Science, Service, Stewardship

Multispecies models in the AI ecosystem

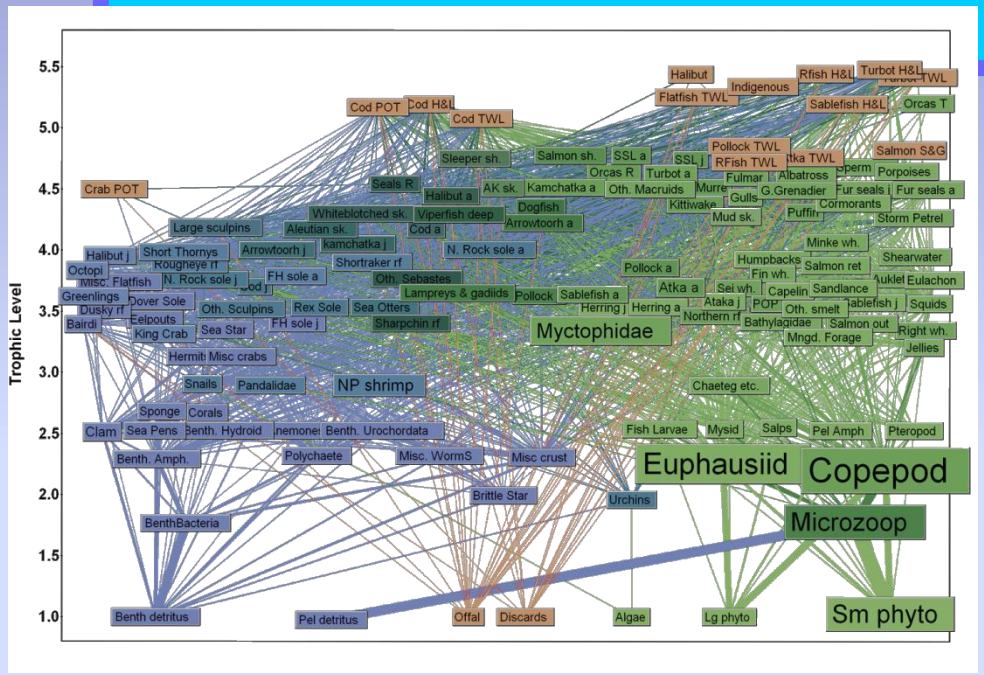
Kerim Aydin

Alaska Fisheries Science Center

Contributions from: Sarah Gaichas, Stephani Zador, Ivonne Ortiz, Pat Livingston

NOAA FISHERIES SERVICE

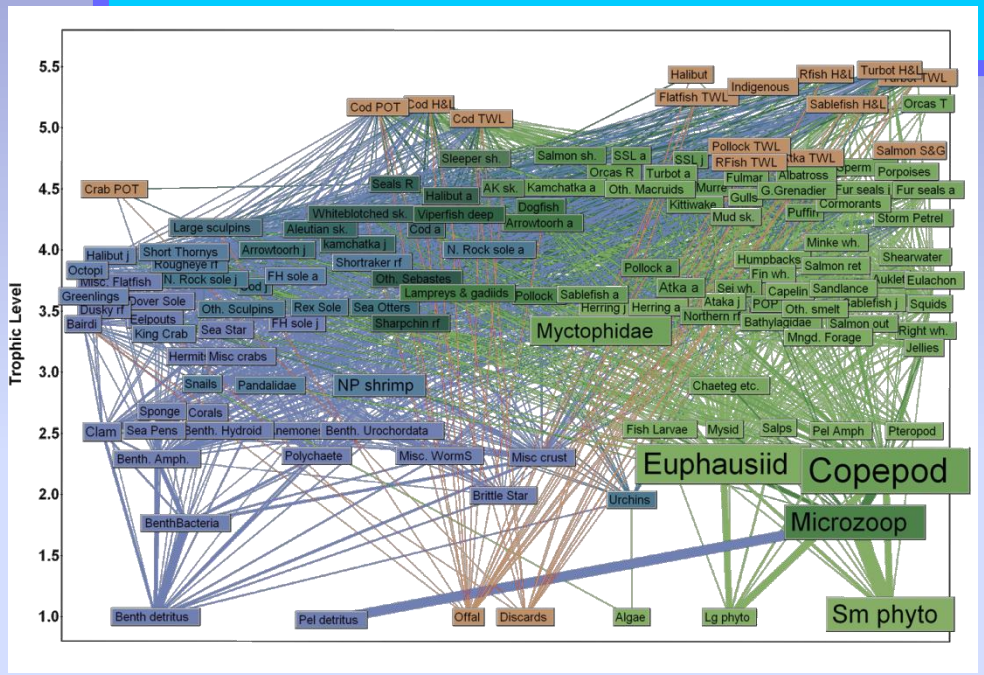
MODEL TYPES



WHOLE FOOD WEB

MINIMUM REALISTIC

Differences



- "All" species/functional groups
- Biomass dynamics model, limited size/age differentiation
- Estimation method "mass-balance"
- Includes production dynamics

- Age-structured 3-species model
- Structure similar/identical to stock assessments with addition of dynamic natural mortality

Similarities

Predator	Samples	Predator	Samples
AK Plaice	4,695	Mud Skate	68
AK Skate	2,043	Myctophidae	204
Aleutian Skate	83	N Rock Sole	6,620
Arrowtooth	**18,277**	**P. Cod**	**42,491**
Atka	2,264	**P. Halibut**	**6,619**
Bathylagidae	61	POP	1,865
Bering Skate	44	Rex sole	270
Big Skate	8	S Rock Sole	285
Black Skate	4	Sablefish	1,910
Canary Rock	1	Salmon	91
Capelin	1	Sculpin	209
Dogfish	1	Sebastes	34
Dover Sole	59	Shrp Nth Dusky	634
Eelpout	490	Shrtrk Rougheye	1,027
Eulachon	53	Shortsp Thorny	588
FH Sole	12,421	Sleeper Shark	13
Giant Grenadier	71	Bathyraja	297
Gr. Turbot	3,098	Rajidae	655
Greenlings	24	**W. Pollock**	**82,161**
Herring	380	WhtBlotch Skate	33
Kamchat fl	1,412	YF Sole	21,525
Lg Sculpin	3,107	Grand Total	**216,196**

Food habits data collected on surveys and by observers,1982-2009

- **Species interactions are based on extensive database of fish and mammal diets.**

- **Primary data source is SUMMER SURVEYS, with supplementation by observer-collections in other seasons.**

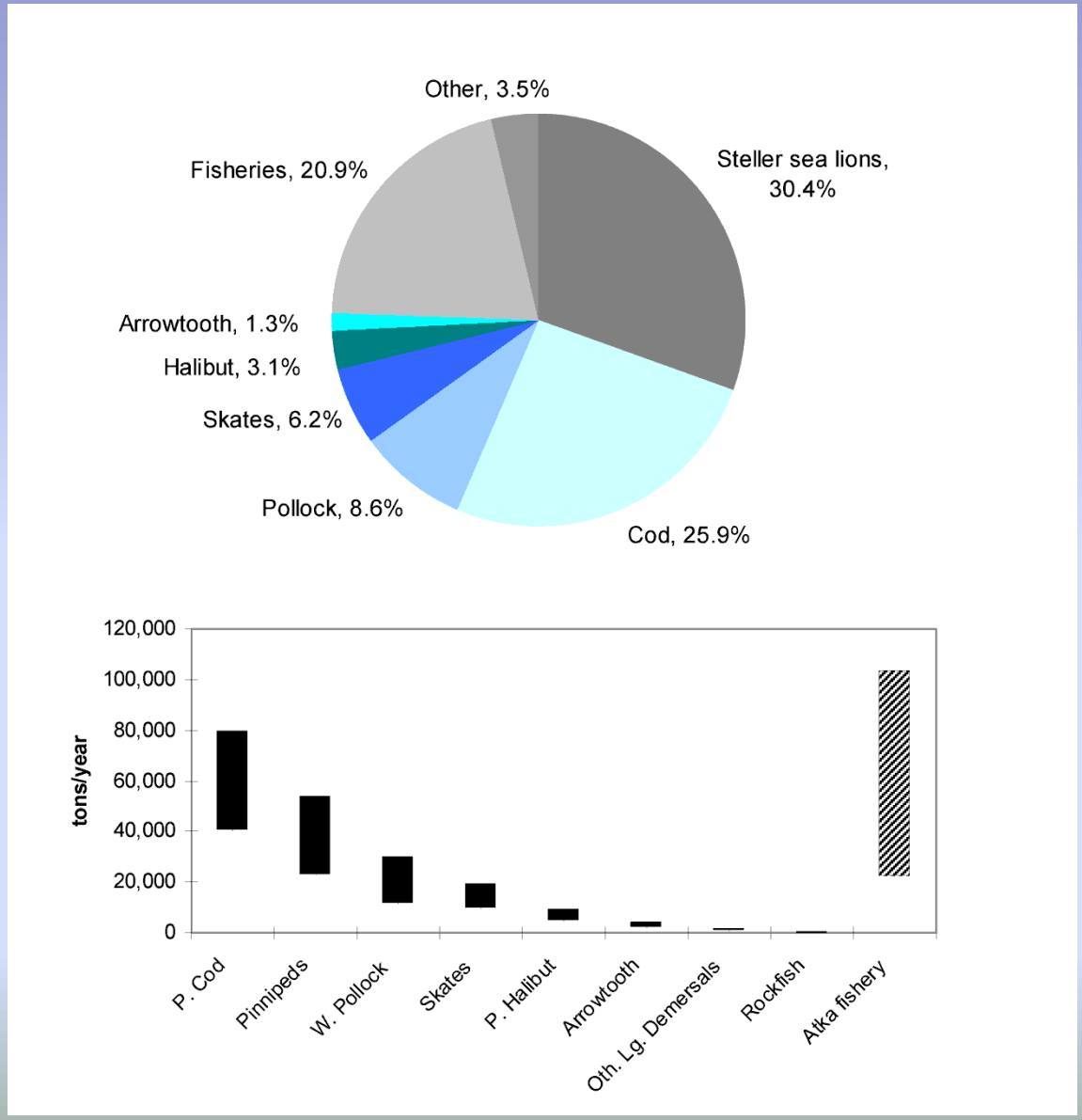
- **Models are WHOLE AI only (541-543). While diet data has been analyzed on a finer spatial scale, the current generation of models are NOT SPATIAL.**

- **Models were last updated 2008-2009, data only to 2003. Loss of staff expertise/tasking limits ability to update and make projections.**

WHOLE FOOD-WEB RESULTS

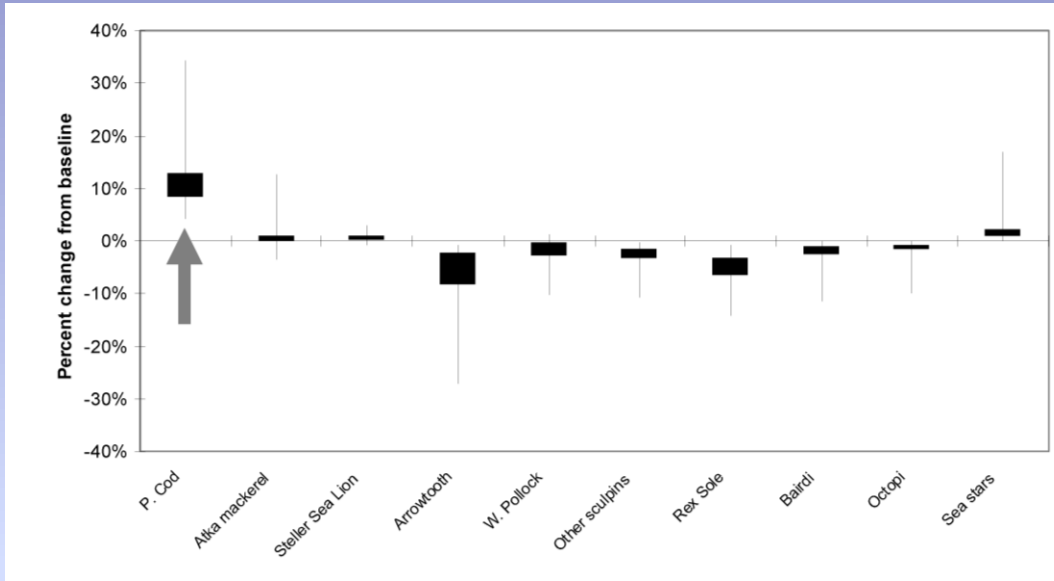
- Mortality of Atka mackerel > 20cm fork length

(Fisheries scaled to early 1990s)

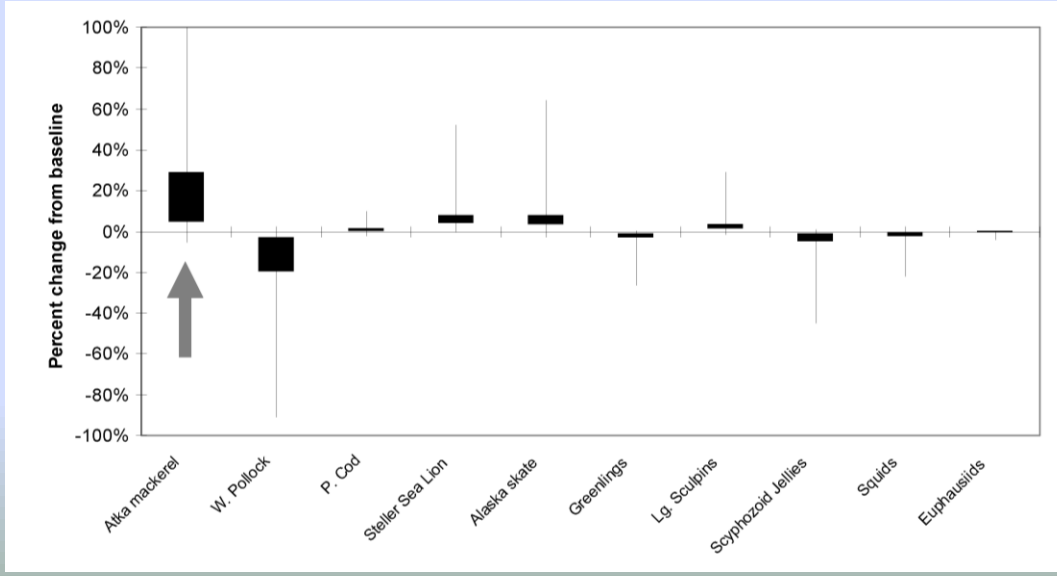


Model/food web sensitivity

- Result of increase in P. cod



- Result of increase in Atka mackerel



Consumption of juvenile Atka mackerel

- **Food web structure leads to instability in food web model**
- **Is this limited by space?**

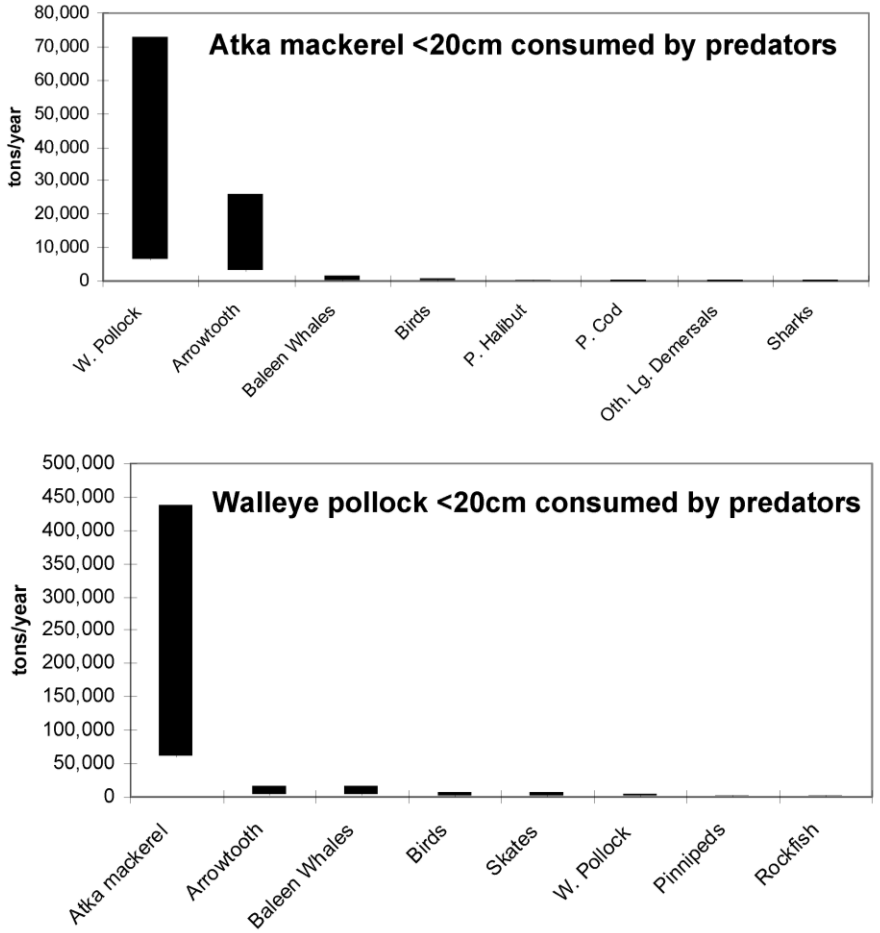
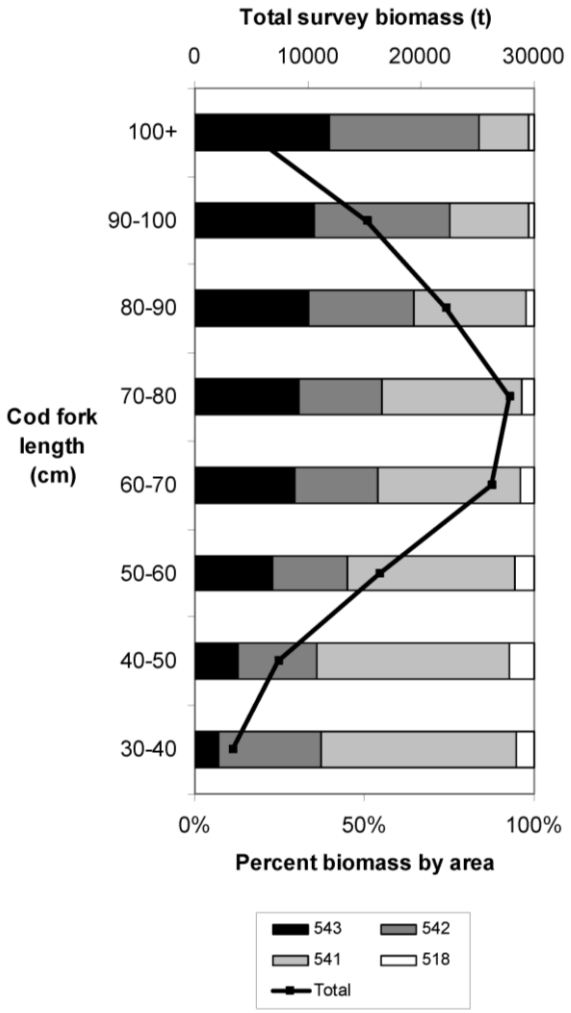


Figure 8.
Top: mean length (mm) and 99% CI of Atka mackerel eaten by predators and included in the biomass estimates at several study sites (from Ortiz and Logerwell 2010). Middle: Consumption of Atka mackerel <20cm fork length by predators in the Aleutian Islands during the early 1990s (Aydin et al. 2007). Bottom: Consumption of walleye pollock <20cm fork length by predators in the Aleutian Islands during the early 1990s (Aydin et al. 2007).

Size and space matter for P. cod diet



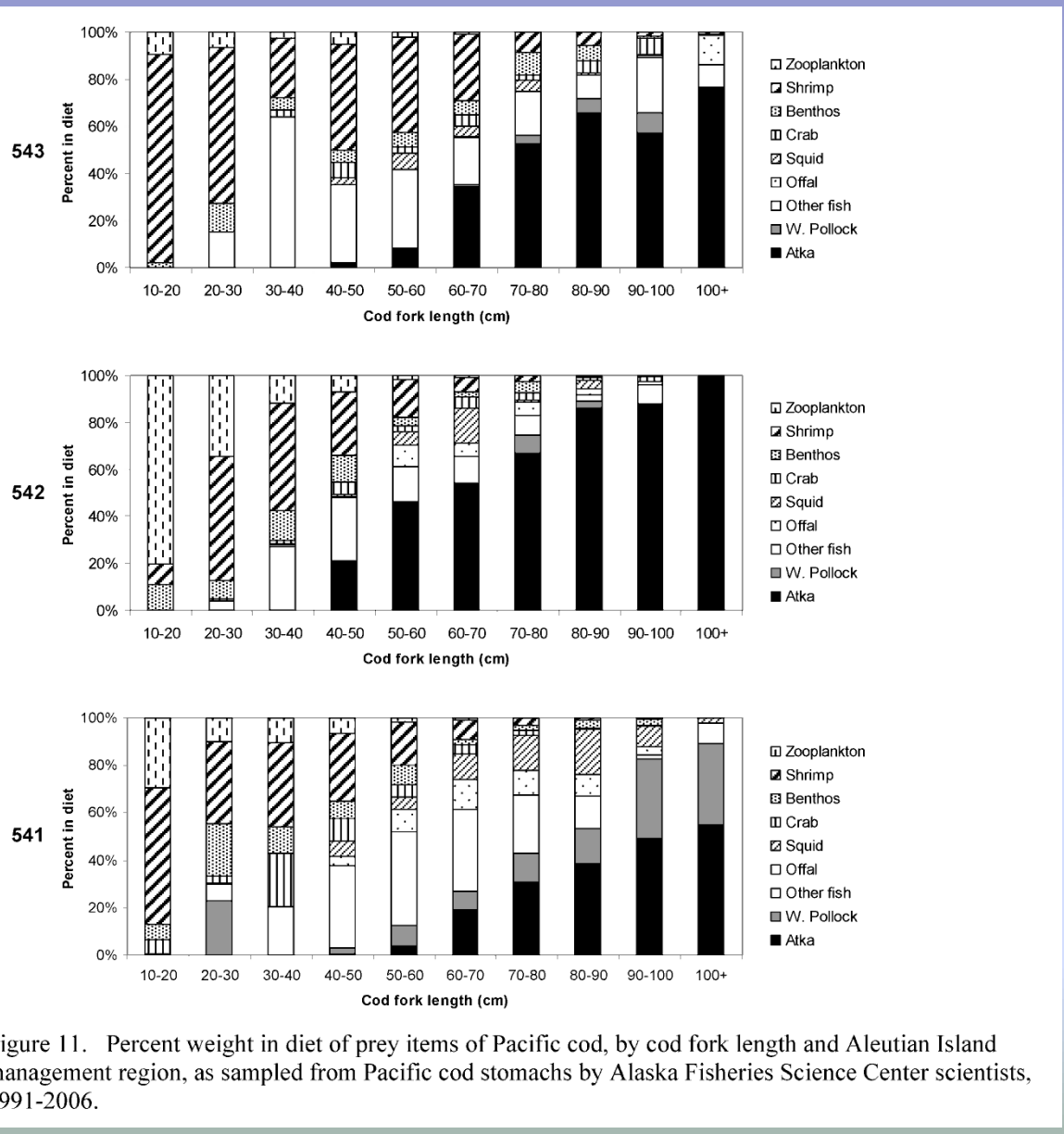


Figure 11. Percent weight in diet of prey items of Pacific cod, by cod fork length and Aleutian Island management region, as sampled from Pacific cod stomachs by Alaska Fisheries Science Center scientists, 1991-2006.

MLMAK

- Extends AMAK to model several species simultaneously.
- Uses data on diets from stomach samples of each species as predator.
- Allows alternative submodels for predation based on different forms for the predator functional response.
- Allows either single-species (no diet data or explicit predation) or multispecies configurations to be fitted using the same fisheries and survey data.
- Space **MAY** be simulated by choice of functional response.

AMAK to MLMAK

$$Z_{k,a,y} = \sum_f F^f_{k,a,y} + M_k \quad +$$

$$F^f_{k,a,y} = \begin{cases} S^f_{k,a,y}\, e^{\mu^{k,f} + \varepsilon^{k,f}_y} \\ 0 \end{cases}$$

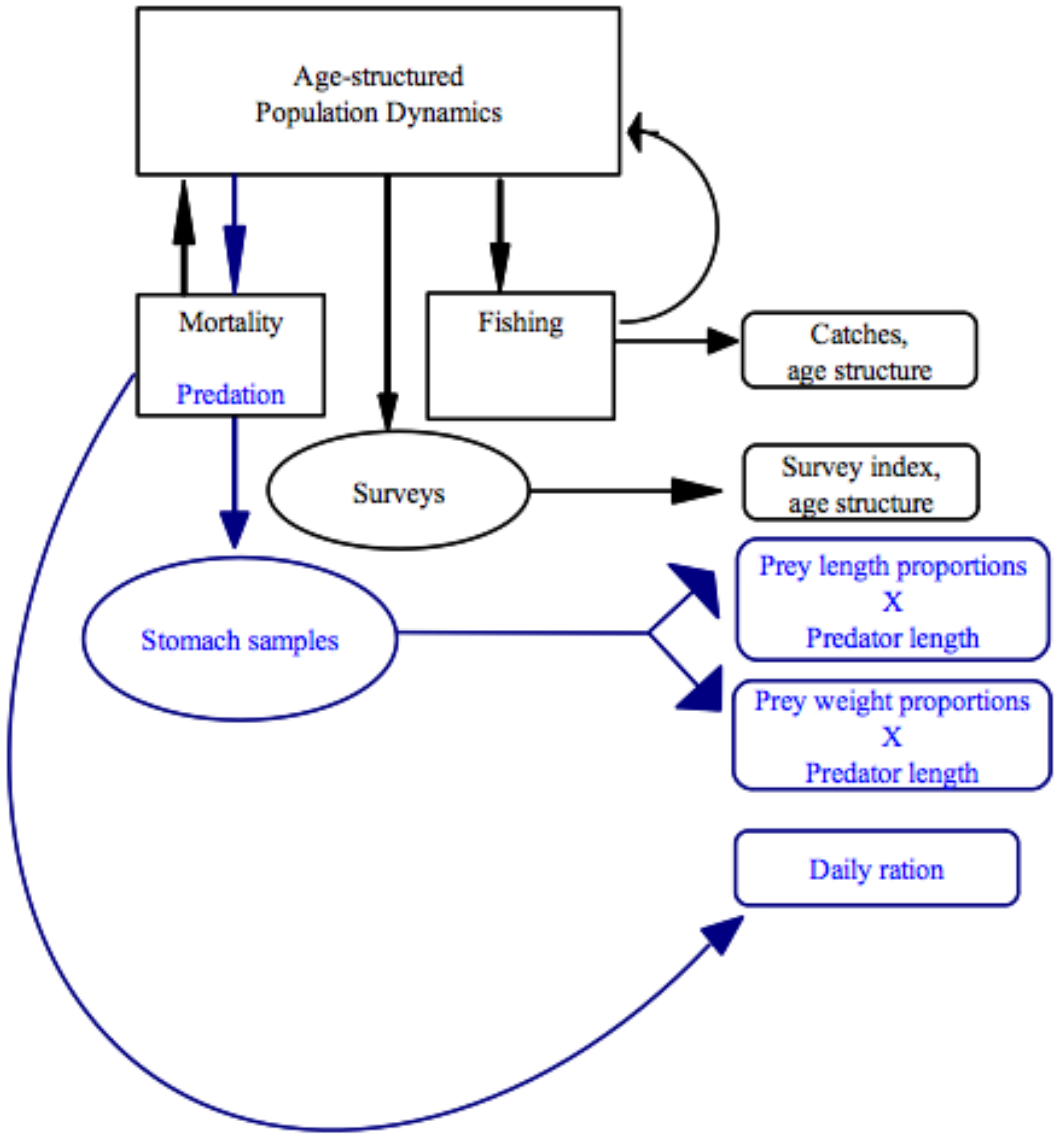
$$P_{k,a,y} = \sum_{r,u} \left(N_{r,u,y}\, \phi^{r,u}_{k,a,y}\, \gamma^{r,u}_{k,a} \right.$$

$$C_t = \frac{k \left(W_\infty\right)^{1-d} W_{t+0.5} A^{-1}}{365}$$

where

k = prey species
a = prey age
y = year
f = fishery

r = predator species
u = predator age



Data vs model fits: *survey biomass*

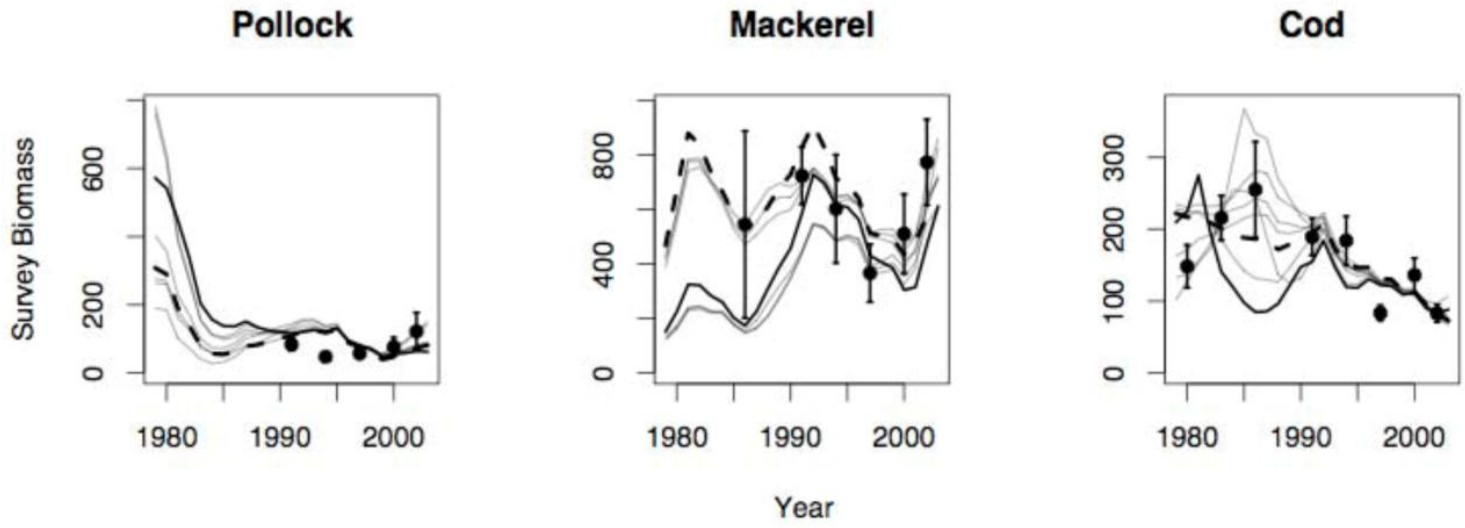


FIGURE 3. Model fits to survey biomass indices (metric tons X 1000) based on the "with predation off" (dashed lines) and on seven multispecies models (solid lines, with wider line indicating the best-fitting, preemption type of response).

Kinzey, D, AE *Punt*. 2009. Multispecies and single-species models of fish population dynamics: comparing parameter estimates. Nat. Res. Model. 22(1):67-104.

Model estimates of population state: *spawning biomass*

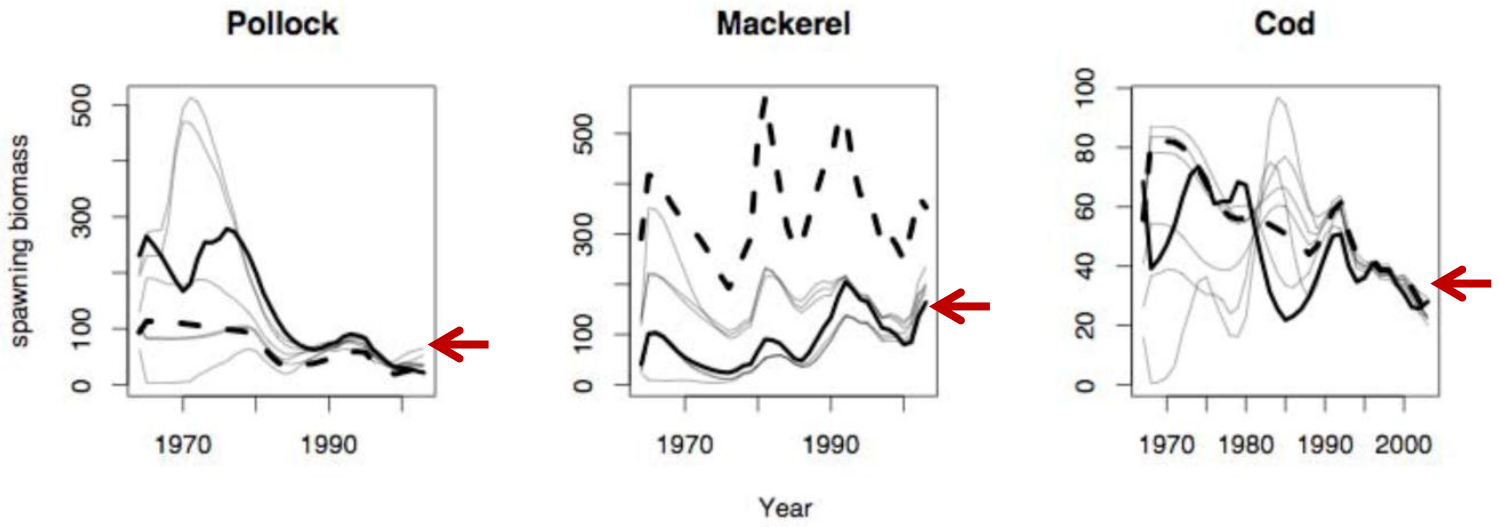


FIGURE 4. Model estimates of total spawning biomass (metric tons X 1000). The dashed line indicates a model "with predation off" while the remaining lines correspond to the seven multispecies models (the wider line indicates the best-fitting multispecies model).

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Implications of model choice

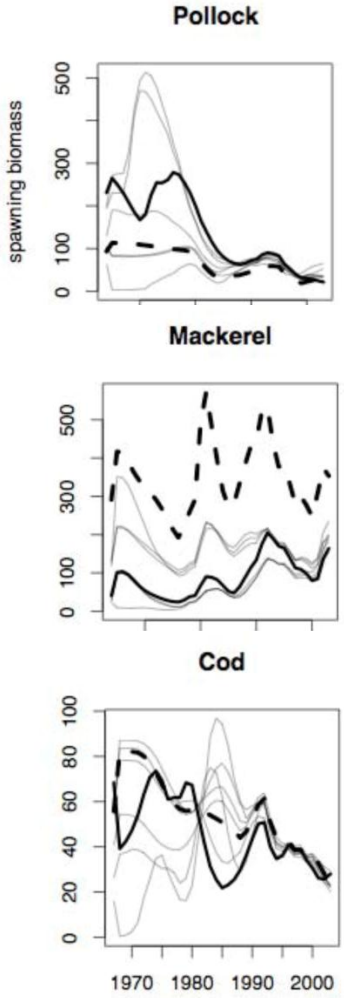

TABLE 3. AIC, objective function, and individual contributions to the objective function for the different model configurations (see Table 1 for the definitions of the alternative predator functional relationships).

	Response Type							
	Predation off	**I**	**II**	**III**	**IV**	**V**	**VI**	**VII**
# parameters	568	586	595	604	604	604	604	595
AIC	2,308	7,482	7,090	7,099	7,136	7,077	7,169	7,154
ΔAIC	*	405	13	22	59	0	92	77
Objective fn	586.1	3154.9	2950.2	2945.4	2964.2	2934.6	2980.6	2981.8
Traditional data sources								
Catch biomass	4.7	8.1	2.8	11.3	3.0	2.6	4.1	4.1
Fishery age-composition	245.8	299.0	271.9	300.3	262.7	316.6	263.9	312.4
Fishery length-composition	107.8	121.7	109.8	126.8	108.0	110.7	110.8	120.0
Survey index	46.4	62.8	47.1	62.8	45.4	55.5	53.4	51.3
Survey age-composition	114.1	167.0	134.2	168.9	128.2	149.7	130.8	138.9
Survey length-composition	20.9	32.8	41.3	37.6	39.4	44.8	41.8	33.7
Total	539.7	691.4	607.1	707.7	586.7	679.9	604.8	660.4
Diet data								
Daily ration	N/A	74.2	23.8	85.6	50.0	44.1	43.7	54.1
Diet (weights)	N/A	1365.3	1318.6	1215.3	1334.0	1221.0	1311.8	1252.2
Diet (lengths)	N/A	936.9	923.3	798.2	923.5	907.4	933.0	906.9
Total	N/A	2376.4	2265.7	2099.1	2307.5	2172.5	2288.5	2213.2
Penalties	46.4	87.0	77.3	138.6	70.4	82.2	87.3	108.1

* The results for predation off are not comparable to those for Types I- VII because the single-species model does not use the diet data

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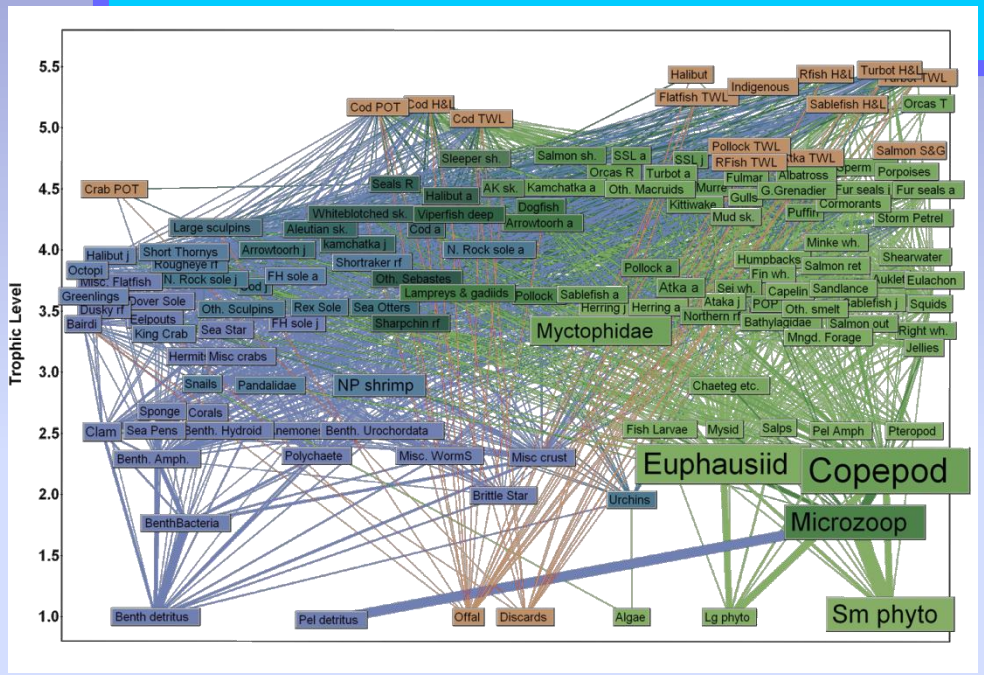
Using these tools



- **MODELS have produced reported and published results, used in BiOp analyses.**

- **UPDATING THESE MODELS and to represent "best available" science, and in particular, to project the results of closures requires:**
  - **6+ months of staff time (currently not available).**
  - **SSC or similar body model review process.**

- **Projective SPATIAL MODELS would require a substantial new effort.**