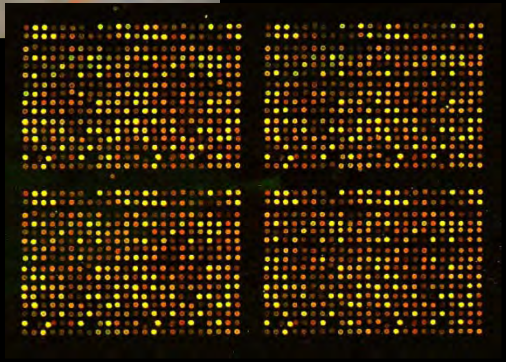
Genome Expression Response of Resident Killifish Impacted by the DWH Oil Spill



Andrew Whitehead
Fernando Galvez

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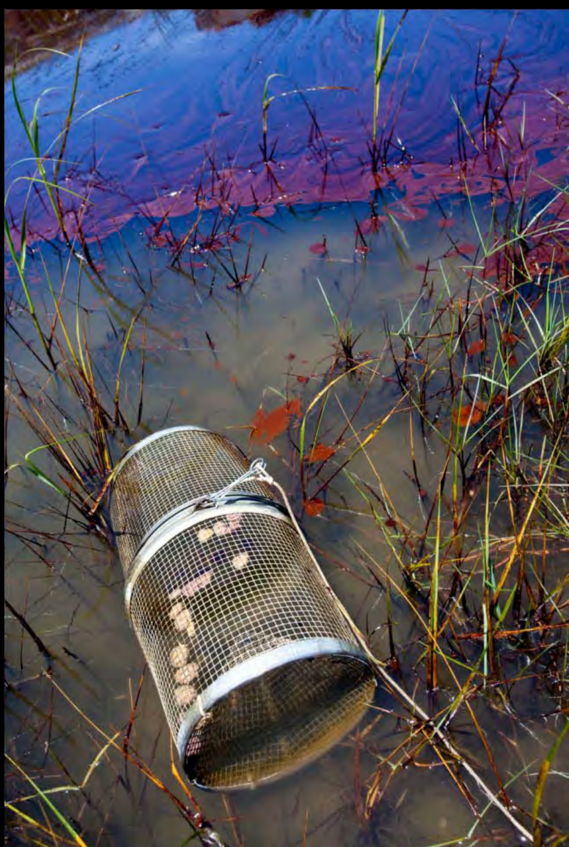
April 20, 2010

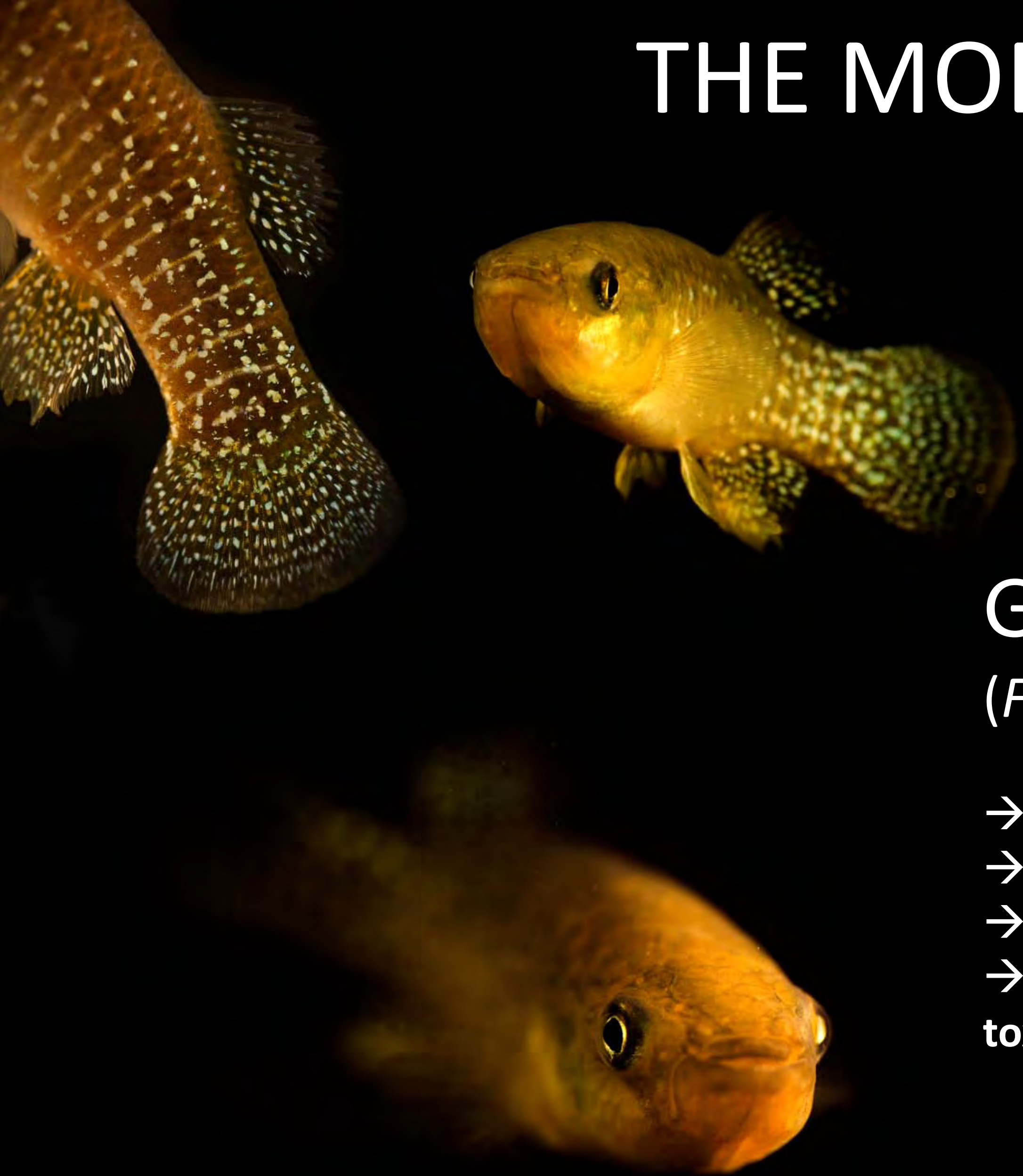




LSU

THE MODEL:



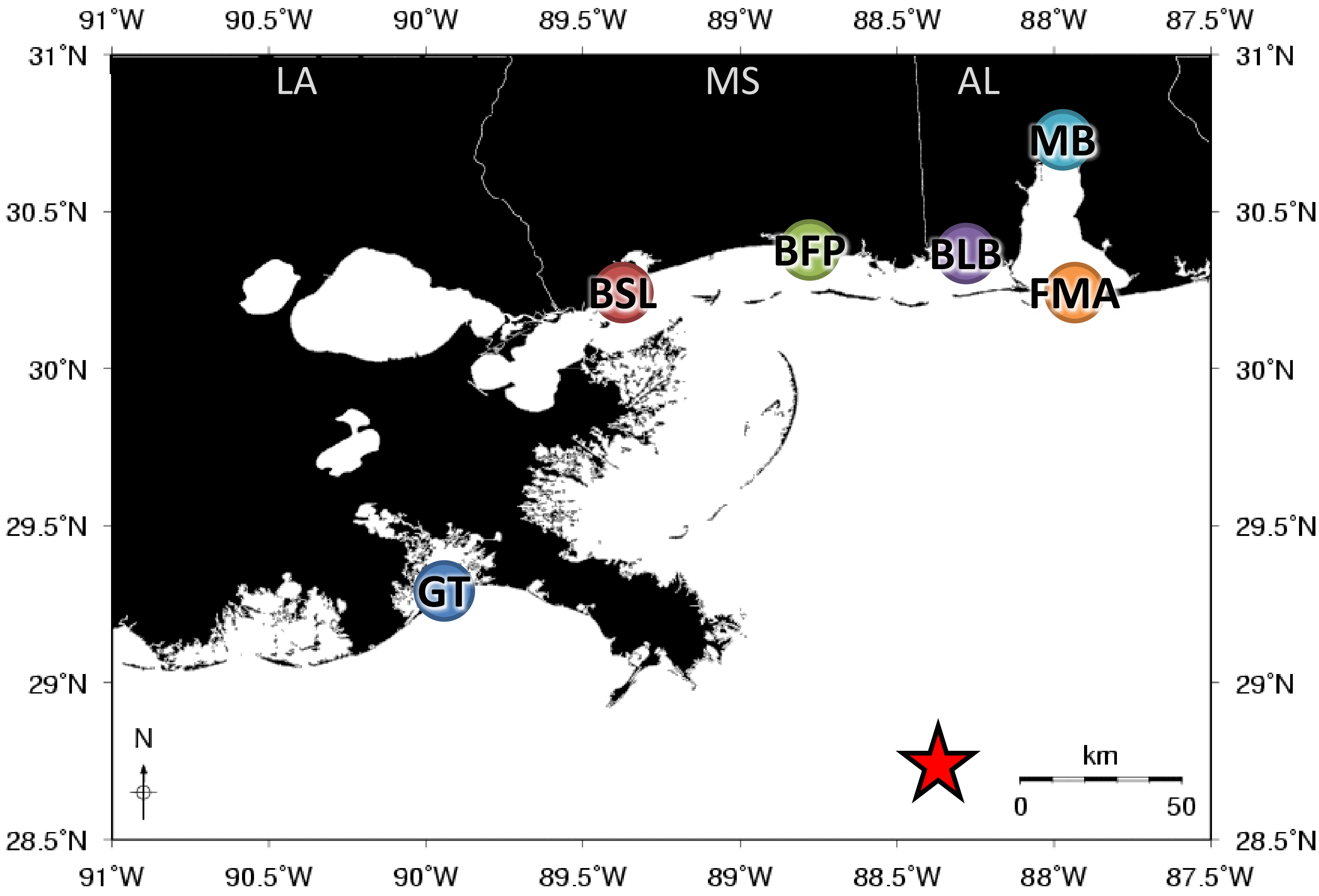
Gulf Killifish

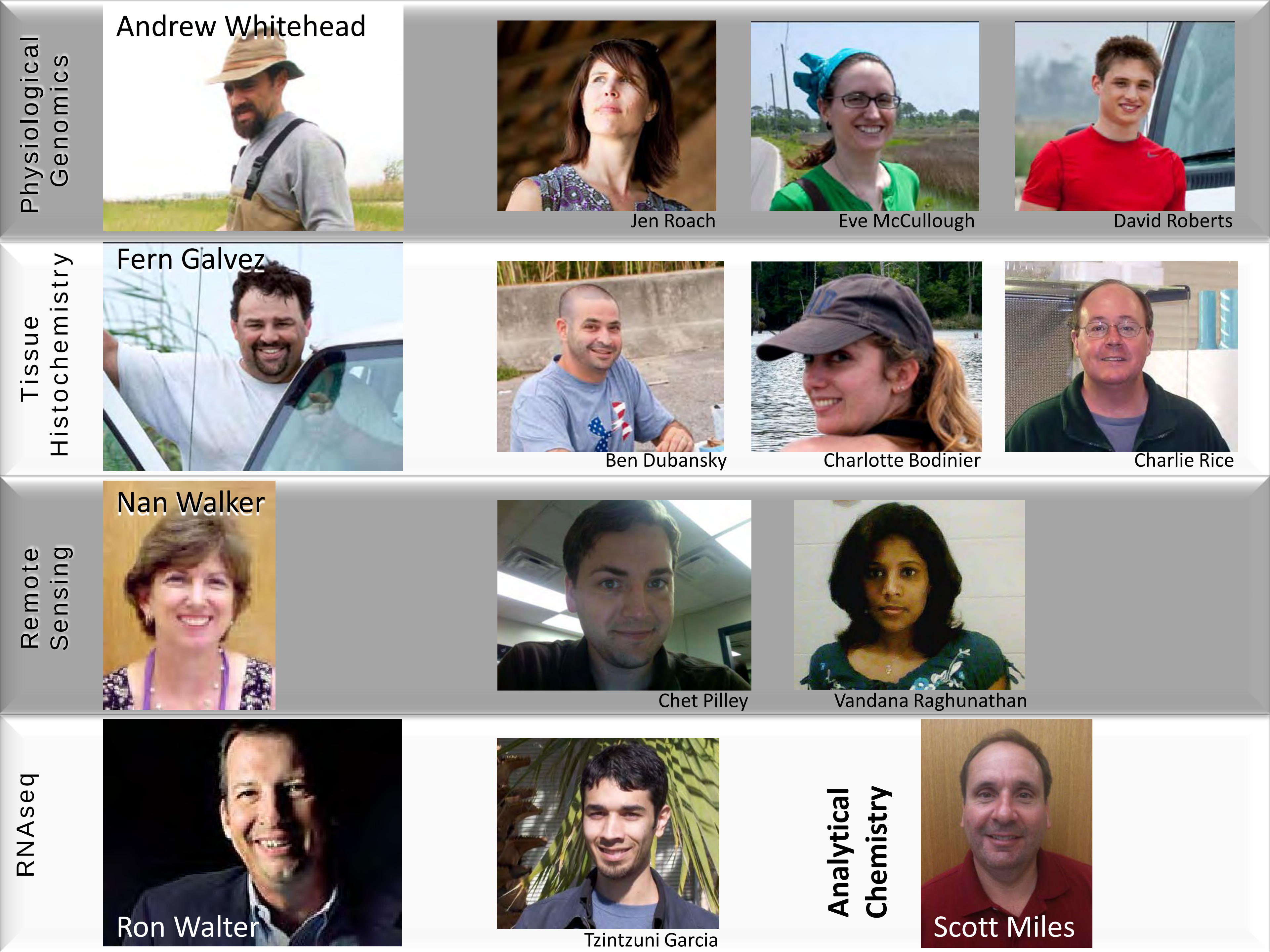
(*Fundulus grandis*)

→ **large population sizes**
→ **non-migratory**
→ **high site fidelity**
→ **relatively sensitive (among fishes) to toxicity from organic pollutants**

Photo: A. Whitehead

Deepwater Horizon oil spill – field study

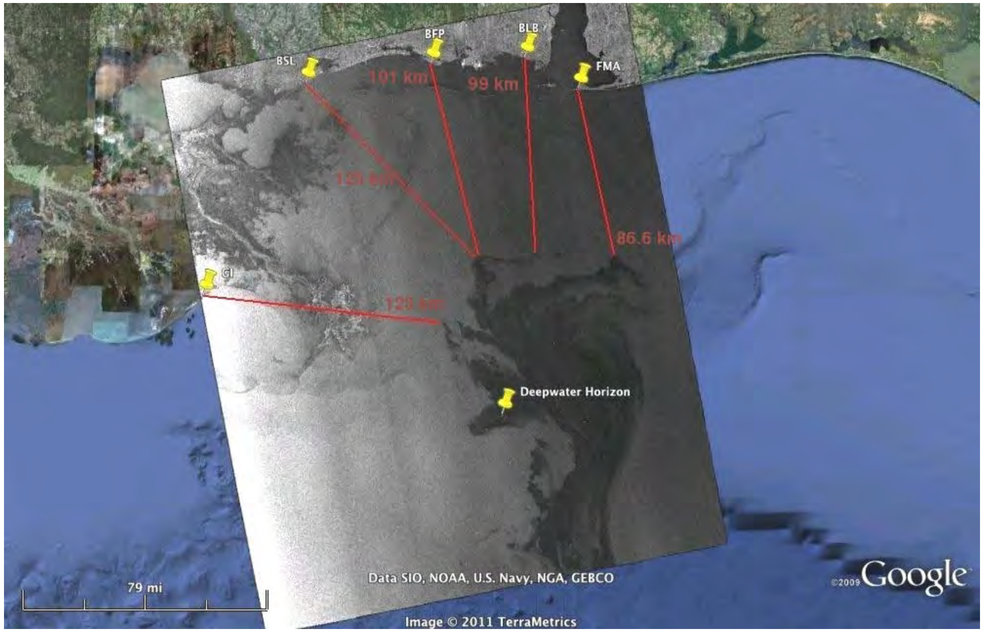


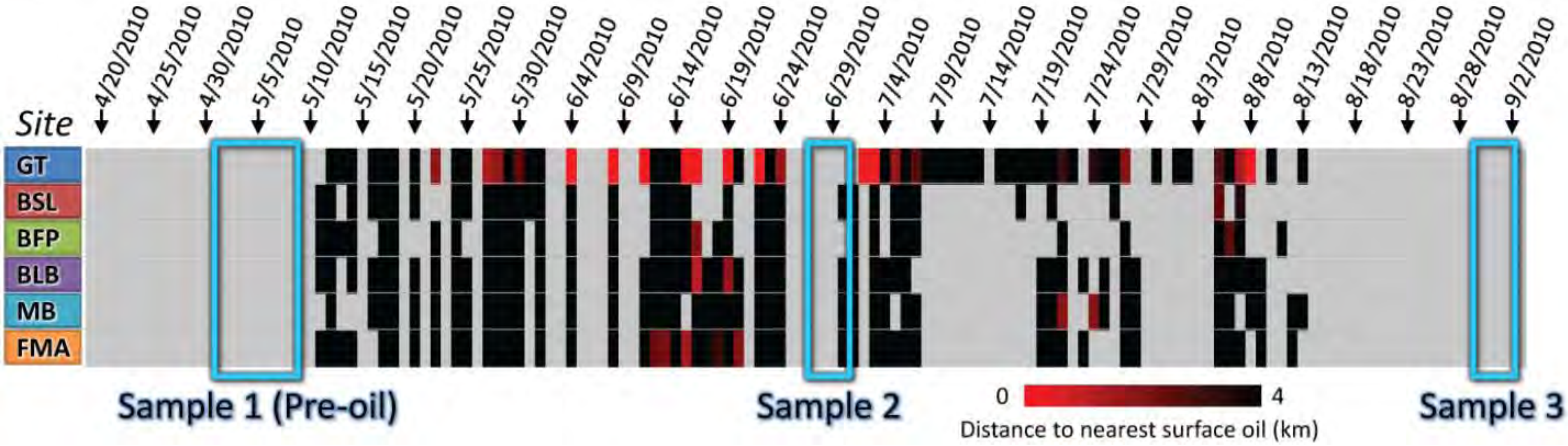


Physiological Genomics
Andrew Whitehead
Jen Roach
Eve McCullough
David Roberts
Tissue Histochemistry
Fern Galvez
Ben Dubansky
Charlotte Bodinier
Charlie Rice
Remote Sensing
Nan Walker
Chet Pilley
Vandana Raghunathan
RNAseq
Ron Walter
Tzintzuni Garcia
Analytical Chemistry
Scott Miles

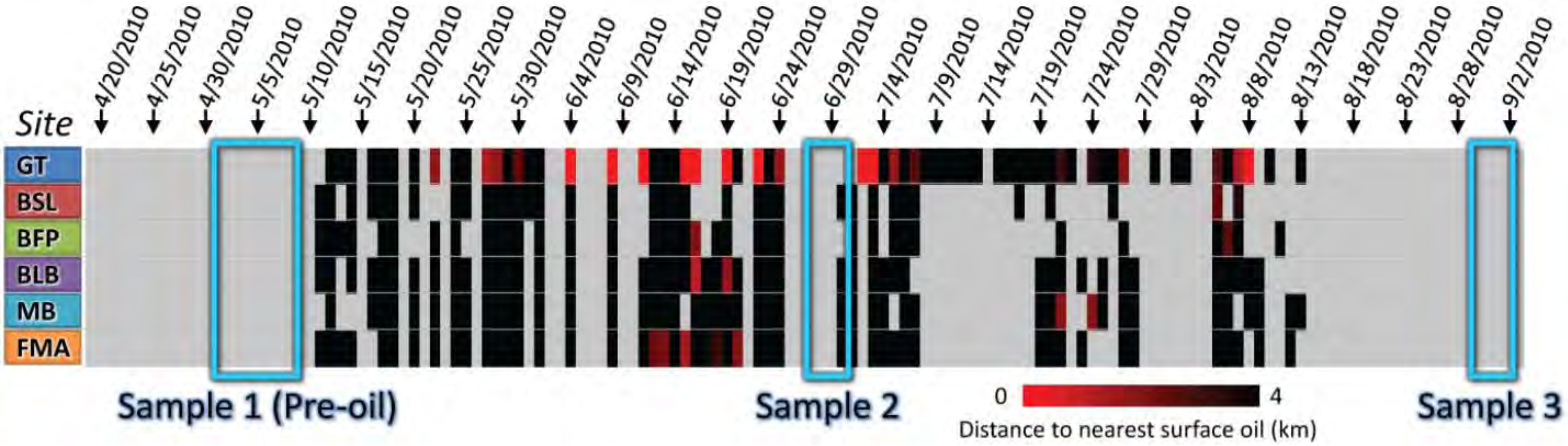
Deepwater Horizon oil spill → Exposure: SAR

Collaborator: Nan Walker





Deepwater Horizon oil spill
→ Exposure: Photo



Deepwater Horizon oil spill

→ Exposure: Analytical chemistry

Collaborator: Scott Miles

WATER

SITE	GT	GT	GT	BSL	BSL	BSL	BFP	BFP	BFP	BLB	BLB	BLB	MB	MB	FMA	FMA	FMA
DATE (2010)	5/9	6/28	8/30	5/1	6/30	8/31	5/4	6/29	8/31	5/2	6/29	9/1	5/5	6/30	5/5	6/29	9/1
Concentration (µg/L)																	
nC-10 Decane	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
nC-11 Undecane	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
nC-12 Dodecane	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
nC-13 Tridecane	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
nC-14 Tetradecane	0	0.0995	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
nC-15 Pentadecane	0	0.1305	0	0.024	0	0	0	0	0	n/m	0	0	0	0	0.046	0	0.041
nC-16 Hexadecane	0.133	0.1035	0.074	0.063	0.0525	0.0375	0.0835	0	0.0945	n/m	0.1445	0.0275	0.19	0.087	0.1045	0	0.032
nC-17 Heptadecane	0.182	0.6295	0.12	0.164	0.12	0.0715	0.235	0.181	0.1875	n/m	0.1805	0.0535	0.2285	0.1895	0.4295	0.1775	0.0705
Pristane	0.12	0.2975	0.113	0.121	0.099	0.07	0.207	0.1565	0.1775	n/m	0.1785	0.0405	0.2045	0.151	0.33	0.168	0.0455
nC-18 Octadecane	0.13	0.702	0.071	0.104	0.0755	0	0.1605	0.11	0.109	n/m	0.1065	0.025	0.1885	0.156	0.503	0.123	0.035
Phytane	0.129	0.2995	0.113	0.1245	0.104	0.075	0.2015	0.176	0.1975	n/m	0.169	0.02	0.2515	0.194	0.37	0.183	0.021
nC-19 Nonadecane	0.0975	0.3615	0	0.056	0	0	0.05	0.0525	0	n/m	0.0445	0	0.075	0.062	0.2015	0.086	0
nC-20 Eicosane	0.072	0.159	0	0	0	0	0	0	0	n/m	0	0	0	0.186	0.1455	0.0575	0
nC-21 Heneicosane	0.094	0.1825	0	0	0	0	0	0	0	n/m	0	0	0	0	0.1095	0	0
nC-22 Docosane	0.1075	0.2125	0	0	0	0	0	0	0	n/m	0	0	0	0	0.0855	0	0
nC-23 Tricosane	0.1115	0.2175	0	0	0	0	0	0	0	n/m	0	0	0	0	0.0875	0	0
nC-24 Tetracosane	0.0985	0.146	0	0	0	0	0	0	0	n/m	0	0	0	0	0.065	0	0
nC-25 Pentacosane	0	0.2265	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
nC-26 Hexacosane	0	0.1175	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
nC-27 Heptacosane																	0
nC-28 Octacosane																	0
nC-29 Nonacosane																	0
nC-30 Triacontane																	0
nC-31 Hentriacontane																	0
nC-32 Dotriacontane																	0
nC-33 Tritriacontane																	0
nC-34 Tetratriacontane																	0
nC-35 Pentatriacontane																	0
Naphthalene																	0
C1-Naphthalenes																	0
C2-Naphthalenes																	0
C3-Naphthalenes																	0
C4-Naphthalenes																	0
Fluorene																	0
C1-Fluorenes																	0
C2-Fluorenes																	0
C3- Fluorenes																	0
Dibenzothiophene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C1-Dibenzothiophenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C2-Dibenzothiophenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C3- Dibenzothiophenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Phenanthrene	0	6.015	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C1-Phenanthrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C2-Phenanthrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C3-Phenanthrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C4-Phenanthrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Anthracene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Fluoranthene	0	4.94	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Pyrene	0	4.42	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C1- Pyrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C2- Pyrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C3- Pyrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C4- Pyrenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Naphthobenzothiophene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C-1 Naphthobenzothiophenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C-2 Naphthobenzothiophenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C-3 Naphthobenzothiophenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Benzo (a) Anthracene	24.7	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Chrysene	81.5	1.06	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C1- Chrysenes	106.85	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C2- Chrysenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C3- Chrysenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
C4- Chrysenes	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Benzo (b) Fluoranthene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Benzo (k) Fluoranthene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Benzo (e) Pyrene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Benzo (a) Pyrene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Perylene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Indeno (1,2,3 - cd) Pyrene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Dibenzo (a,h) anthracene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Benzo (g,h,i) perylene	0	0	0	0	0	0	0	0	0	n/m	0	0	0	0	0	0	0
Salinity (ppm)	18.8	13.3	17.3	9.6	8.7	14.7	18.2	14.1	12.7	16.2	10.2	18.4	0.34	1.9	9.7	20.4	24.2

TISSUES

SITE	GT	GT	BSL	BSL	BFP	BFP	BLB	BLB	MB	FMA	FMA
DATE (2010)	6/28	8/30	6/30	8/31	6/29	8/31	6/29	9/1	6/30	6/29	9/1
nC-10 Decane	0	0	0	0	0.024	0	0	0	0	0	0
nC-11 Undecane	0	0	0	0	0	0	0	0	0	0	0
nC-12 Dodecane	0	0	0	0	0	0	0	0	0	0	0
nC-13 Tridecane	0	0	0	0	0	0	0.08	0	0.011	0.08	0
nC-14 Tetradecane	0	0	0	0	0	0	0	0	0	0	0
nC-15 Pentadecane	0.04	0.108	0.066	0.031	0.024	0	0	0.03	0.049	0	0.067
nC-16 Hexadecane	0	0.349	0.125	0.076	0.062	0	0	0.058	0.117	0	0.104
nC-17 Heptadecane	0.407	1.31	0.466	0.324	0.264	0.135	0.322	0.193	0.435	0.408	0.444
Pristane	0.185	0.573	0.21	0.142	0.114	0	0.216	0.1	0.182	0.189	0.189
nC-18 Octadecane	0	0.756	0.227	0.189	0.147	0	0	0.101	0.211	0	0.228
Phytane	0	0.659	0.187	0.149	0.109	0	0	0.089	0.181	0	0.168
nC-19 Nonadecane	0	0	0	0	0	0	0	0	0	0	0
nC-20 Eicosane	0	0	0	11.5	0	6.63	0	0	0	0	0
nC-21 Heneicosane	0	0	0	0	0.303	0	0	0	0	0	0
nC-22 Docosane	0	0	0	0	0.181	0	0	0.478	0	0	0
nC-23 Tricosane	0	0	0	0	0	0	0	0	0	0	0
nC-24 Tetracosane	0	0	0	0	0	0	0	0	0	0	0
nC-25 Pentacosane	0	0.39	0	0	0	0.195	0	0	0	0	0.185
nC-26 Hexacosane	0	0	0.35	0	0.233	0	0	0	0	0	0
nC-27 Heptacosane	[illegible]										0
nC-28 Octacosane											0
nC-29 Nonacosane											0
nC-30 Triacontane											0
nC-31 Hentriacontane											0
nC-32 Dotriacontane											0
nC-33 Tritriacontane											0
nC-34 Tetratriacontane											0
nC-35 Pentatriacontane											0
Naphthalene	[illegible]										3.64
C1-Naphthalenes											0
C2-Naphthalenes											0
C3-Naphthalenes											0
C4-Naphthalenes											0
Fluorene	0	0.187	1.33	0	0.859	0	0	0	0.785	0	0.466
C1-Fluorenes	0	0	0	0	0	0	0	0	0	2.15	0
C2-Fluorenes	0	0.502	0	0	0	0	0	0	0	0	0
C3- Fluorenes	0	0	0	0	0	0	0	0	0	0	0
Dibenzothiophene	0	0	0	0	0	0	0	0	0	0	0
C1-Dibenzothiophenes	1.48	0	0	0	1.25	0	0	0	0	1.74	0
C2-Dibenzothiophenes	0	8.67	0	0	0	0	0	0	0	0	2.14
C3- Dibenzothiophenes	0	0	1.1	0	0.831	0	0	0	0	0	0.654
Phenanthrene	3.64	6.2	6.91	3.01	3.07	0.67	4.42	1.78	0	2.91	2.95
C1-Phenanthrenes	11.7	3.86	4.34	1.25	0	0.665	0	0	2.74	0	0
C2-Phenanthrenes	0	0	0	0	0	0	0	0	0	0	0
C3-Phenanthrenes	0	5.75	0	0	0	0	0	0	0	0	0
C4-Phenanthrenes	0.368	0	0	0	0.745	0	0	0	0	0.652	0
Anthracene	0.402	0	0.727	0	1.04	0	1.16	0	1.79	0.502	0.647
Fluoranthene	0	0	0	0	5.08	0	0	0	0	0	0
Pyrene	0	0	0	0	12.5	0	0	0	0	0	0
C1- Pyrenes	0	0	1.98	0	0	0	0	0	0	0	0
C2- Pyrenes	0	0	0	0	0	0	0	0	0	0	0
C3- Pyrenes	0	0	0	0	0	0	0	0	0	0	0
C4- Pyrenes	0	0	0	0	0	0	2.12	0	0	0	0
Naphthobenzothiophene	0	0	0	0	0	0	0	0	0	0	0
C-1 Naphthobenzothiophenes	6.34	0	2.33	0	0	0	0	0	0	0	0
C-2 Naphthobenzothiophenes	0	0	0	0	0	0	0	0	0	0	0
C-3 Naphthobenzothiophenes	0	0	0	0	0	0	0	0	0	0	0
Benzo (a) Anthracene	0	0	0	0	3.63	0	0	2.46	0	0	0
Chrysene	0	0	0	0	3.15	0	0	0	0	0	0
C1- Chrysenes	0	0	0	0	0	0	0	0	0	0	0
C2- Chrysenes	0	0	0	0	0	0	0	0	0	0	0
C3- Chrysenes	0	0	0	0	0	0	0	0	0	0	0
C4- Chrysenes	0	0	0	0	0	0	0	0	0	0	0
Benzo (b) Fluoranthene	0	0	0	0	0	0	0	0	0	0	0
Benzo (k) Fluoranthene	0	0	0	0	0	0	0	0	0	0	0
Benzo (e) Pyrene	0	0	0	0	0	0	0	0	0	0	0
Benzo (a) Pyrene	0	0	0	0	0	0	0	0	0	0	0
Perylene	0	0	0	1.91	0	3.04	0	0	0	0	4.34
Indeno (1,2,3 - cd) Pyrene	0	0	0	0	0	0	0	0	0	0	0
Dibenzo (a,h) anthracene	0	0	0	0	0	0	0	0	0	0	0
Benzo (g,h,i) perylene	0	0	0	0	0	0	0	0	0	0	0

SEDIMENT

SITE	GT	BSL	BFP	BLB	MB	FMA
DATE (2010)	10/5	9/12	9/12	9/12	9/12	9/12
nC-10 Decane	0	0	0	0	0	0
nC-11 Undecane	0	0	0	0	0	0
nC-12 Dodecane	0.006	0	0	0	0	0
nC-13 Tridecane	0	0	0	0	0	0
nC-14 Tetradecane	0	0	0	0	0	0
nC-15 Pentadecane	0.042	0	0	0.01	0	0.013
nC-16 Hexadecane	0	0.029	0.037	0.025	0.054	0.088
nC-17 Heptadecane	0.234	0.079	0.118	0.069	0.211	0.225
Pristane	0.5725	0.023	0.035	0.02	0.068	0.061
nC-18 Octadecane	0.2295	0.109	0.2	0.112	0.192	0.371
Phytane	1.0075	0.055	0.06	0.034	0.062	0.082
nC-19 Nonadecane	0.224	0.072	0.118	0.069	0.132	0.197
nC-20 Eicosane	0	0.019	0.034	0.019	0.045	0.05
nC-21 Heneicosane	0.1475	0.018	0.033	0.019	0.045	0.046
nC-22 Docosane	0.078	0.021	0.036	0.022	0.052	0.054
nC-23 Tricosane	0.0885	0.021	0.04	0.025	0.048	0.056
nC-24 Tetracosane	0.104	0.036	0.029	0.02	0.032	0.044
nC-25 Pentacosane	1.215	0.056	0.074	0.047	0.091	0.131
nC-26 Hexacosane	0.565	0.02	0.031	0.017	0.021	0.042
nC-27 Heptacosane	[illegible]					
nC-28 Octacosane						
nC-29 Nonacosane						
nC-30 Triacontane						
nC-31 Hentriacontane						
nC-32 Dotriacontane						
nC-33 Tritriacontane						
nC-34 Tetratriacontane						
nC-35 Pentatriacontane						
Naphthalene						
C1-Naphthalenes						
C2-Naphthalenes						
C3-Naphthalenes						
C4-Naphthalenes						
Fluorene	0					
C1-Fluorenes						
C2-Fluorenes	[illegible]					
C3- Fluorenes	[illegible]					
Dibenzothiophene	0	0	0	0	0	0
C1-Dibenzothiophenes	68.9	0	1.12	0.719	0	1.43
C2-Dibenzothiophenes	388.5	0.659	1.55	0.943	1.44	1.66
C3- Dibenzothiophenes	507.5	0	0	0	0	0
Phenanthrene	8	1.99	5.04	2.69	7.81	3.87
C1-Phenanthrenes	274	0	0	0	0	0
C2-Phenanthrenes	1115	1.81	3.56	3.45	4.35	2.86
C3-Phenanthrenes	1196	0.796	0	2.29	1.96	0
C4-Phenanthrenes	689	0	0	0	0	0
Anthracene	1.555	0.532	2	1.15	1.24	0.927
Fluoranthene	29.4	6.19	21.7	5.7	35.2	3.22
Pyrene	55.55	3.99	15.1	6.74	25.7	2.24
C1- Pyrenes	0	1.77	9.06	6.85	12	0
C2- Pyrenes	312.5	0	4.93	3.42	6.34	0
C3- Pyrenes	329.5	0	0	1.48	2.69	0
C4- Pyrenes	0	0	0	0	0	0
Naphthobenzothiophene	69.5	0.273	1.22	0.746	1.45	0
C-1 Naphthobenzothiophenes	238	0	0	0	0	0
C-2 Naphthobenzothiophenes	312	0	1.24	0.663	0	0
C-3 Naphthobenzothiophenes	0	0	0	0	0	0
Benzo (a) Anthracene	0	1.6	0	0	0	0
Chrysene	853	2.35	17.8	25.4	16	1.24
C1- Chrysenes	1020	0	0	4.69	6.4	0
C2- Chrysenes	388	0	0	0	0	0
C3- Chrysenes	210	0	0	0	0	0
C4- Chrysenes	0	0	0	0	0	0
Benzo (b) Fluoranthene	0	1.08	13.8	11.3	11.3	0.397
Benzo (k) Fluoranthene	0	0.974	12.4	11.3	10.5	0.489
Benzo (e) Pyrene	99.2	0.817	9.17	8.3	7.4	0.483
Benzo (a) Pyrene	0	0.518	9.77	9.37	10	0.444
Perylene	0	0.474	4.37	2.99	2.68	0
Indeno (1,2,3 - cd) Pyrene	0	0.419	6.91	5.04	6.17	0
Dibenzo (a,h) anthracene	0	0	4.01	2.24	3.66	0
Benzo (g,h,i) perylene	0	0.374	6.86	6.33	6.68	0

WATER:

→No elevated hydrocarbons
… except at GT in June
… and only barely above DL

TISSUES:

→No sites stand out, including GT

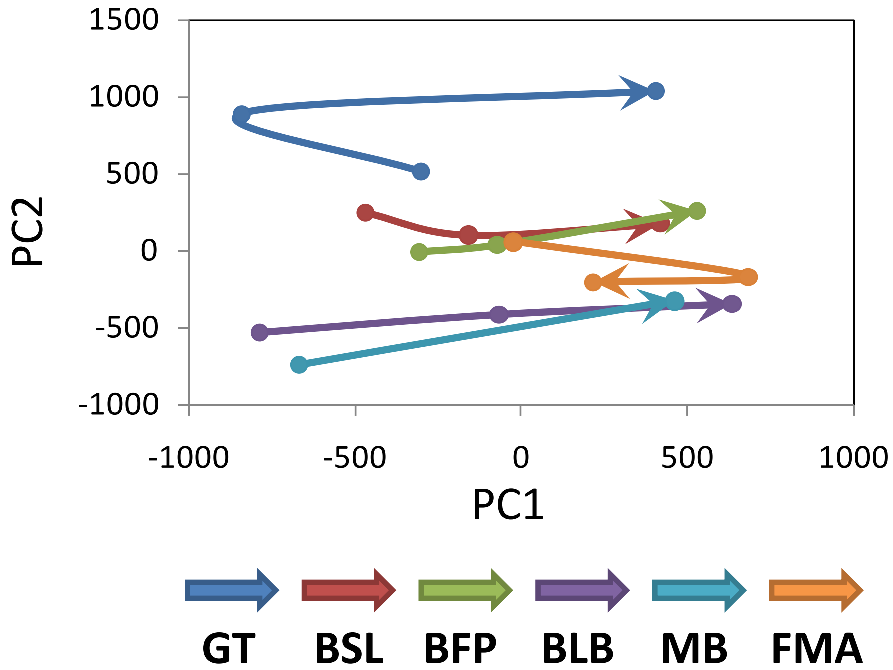
SEDIMENT:

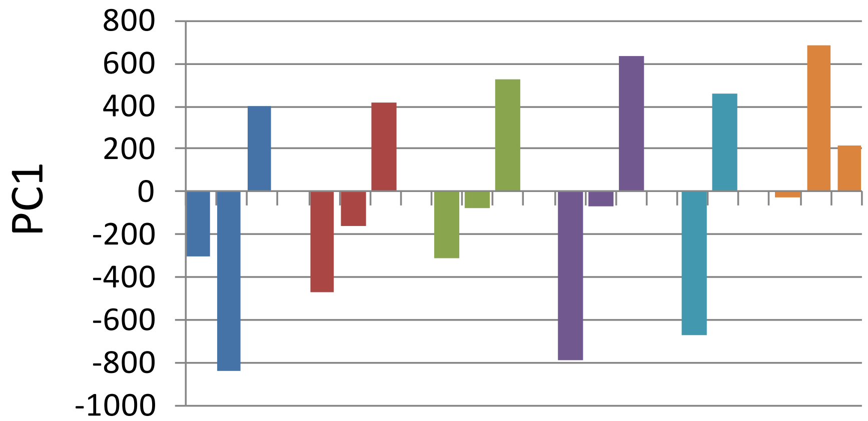
→Off the chart at GT, as late as October

Genome expression: Microarray

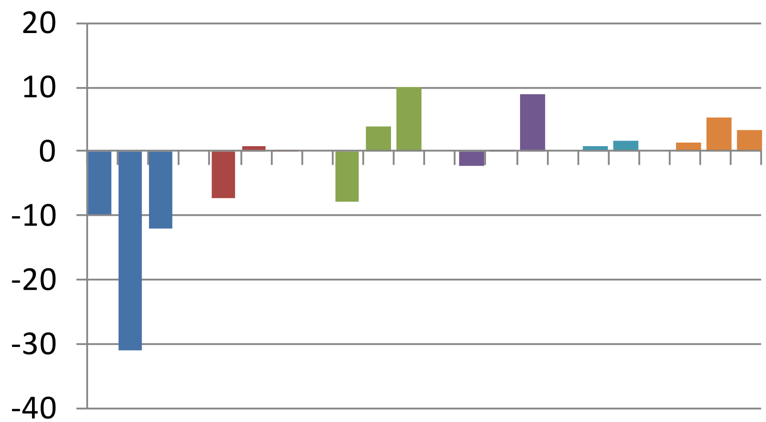
→ Probes for 15,000 genes

Genome expression response trajectories through time (liver)

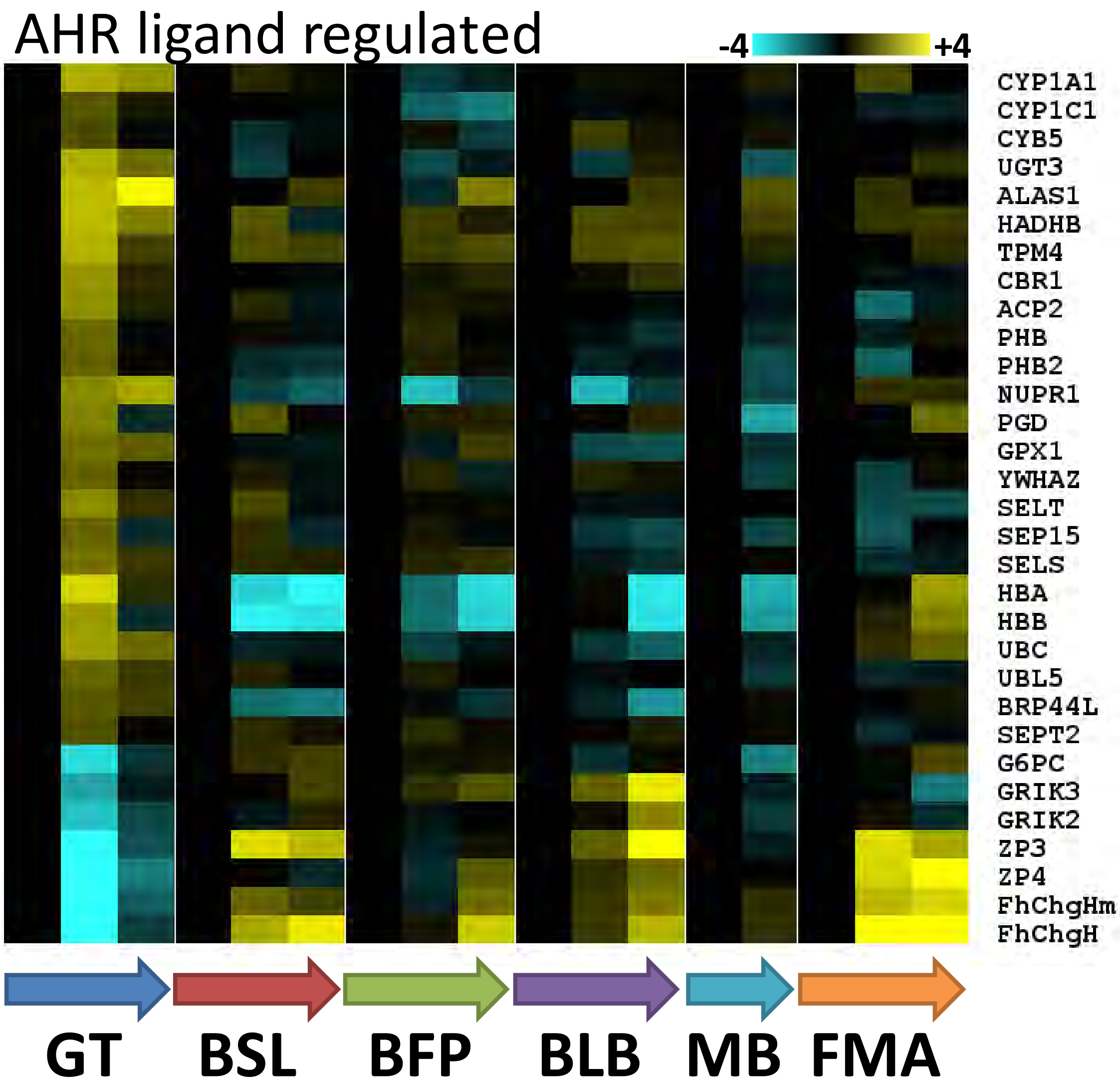




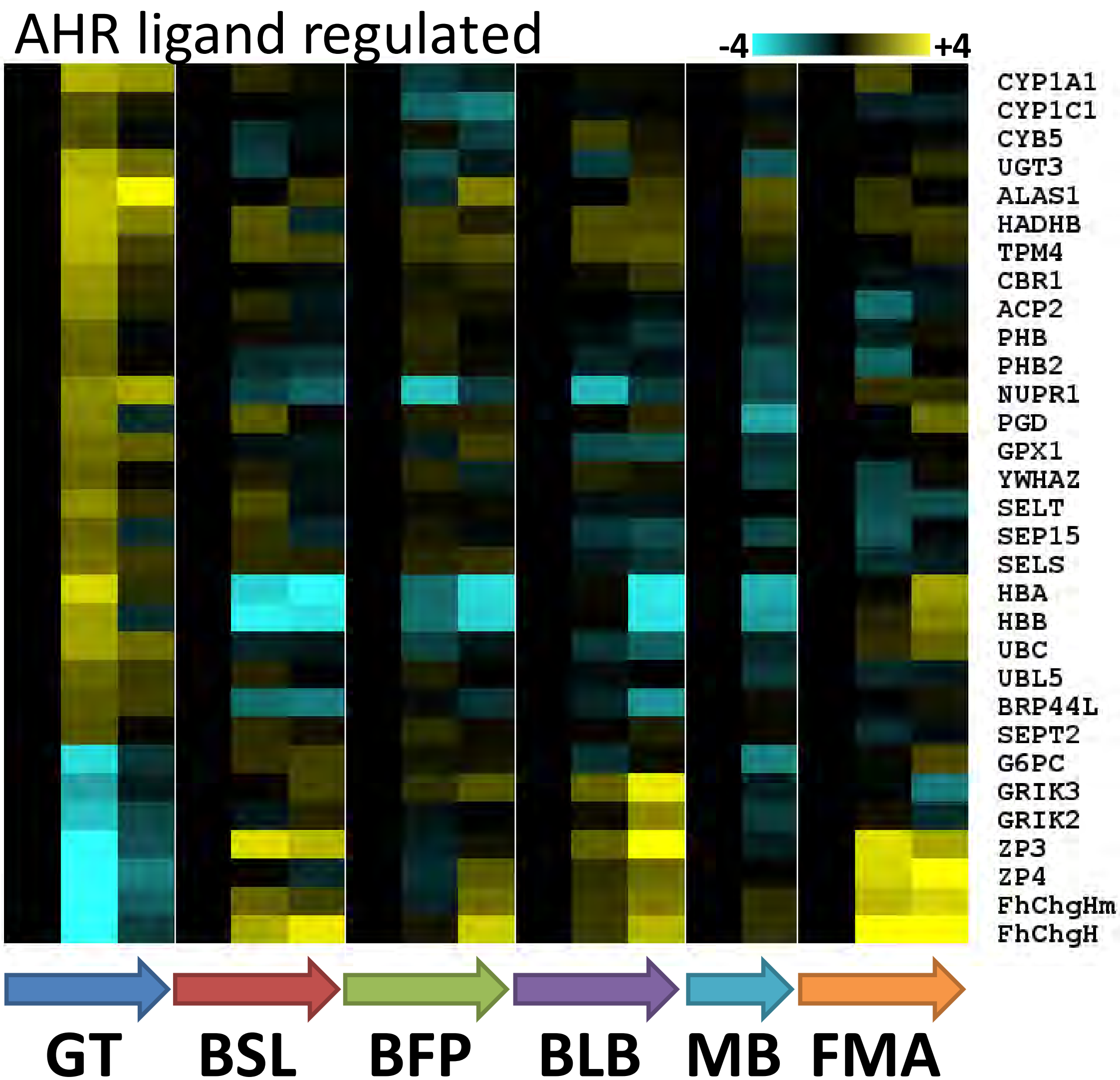
Subset of genes that are PCB- induced in killifish



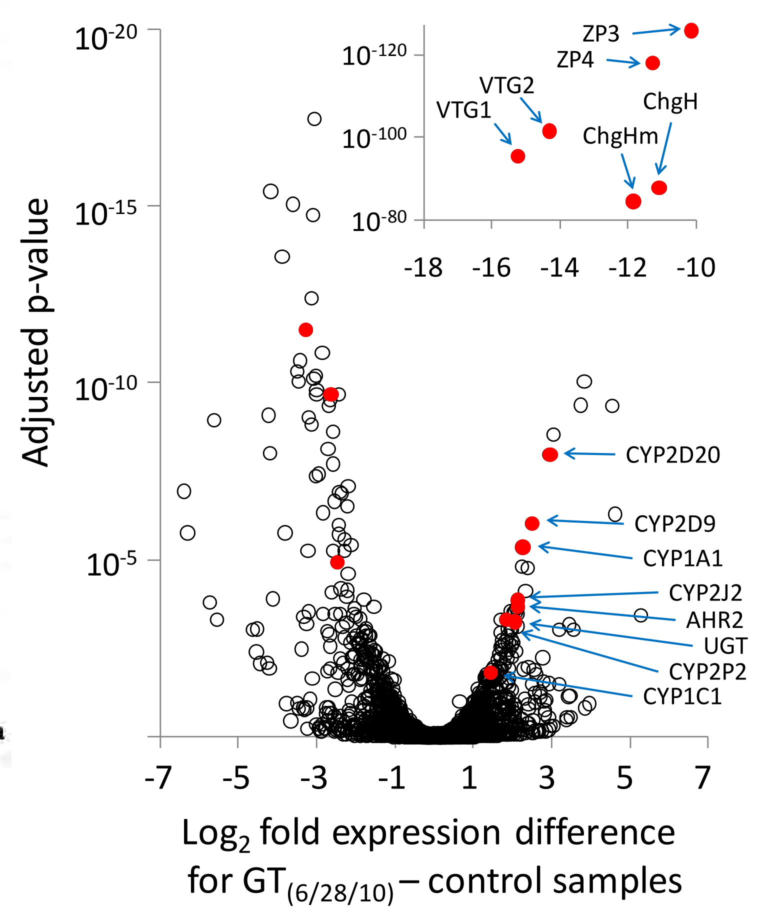
Genome expression response → GT outlier



Genome expression response → GT outlier

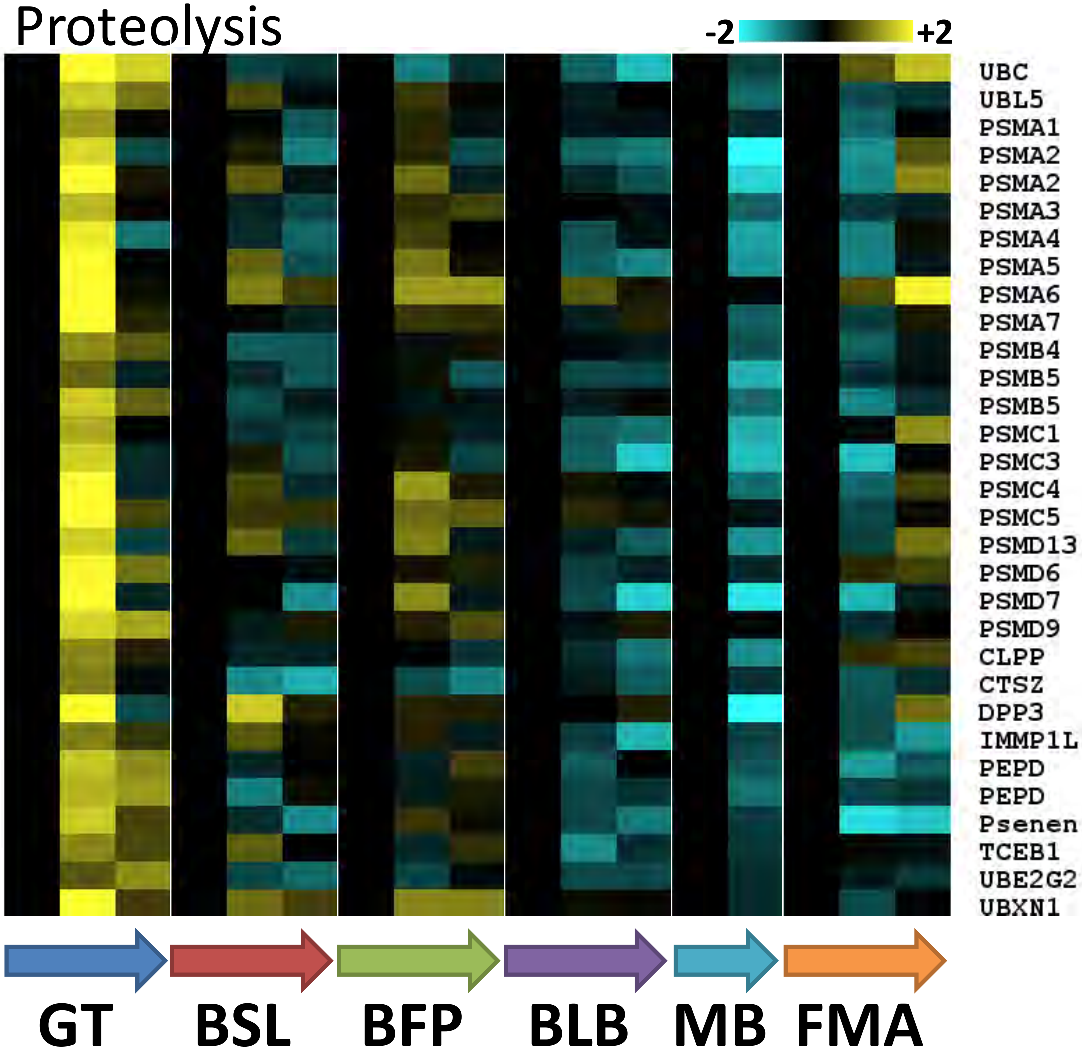


Collaborator: Ron Walter, Post-doc: Tzintzuni Garcia



Genome expression response → GT outlier

Proteolysis




nature | Vol 446 | 29 March 2007 | doi:10.1038/nature05683

LETTERS

Dioxin receptor is a ligand-dependent E3 ubiquitin ligase

Fumiaki Ohtake, Atsushi Baba, Ichiro Takada, Maiko Okada, Kei Iwasaki, Hiromi Miki, Sayuri Takahashi, Alexander Kouzmenko, Keiko Nohara, Tomoki Chiba, Yoshiaki Fujii-Kuriyama & Shigeaki Kato

Ligand (PAH)-activated AHR

↓

Ubiquitin-ligase activity

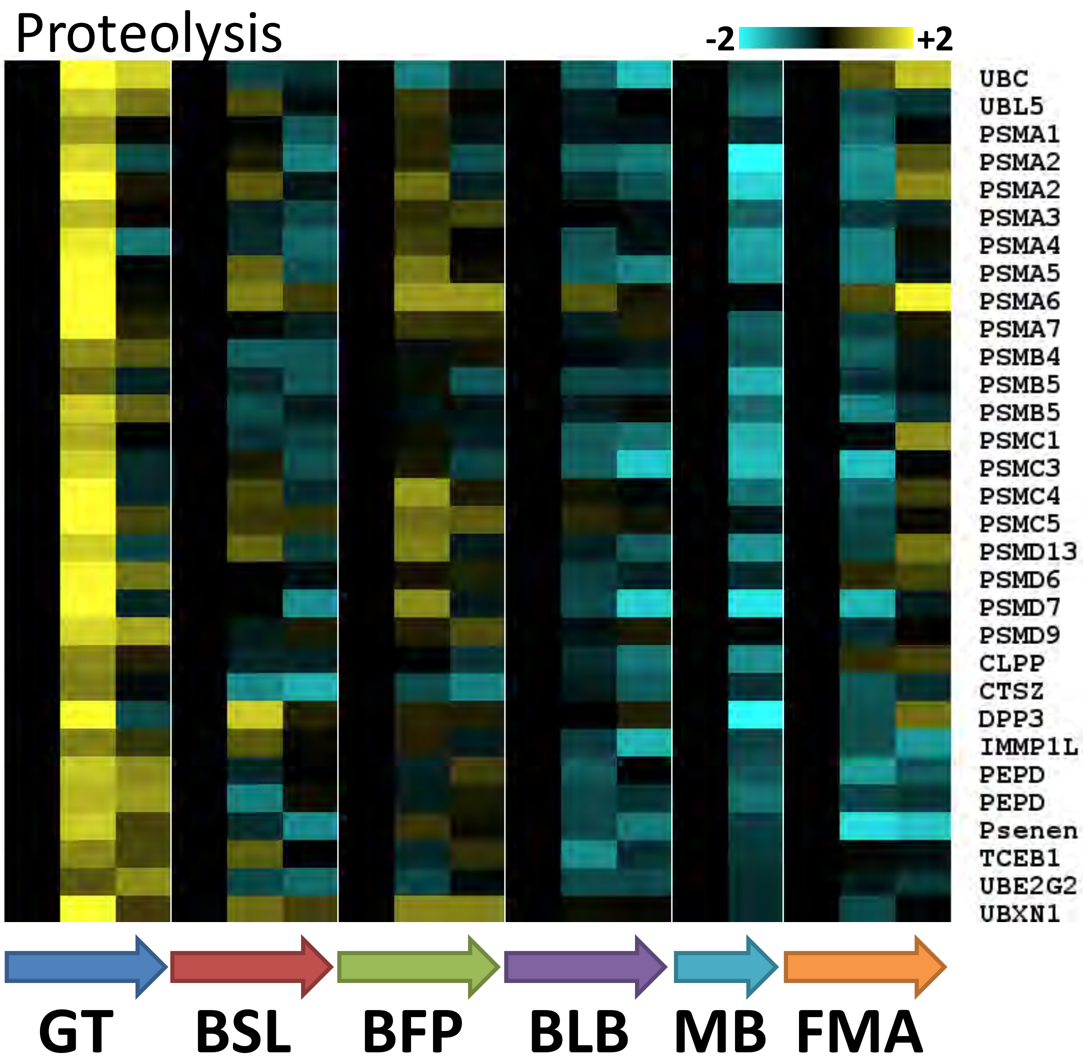
↓

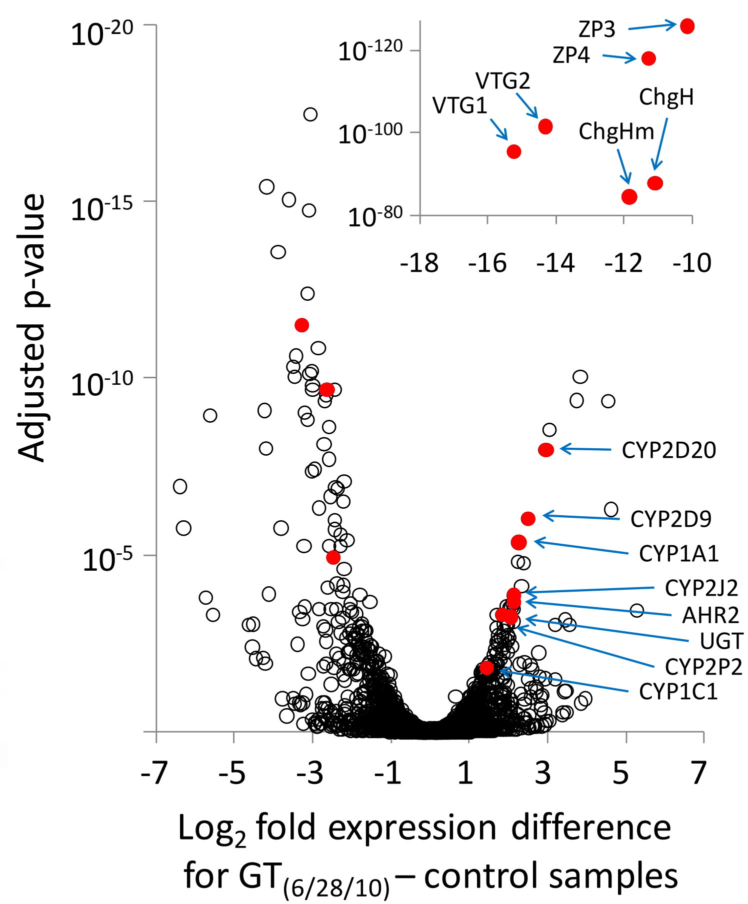
Proteolytic degradation of sex steroid receptors

↓

Suppression of sex hormone induced gene expression

Genome expression response
→ GT outlier

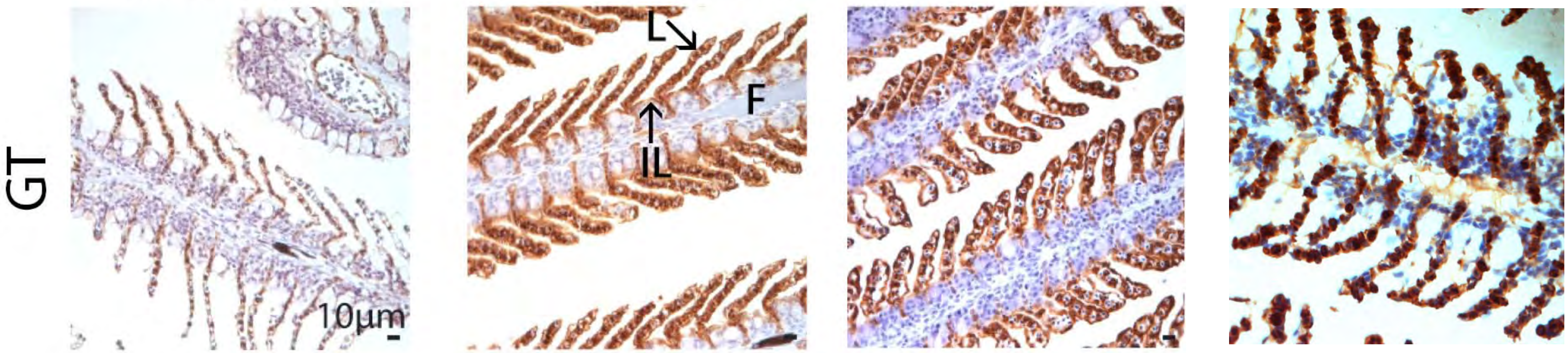




Genome expression response → GT outlier

Collaborator: Fern Galvez
Student: Ben Dubansky

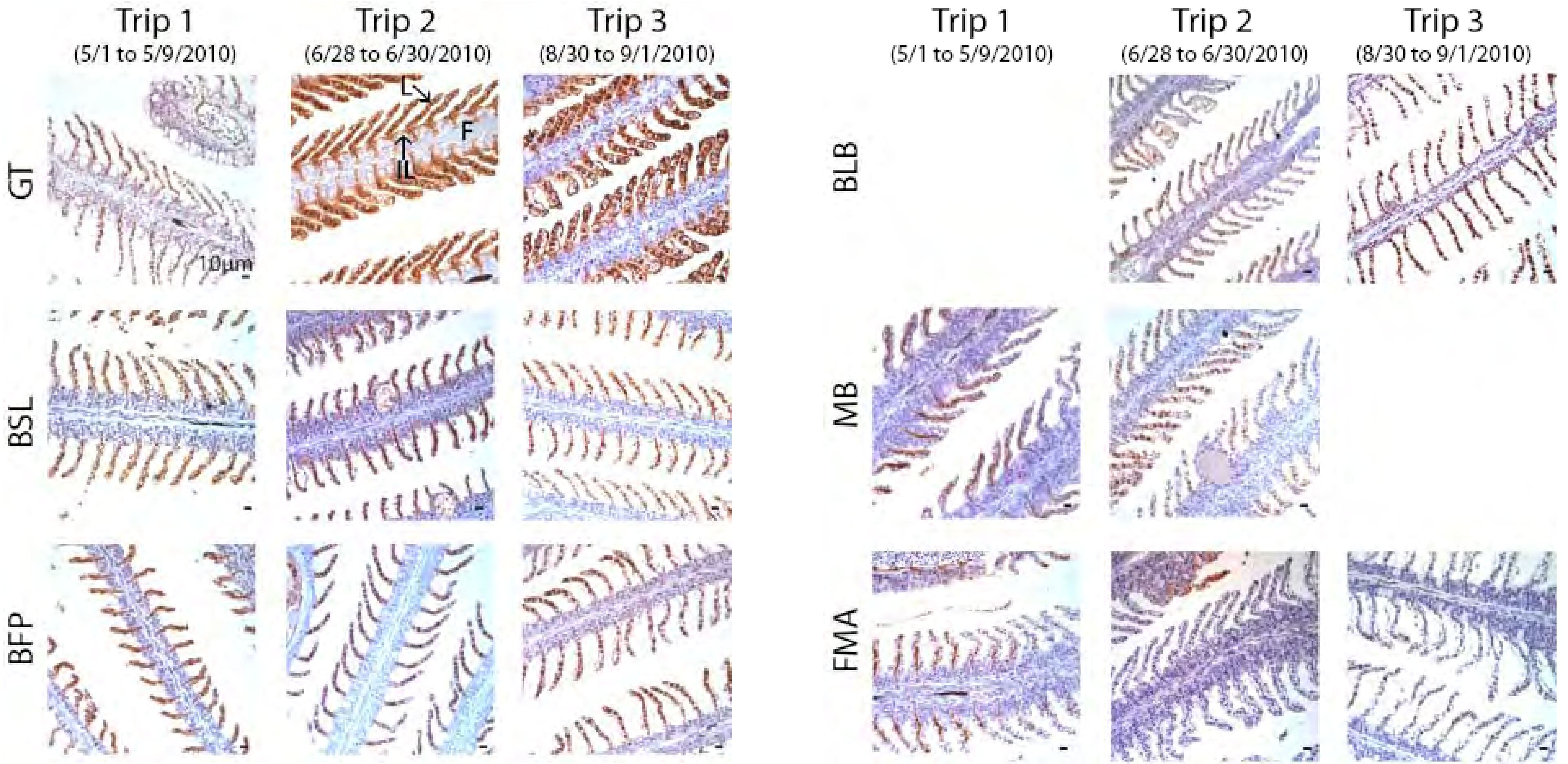
Trip 1	Trip 2	Trip 3	Trip 4
(5/1 to 5/9/2010)	(6/28 to 6/30/2010)	(8/30 to 9/1/2010)	(August 2011)



Dark red stain = CYP1A protein in gills from fish collected *in situ*
Blue stain = hematoxylin (nuclei)

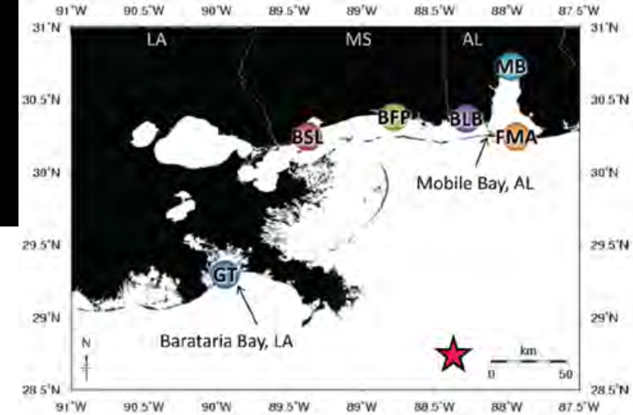
Genome expression response → GT outlier

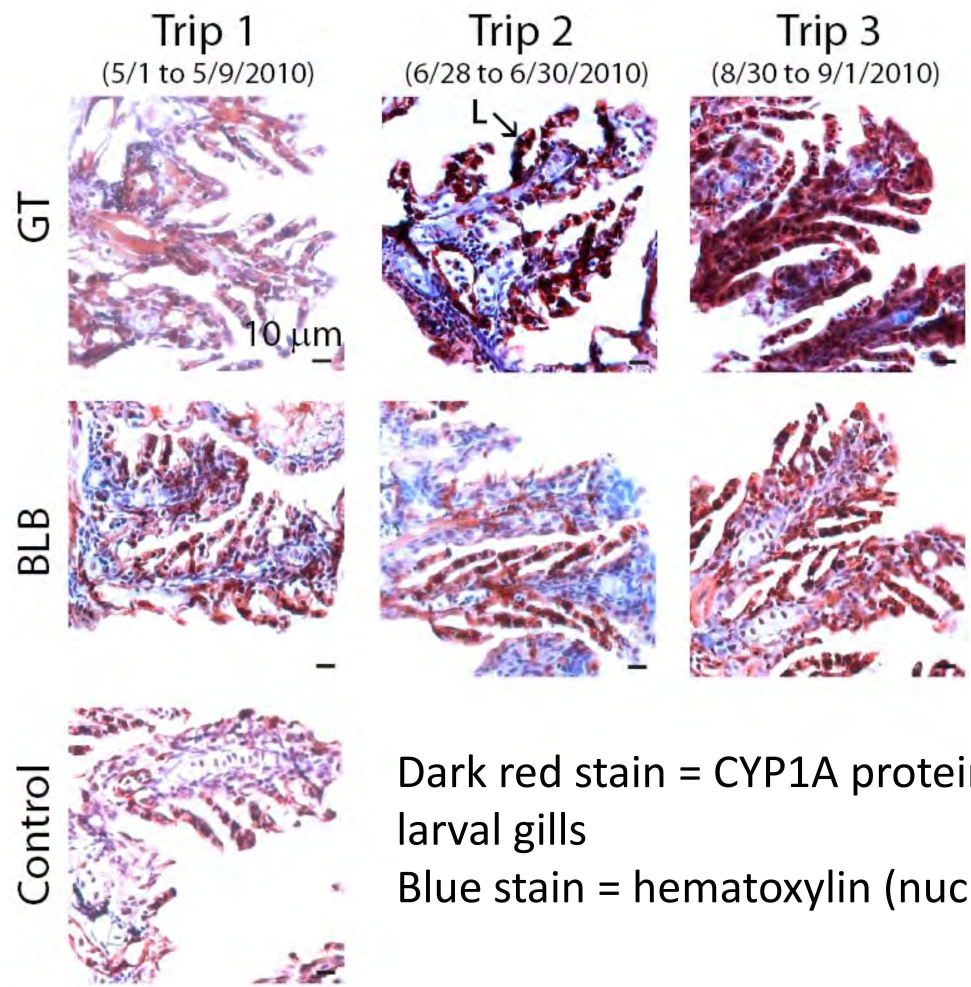
Collaborator: Fern Galvez
Student: Ben Dubansky



Early life-stage exposures to field-collected waters

Collaborator: Fern Galvez
Post-doc: Charlotte Bodinier





Dark red stain = CYP1A protein in larval gills
Blue stain = hematoxylin (nuclei)

Early life-stage exposures to field-collected waters

No developmental abnormalities observed in killifish exposed to field-collected waters

BUT…

Sublethal exposure to crude oil during embryonic development alters cardiac morphology and reduces aerobic capacity in adult fish

Corinne E. Hicken[a], Tiffany L. Linbo[b], David H. Baldwin[b], Maryjean L. Willis[b], Mark S. Myers[b], Larry Holland[c], Marie Larsen[c], Michael S. Stekoll[a], Stanley D. Rice[c], Tracy K. Collier[b,1], Nathaniel L. Scholz[b], and John P. Incardona[b,2]

PNAS Early Edition

→ very low-concentration exposures during development, insufficient to induce cardiovascular abnormalities in embryos, can impair cardiac performance in adulthood

DWH Oil Spill: NEXT?...

→ Consequences of multiple-stressor exposures?

→ Impacts on FITNESS

→ Consequences of low-level early life stage exposures (cardiac performance)?

→ How does evolutionary history and exposure history affect sensitivity?

Genomic and physiological footprint of the *Deepwater Horizon* oil spill on resident marsh fishes

Andrew Whitehead[a,1], Benjamin Dubansky[a], Charlotte Bodinier[a], Tzintzuni I. Garcia[b], Scott Miles[c], Chet Pilley[d], Vandana Raghunathan[e], Jennifer L. Roach[a], Nan Walker[e], Ronald B. Walter[b], Charles D. Rice[f], and Fernando Galvez[a]

Departments of [a]Biological Sciences, [c]Environmental Sciences, and [e]Oceanography and Coastal Sciences, and [d]Coastal Studies Institute, Louisiana State University, Baton Rouge, LA 70803; [b]Department of Chemistry and Biochemistry, Texas State University, San Marcos, TX 78666; and [f]Department of Biological Sciences, Clemson University, Clemson, SC 29634

Edited by Paul G. Falkowski, Rutgers, The State University of New Jersey, New Brunswick, NJ, and approved September 1, 2011 (received for review June 13, 2011)

The biological consequences of the *Deepwater Horizon* oil spill are unknown, especially for resident organisms. Here, we report results from a field study tracking the effects of contaminating oil across space and time in resident killifish during the first 4 mo of the spill event. Remote sensing and analytical chemistry identified exposures, which were linked to effects in fish characterized by genome expression and associated gill immunohistochemistry, despite very low concentrations of hydrocarbons remaining in water and tissues. Divergence in genome expression coincides with contaminating oil and is consistent with genome responses that are predictive of exposure to hydrocarbon-like chemicals and indicative of physiological and reproductive impairment. Oil-contaminated waters are also associated with aberrant protein expression in gill tissues of larval and adult fish. These data suggest that heavily weathered crude oil from the spill imparts significant biological impacts in sensitive Louisiana marshes, some of which remain for over 2 mo following initial exposures.

ecological genomics | ecotoxicology | microarray | RNA-seq | toxicogenomics

 www.pnas.org/cgi/doi/10.1073/pnas.1109545108

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- **David Roberts** (undergraduate)

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- DEB: *Evolutionary Genetics*

GULF OF MEXICO RESEARCH INITIATIVE

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- **Nan Walker, Chet Pilley, Vandana Raghunathan** (LSU-EarthScan Lab)
- **Scott Miles** (LSU-Environ.Sci.)
- **Diane Nacci** (US EPA)
- **Ron Walter, Tzintzuni Garcia** (TX State U)
- **Charles Rice** (Clemson U.)