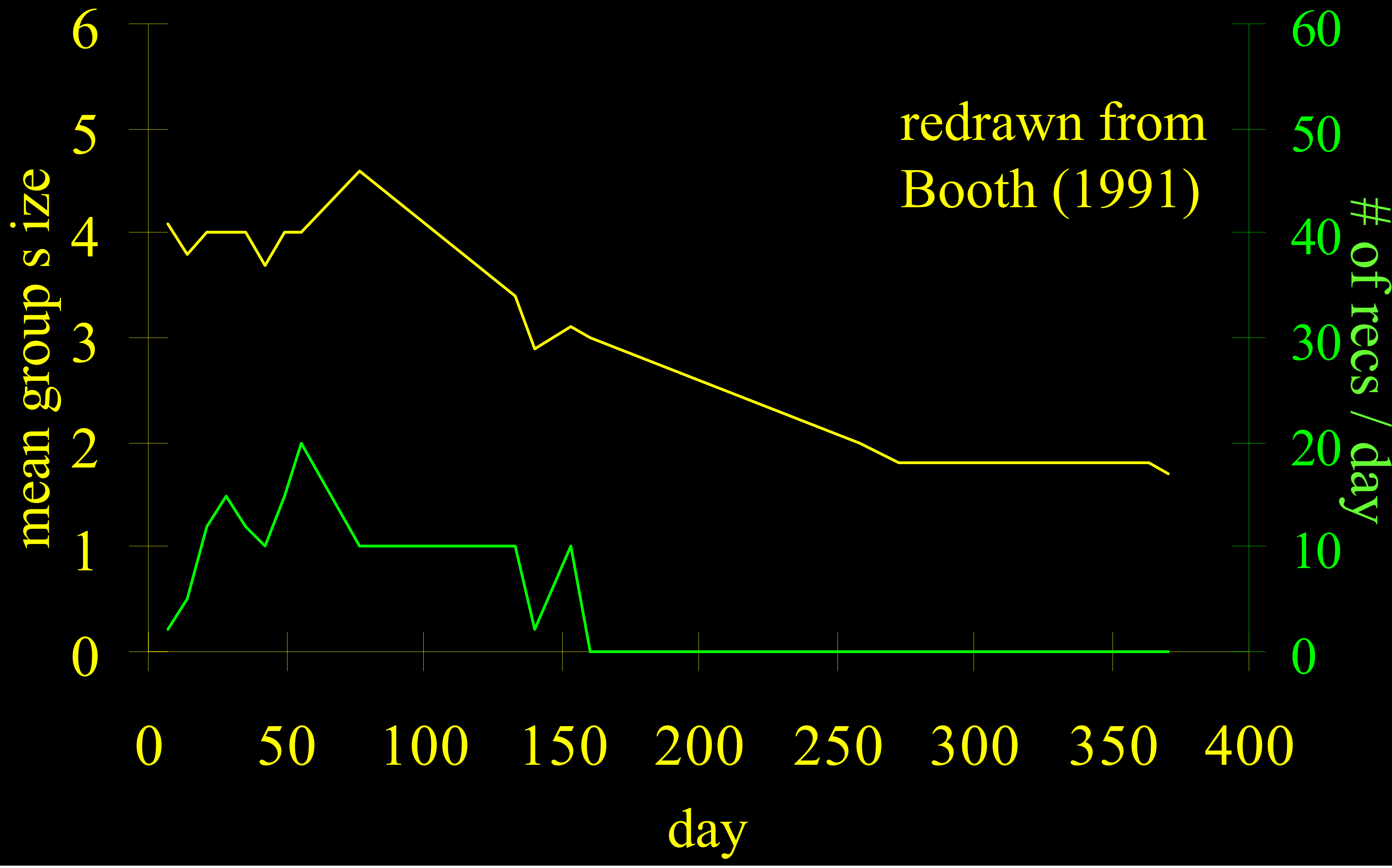


13 mm
127th day
119th day
95th day
fitness
0
40
80
160
1 2 3 4 5 6 7 8 9 10
group size



119th day
50
25
0
10 mm
80
40
0
13 mm
fitness
160
80
0
16mm
1
2
3
4
5
6
7
8
9
10
group size


13 mm
(119th day)
settle
search
1st day on reef
3rd day on reef
5th day on reef
fitness
0
20
40
60
80
1
2
3
4
5
6
7
8
9
10
group size



redrawn from
Booth (1991)
mean group size
# of recs / day
day
0
1
2
3
4
5
6
0
10
20
30
40
50
60
0
50
100
150
200
250
300
350
400

Summary

- Growth / survival trade offs influence settlement choices
- Choices are compromised by individual size and time constraints
- Model illustrates how variability in group sizes can arise from simple optimal decisions

Truth of Life # 58

- Models are only good as your data and assumptions

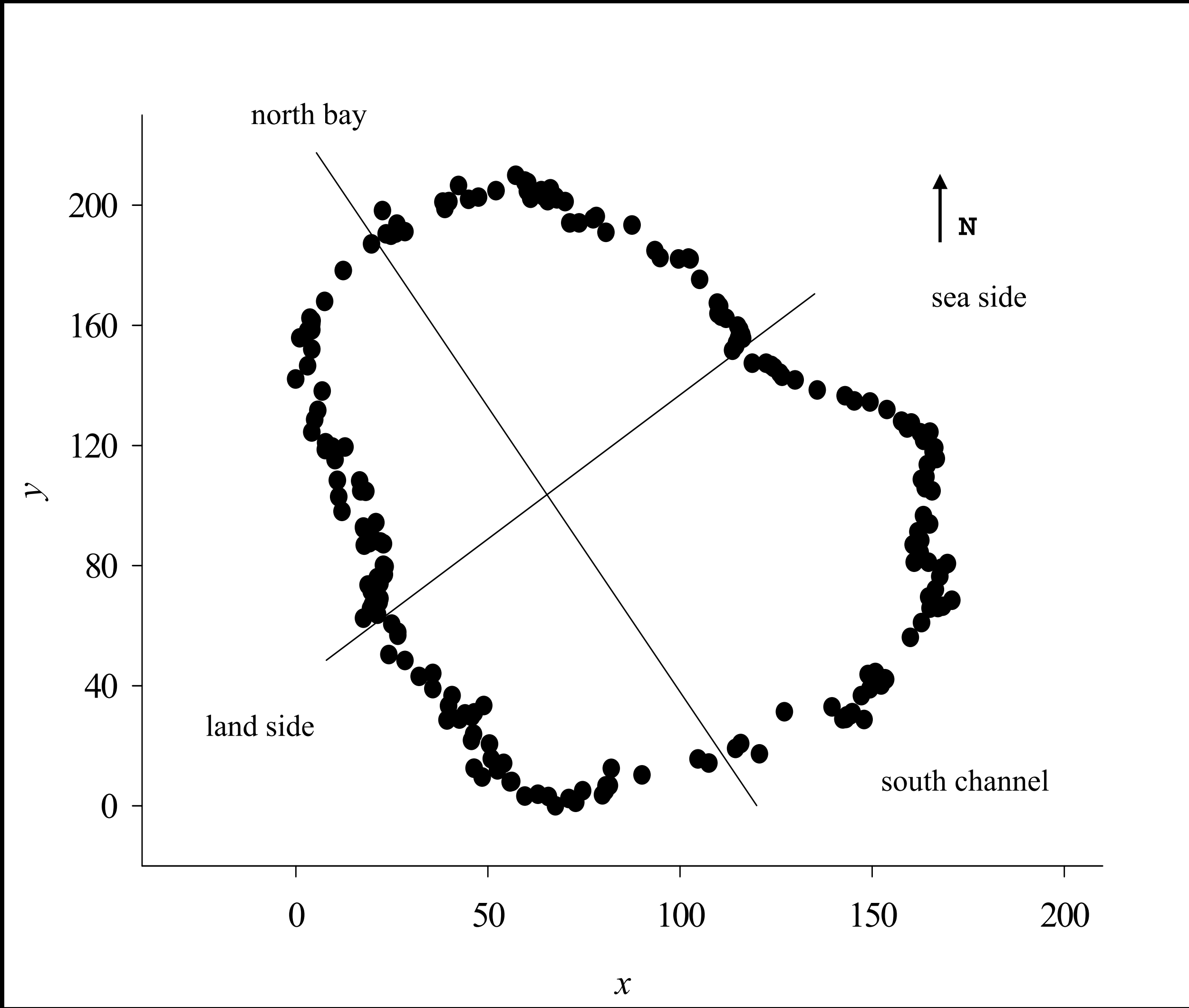
Field Test of the Model

- Natural population in Kaneohe Bay, Hawaii
- Isolated patch reef inside the bay
- Monitored all groups between 4 – 14 m depth
- 3 sampling periods during settlement season
  - late spring (May to mid-June), early summer (mid-June to July), late summer (Aug to mid-Sept)
- Response variable
  - Daily probability that a group would receive an established individual

Kaneohe Bay, Oahu, Hawaii

Dascyllus albisella

Reef # 9


north bay
sea side
land side
south channel
N
y
x
200
160
120
80
40
0
0
50
100
150
200

Potential Factors and Analysis

- Sampling period, group size, location, and depth as potential factors
- One or more of the factors were included in a set of 35 logistic regression models
- Model fit was evaluated with an Akaike Information Criteria (AIC) analysis
  - Models with AIC values ≤ 2 were considered as plausible models
  - A null model (i.e., no factors included) was also included in the model set for comparison

Model Predictions

- Early in the Season:
  - No group size preference
- Later in the Season:
  - Preference for smaller groups to increase growth

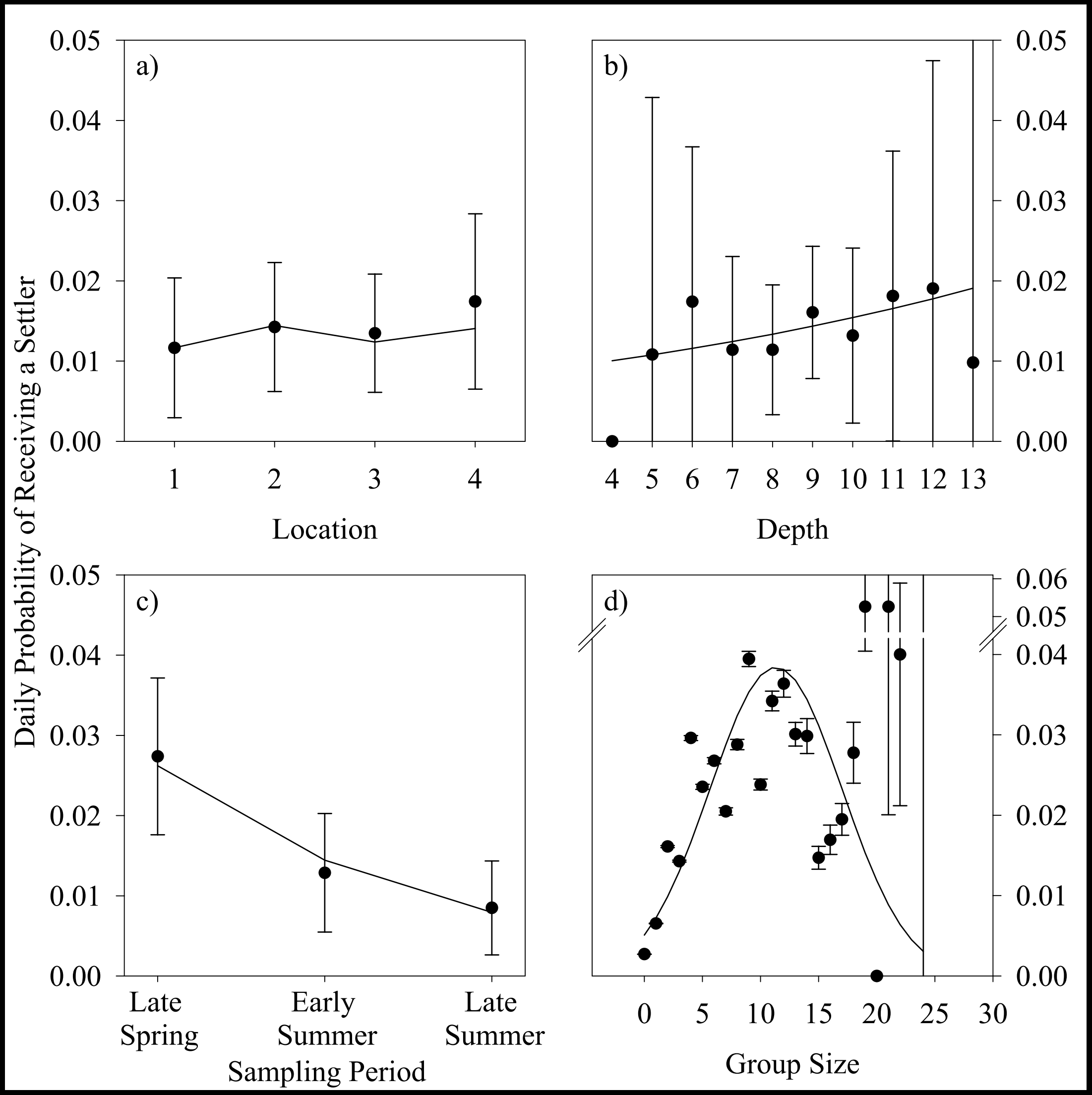
Truth of Life # 89

- Fish do not read science literature

AIC Analysis Results

				Parameter Estimates						
Model (*i*)	*ΔAIC*	w_i	Intercept	Period	Group Size	Group Size^2	Depth	Period x Group Size	Period x Depth	Group Size x Depth
16	0.0	0.64	-4.641	-0.596	0.351	-0.015	0.069	-	-	-
17	1.2	0.36	-3.432	-1.090	0.260	-0.016	0.026	0.032	0.033	0.004
34	5.4	-	-	-	-	-	-	-	-	-
			w_j =	1.00	1.00	1.00	1.00	0.36	0.36	0.36

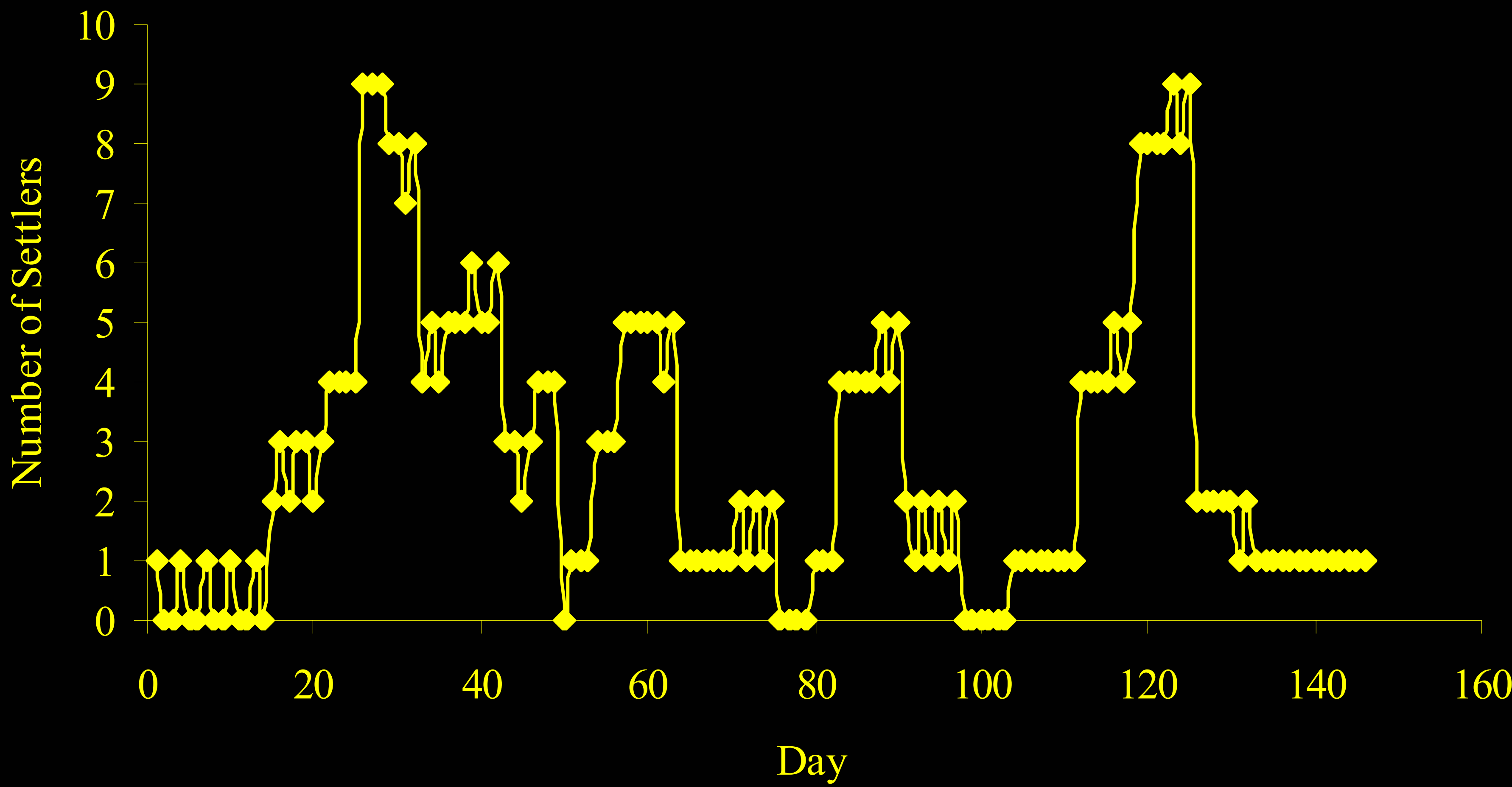
Settlement Results



Summary

- Effect of
  - Time
    - Decrease in Probability
      - Settlement arrival
  - Depth
    - Increase in Probability
  - Group Size
    - Preference for larger groups

Observed Settlement Pattern



Unexpected Observations

- Formation of New Social Groups
  - By established juveniles rather than new settlers
- No tradeoff at time of settlement
  - No immediate consequences to choice

Paradigm Shift?

- Once large enough to enter hierarchy, a juvenile then weighs cost (i.e., increased stress, reduced growth, delayed maturation) against benefit of living in that group
- If cost exceed benefits then the juvenile(s) might leave to join or form another group where competition is less
- Is post-settlement movement important in population dynamics in otherwise sedentary fishes?

Testing the New Paradigm

- Individuals assigned to four length classes: (visual estimates)
  - settlers (< 16 mm), small (16 – 35 mm), medium (36 – 55 mm), large (> 55 mm)
- Surveyed established and new groups as they appeared throughout season

Testing the New Paradigm

- We determined how size composition of a social group affected the daily probability that:
  - An individual would disappear from its group
  - A coral head would receive an established juvenile
- We considered sampling period, group size, and number of individuals in each size class as potential factors
- Fitted logistic regression models; AIC Analysis

Post-Settlement Movement

- New social groups observed:
  - 78 % were established by previously settled juveniles
    - 58 % of those were comprised solely of small juveniles
- New groups were typically ephemeral in nature:
  - 43 % of new groups with 2 – 5 fish disappeared after first observed
  - 70 % of single individuals disappeared after first observed
  - Once a group or single individual had been observed on two consecutive surveys, their probability of dissolving dropped to $\leq$ 21 %

Post-Settlement Movement

- More small individuals moved into groups than disappeared
  - Since the reef was isolated from the nearest (~ 50 m) patch reef by open soft sediment substrate, these individuals originated from the shallow section of the reef outside our study area

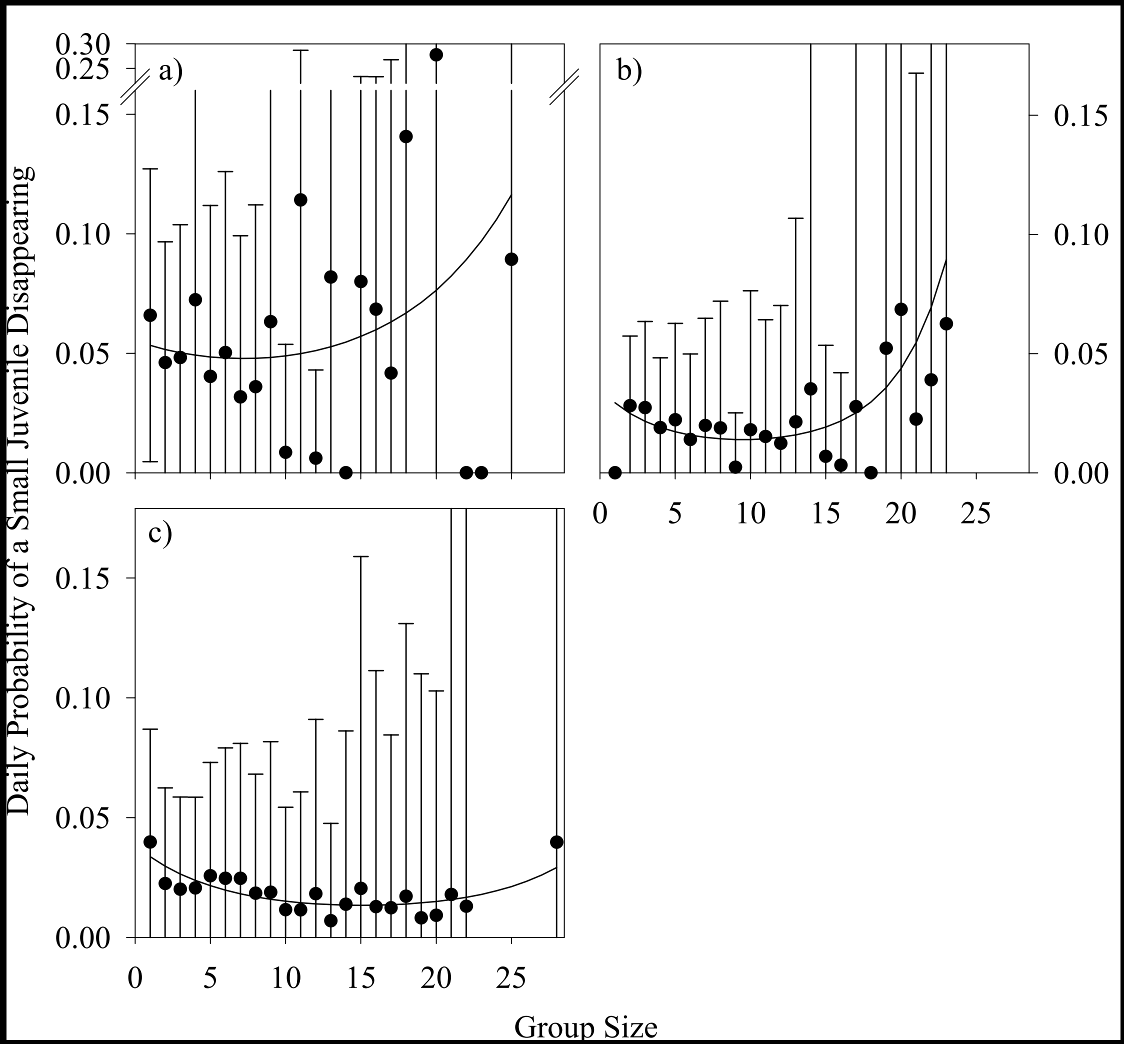
Post-Settlement Movement

- Daily probability of disappearing from a social group increased as group size increased
  - Except for large fish which was a function of the number of medium fish in the group
- Daily probability of group receiving an established individual increased as the number of individuals in the next length class increased
  - Except for large fish which was a function of the number of medium fish in the group

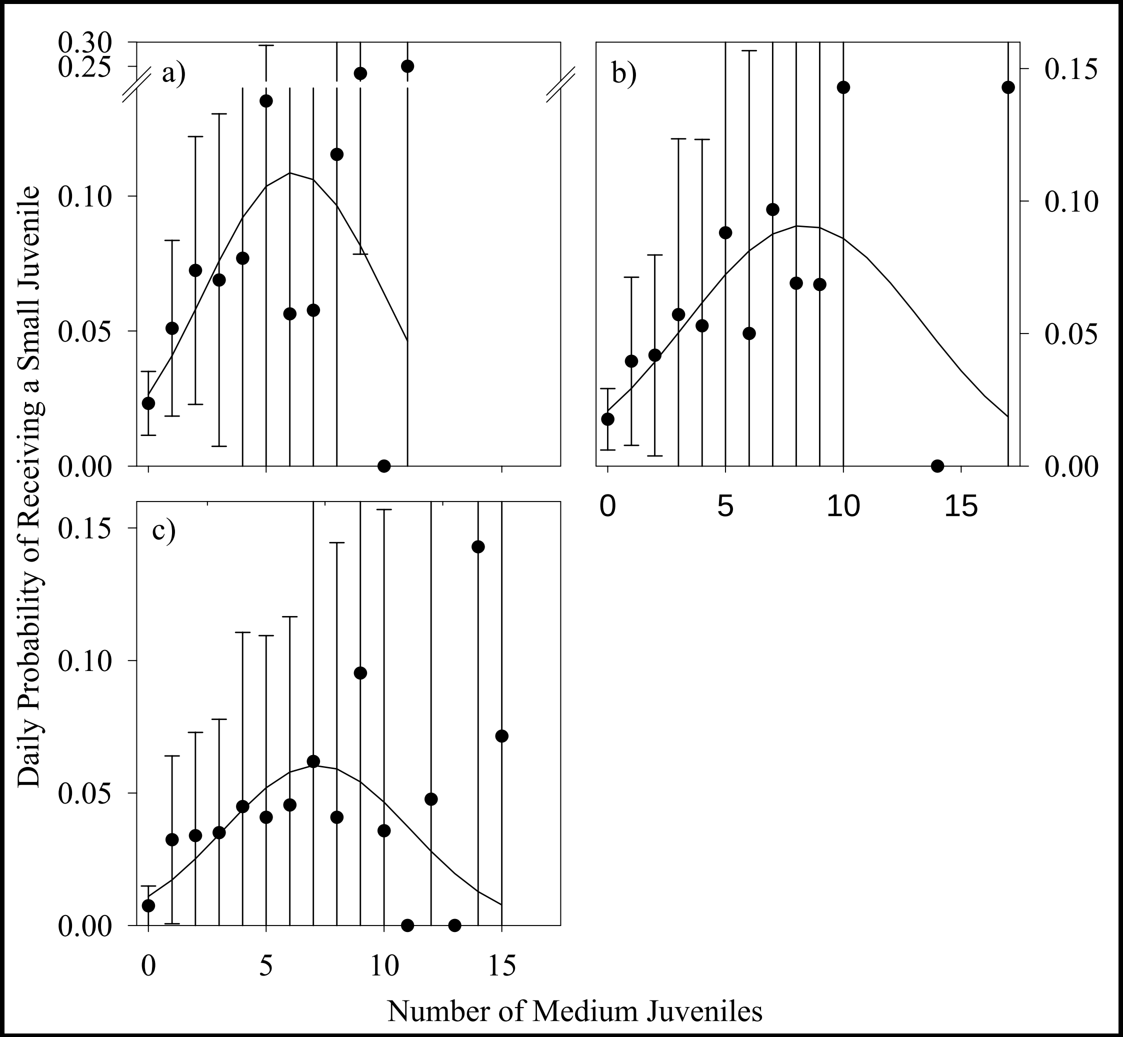
AIC Analysis

Response	Model (i)	ΔAIC	w_i	Parameter Estimates							
				Intercept	Prd	Md	Md$^{(2)}$	Prd x Md	GS	GS$^{(2)}$	Prd x GS
Small juvenile's probability of disappearing	37	0.0	1.00	-2.814	-0.216	-	-	-	-0.032	0.005	-0.033
	36	14.1	-	-	-	-	-	-	-	-	-
				w_j =	1.00	-	-	-	1.00	1.00	1.00
Social group's probability of receiving a small juvenile	18	0.0	0.38	-3.149	-0.413	0.440	-0.30	-	-	-	-
	36	0.7	0.27	-3.367	-0.321	-	-	-	0.307	-0.015	-
	19	1.4	0.19	-3.075	-0.451	0.412	-0.031	0.016	-	-	-
	37	1.9	0.15	-3.273	-0.366	-	-	-	0.282	-0.015	0.011
	33	14.7	-	-	-	-	-	-	-	-	-
				w_j =	1.00	0.57	0.57	0.19	0.19	0.42	0.15

Post-Settlement Movement



Post-Settlement Movement



New Paradigm

- Our results revealed that although individuals do disappear from their social groups, movement to new or other existing social groups is a likely outcome and not just mortality as previously assumed
- Established juveniles may monitor their condition (i.e., stress, growth) relative to their social group's composition and choose to move to another locale with less instraspecific competition

New Paradigm

- Moving to a new location is only beneficial if individuals can capitalize on better access to resources and convert them into growth. Dascyllus albisella typically do not grow during the winter months
  - In our study, the rate of movement to and from social groups was highest during late spring declining significantly by late summer

New Paradigm

- Predation can influence the rate movement between social groups
  - In reefs with few predators, individuals can readily search for new groups and redistribute themselves to balance growth, stress and survival
  - In reefs with many predators, mortality would be high, movement between groups low, and group size dynamics determined mostly by settlement

Summary

- We have demonstrated that movement in fish otherwise considered sedentary, can be an important factor and must be included in the study of their populations