Using marine animal tracking data to help inform management in the GOM

iTAG INTEGRATED TRACKING of AQUATIC ANIMALS in the GULF OF MEXICO

About Integrated Tracking Animals Gulf Publications

https://itagscience.com/

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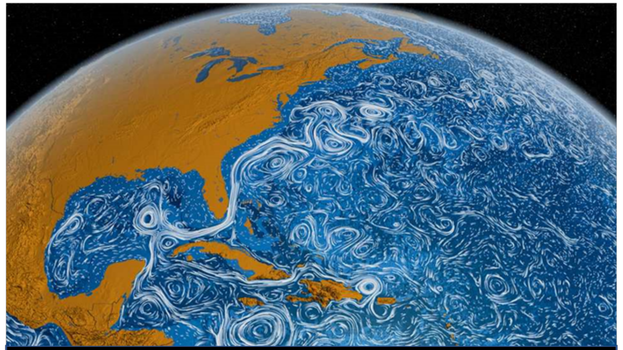
Marine fish: growing recognition of the importance of spatial processes

Integrating spatial ecology into EBM

Ocean use management: 2038



Current
- Maximize single species sustainable yield
- Maximize sustainable yield of all species in an ecosystem

Future
- Optimize: food security & ecosystem services
- Preserve resilience and biodiversity

Lowerre-Barbieri, et al. 2019b

Potential game changers:

New data streams
- Marine vessels & fishing industry
- Genomics
- Remote sensing & tracking

Computing & conceptual advances
- Big data
- Artificial Intelligence
- Modelling

Social dimensions & management
- Stakeholder engagement
- Economics
- Ecosystem functionality & service transfers

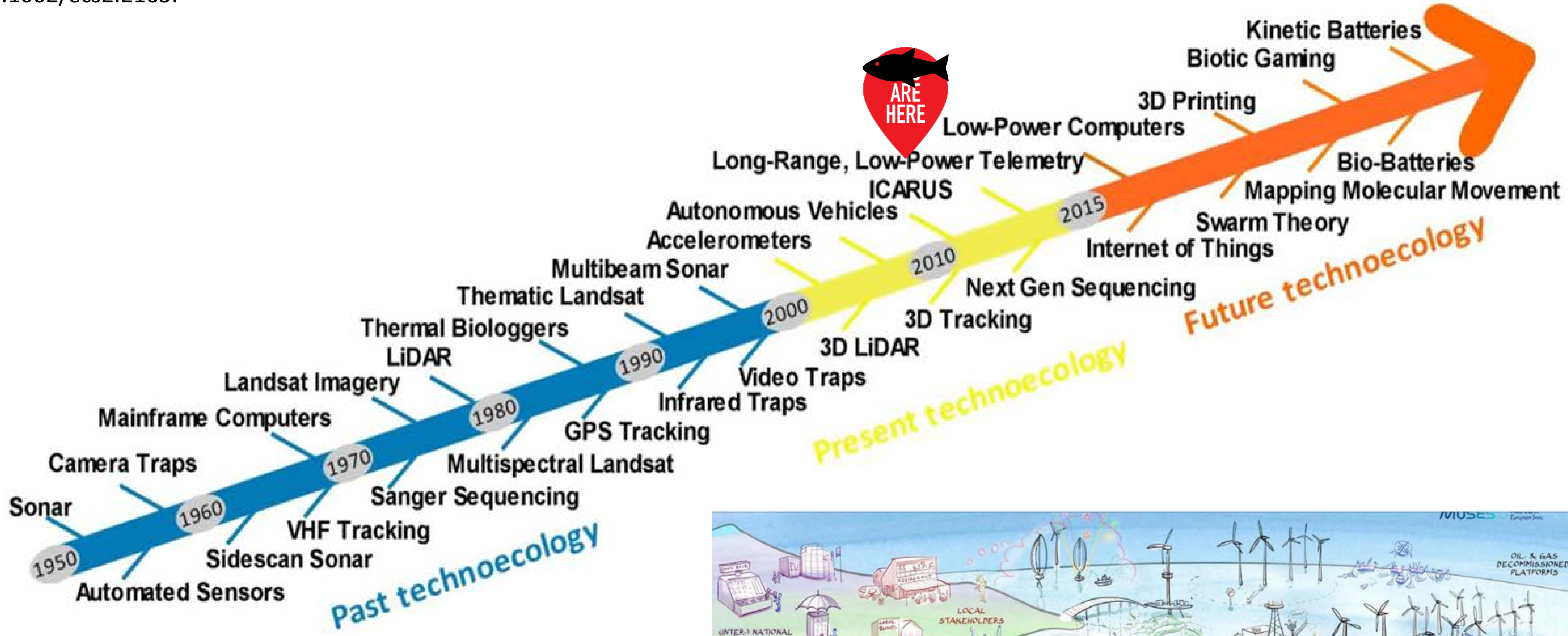
(1) Need for spatial stock assessment models that match the spatiotemporal management and biological structure of marine species is growing
Kerr et al, 2016; Berger et al., 2017; Cadrin 2019; Goethel et al., 2019

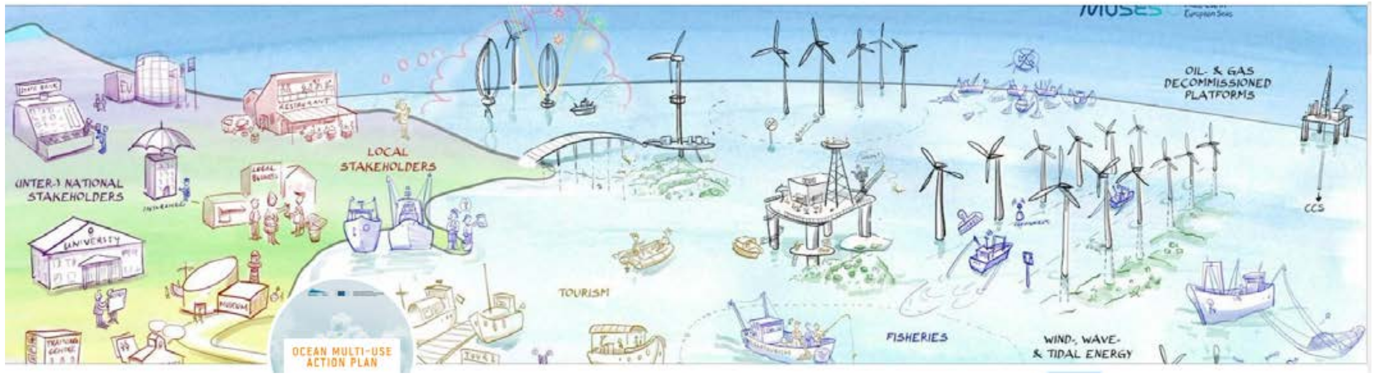
(2) Spatial structure often a consequence of movement processes, habitat, or spatial distribution of fishing effort, and may change over time…. Of particular concern are changes in spatial distribution over time due to movement of the stock, recruitment dynamics, and/or local depletion.
CAPAM, 2019

(3) A range of new data streams, modelling approaches, and improved recognition of social dimensions has the potential to greatly improving our ability to optimize both food security and ecosystem services

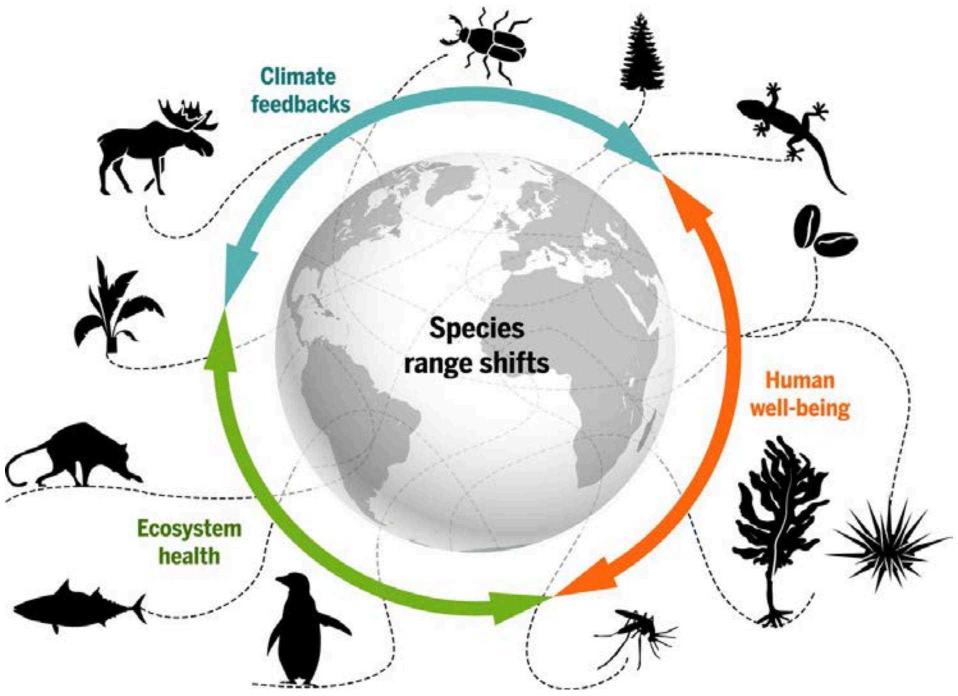
Lots of new tech to study marine ecosystems and better harvest them

Allan, B. M., D. G. Nimmo, D. Ierodiaconou, J. Vanderwal, L. P. Koh, and E. G. Ritchie. 2018. **Futurecasting ecological research: the rise of technoecology**. Ecosphere 9(5):e02163. 10.1002/ecs2.2163.





Fish and other animals are on the move



Pecl et al. Science 2017;355:eaai9214

As the global climate changes, human well-being, ecosystem function, and even climate itself are increasingly affected by the shifting geography of life.

Portugal: ~20 new species in recent years
Northern Europe: sardines replaced herring, cod & haddock moving north
U.S.: Black seabass slowly moving north

- New York suing U.S. Dept of Commerce for > share of fluke.
- Pacific Cod: ~1,000 km shift north in Bering sea in 2-3 y
- Gulf? Go deep?

We don't know and currently do not have the data to predict how different species will react

"The impacts of a changing climate will be far more severe if the data used — and regulation that follows — fails to keep pace with environmental changes"
--U.S. Senators Chris Murphy and Richard Blumenthal (Connecticut) to the inspector general of the Dept. of Commerce/NOAA

Changing oceans and assumptions about vulnerability and productivity

With a changing ocean, assumptions underlying traditional stock assessments may no longer hold: Fishing mortality is not the only cause of vulnerability & productivity often spatially-explicit at scale smaller than the stock unit

Stock Assessment

Assumptions ⟷ Rapidly changing marine ecosystems

Movement path

- Mortality
- Fecundity (spawning frequency)
- Recruitment
- By-catch probability
- Stock structure
- Availability to capture & accuracy of capture-based estimates of abundance

Movescapes: multiple georeferenced movement paths used to evaluate life on earth in a way not previously possible

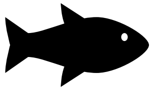
Lowerre-Barbieri, et al. 2019a

Video provided by Roland Kays/movebank; April 2017: 664 taxa & 3,248 studies

Challenges & solutions to collecting fish movescape data

Challenges:

- Big ocean, no marine GPS, marine fish life history, apex predators typically larger home ranges than terrestrial species

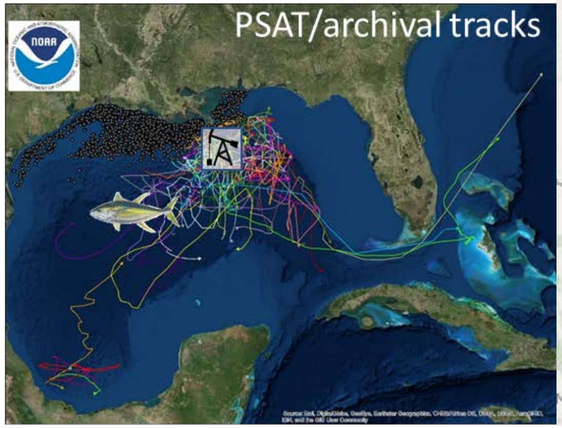



Max ~800,000K:1 50:1

Lowerre-Barbieri et al. 2019

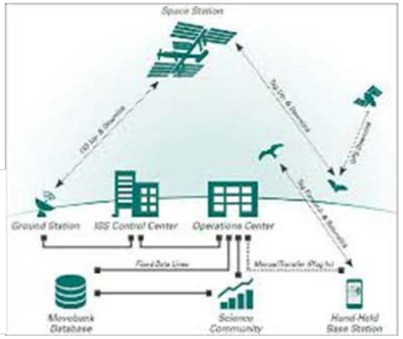
Solutions:

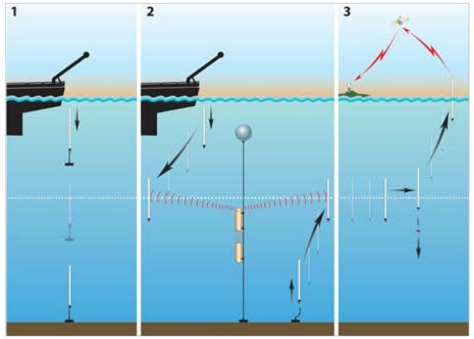
- Networks to help synthesize movement data & integrate it with environmental and habitat layers
- Using multiple methods to understand and ground truth fish movements (dart tags, electronic tracking, biogeochemical tracers, genetics, eDNA etc.)
  - Integrating in-captivity results on individual differences (i.e., physiological thresholds/ personality) with tracked fish in the wild
- New technologies: mobile platforms; new types of tags/systems; increased satellite-based options (ICARUS), the internet of things



iTAG

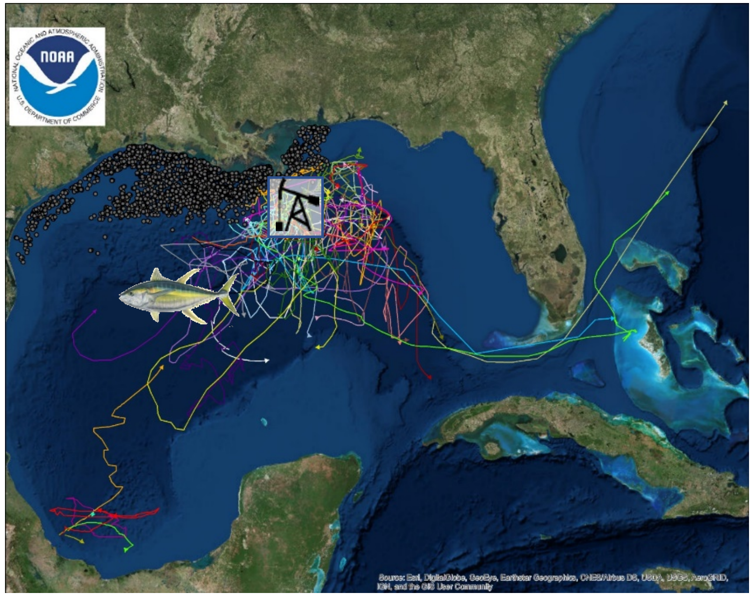
OCEAN TRACKING NETWORK

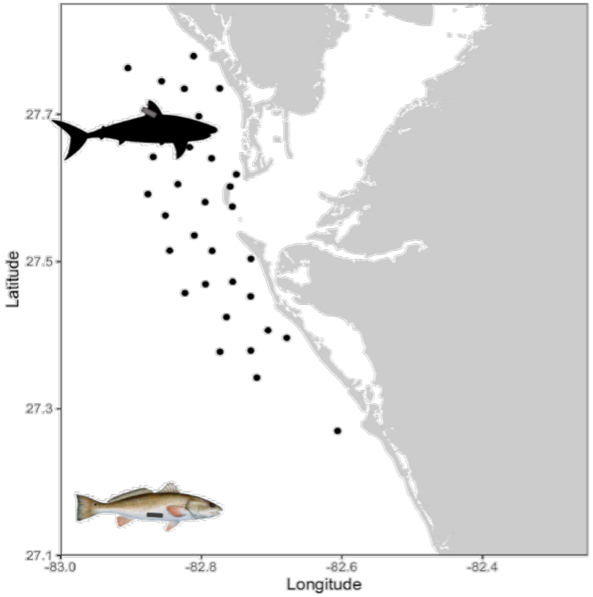


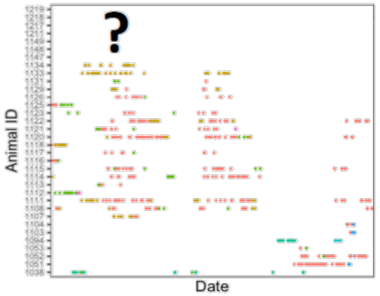


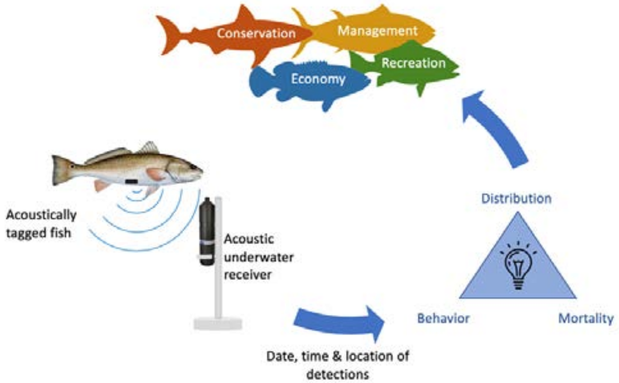
What do tracking networks do?

Leverage on-going or completed tracking research by bringing together PSAT/archival tag tracks or sharing data across arrays (acoustic telemetry); typically they develop a “big data” database

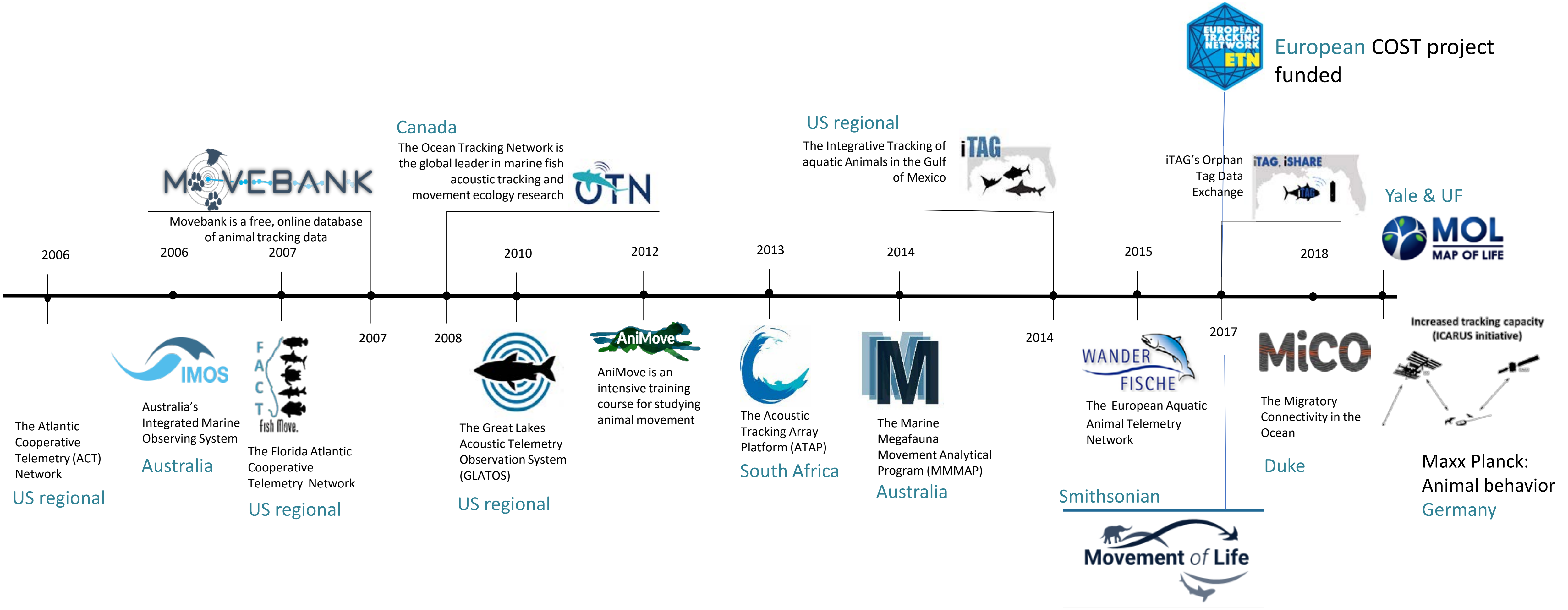








Global interest in better understanding movement ecology

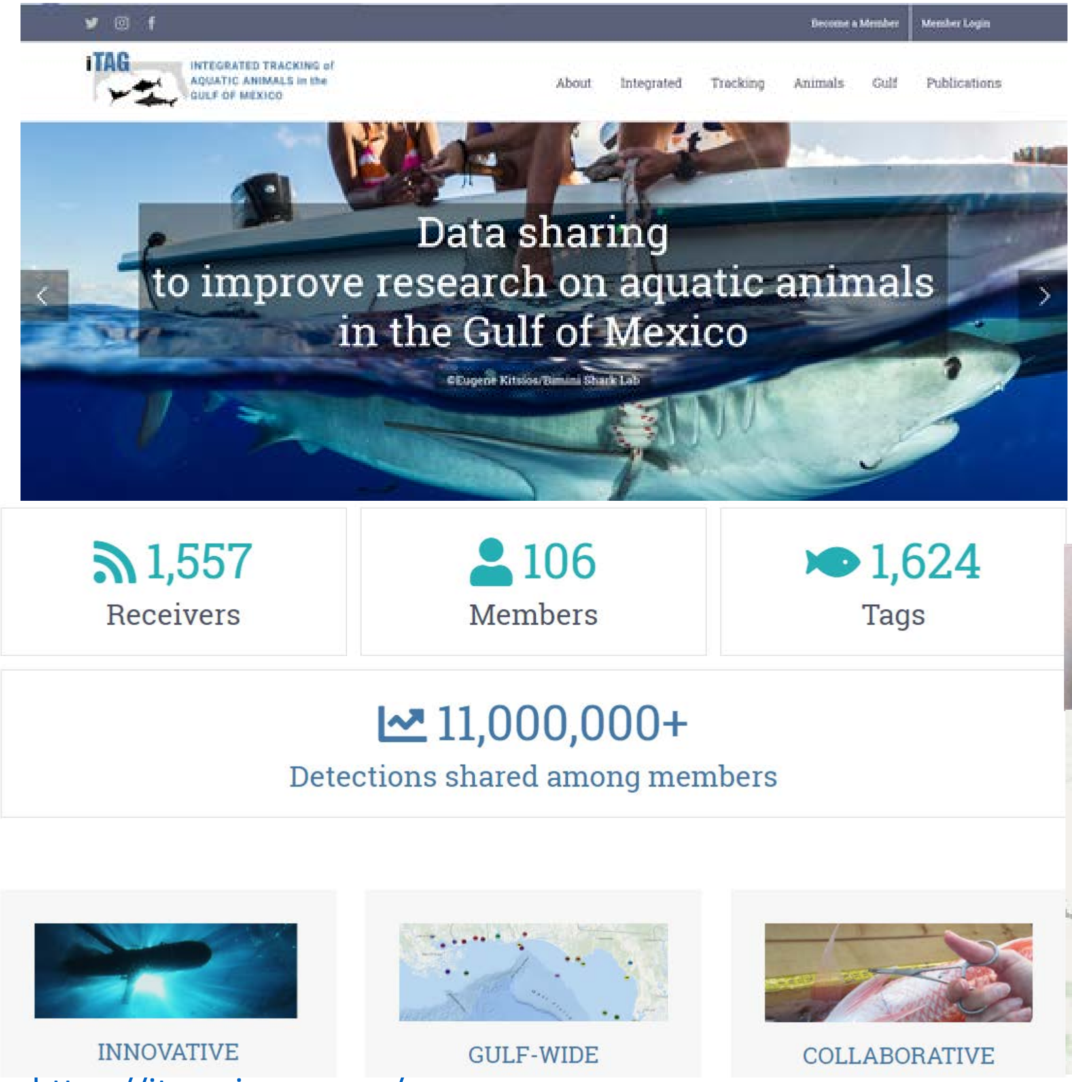


Steering committee: Federal, state, & academic

2014: Developed a steering committee (scientists & stock assessment scientists) to ID movement and fisheries management research and data needs

- Needed first to build tracking capacity to support next generation of research
- Asked Gulf stakeholders what they wanted/needed from a network
    - Concerns about data stealing, data ranching, data hoarding

2019: Workshop on network analysis & to build ms based on iTAG network scale data as a foundation for the research component



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Building tracking capacity in the Gulf

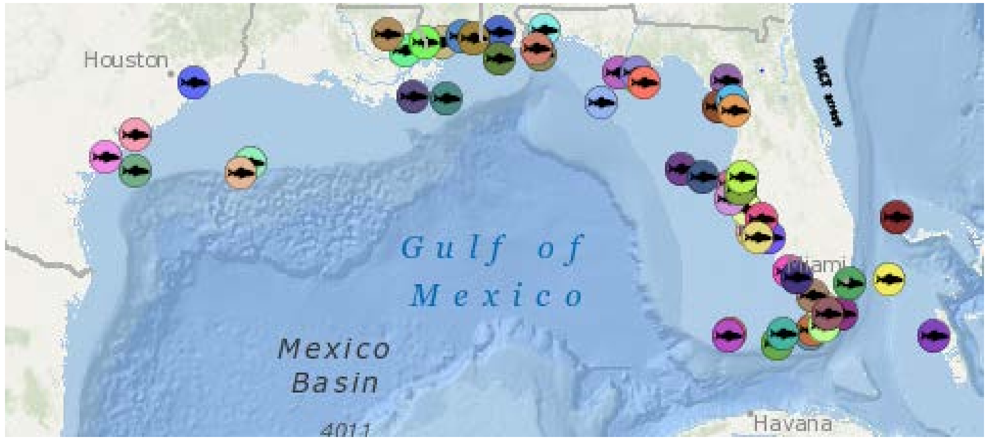
- **Integrative map**
- **Data exchange**
- **Semi-annual meetings/trainings**
- **Increased infrastructure (OTN loan)**
- **Website**
- **Getting too big to run out of my lab**

iTAG steering committee

iTAG data exchange 2017

What: Shares data across arrays: can track an animal throughout the Gulf

How: Researchers upload all non-target tags detected in their arrays at least once a year & their tag meta-data; If your tag is uploaded from someone else's array, automated email generated to connect array owner and tag owner to share data = increase track size and knowing who's in your array



Scientific results: long-distance nurse shark migrations; Gulf-Atlantic connectivity of tarpon, using movements to identify predation events, long-distance migrations of multiple shark species from Alabama to the Keys

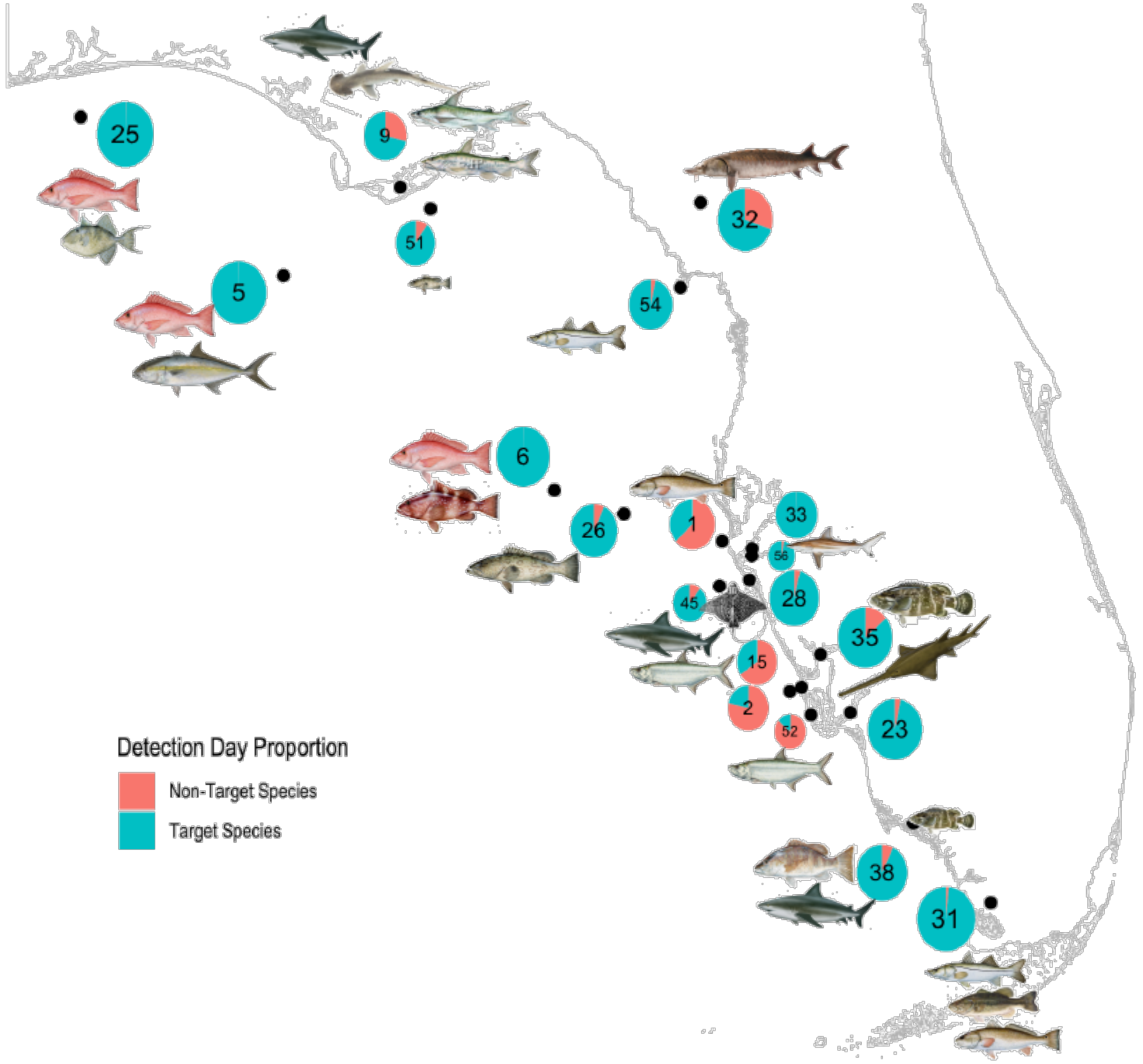
Pratt, H. L. J., T. C. Pratt, D. Morley, S. Lowerre-Barbieri, A. Collins, J. C. Carrier, K. M. Hart, and N. M. Whitney. 2018. Partial migration of the nurse shark, *Ginglymostoma cirratum* (Bonnaterre), from the Dry Tortugas Islands. Environmental Biology of Fishes **101**:515-530.

Griffin LP, Brownscombe JW, Adams AJ, Boucek RE, Finn JT, Heithaus MR, Rehage JS, Cooke SJ, Danylchuk AJ (2018) Keeping up with the Silver King: Using cooperative acoustic telemetry networks to quantify the movements of Atlantic tarpon (Megalops atlanticus) in the coastal waters of the southeastern United States. Fisheries Research 205:65-76

Bohaboy EC, Guttridge TL, Hammerschlag N, Van Zinnicq Bergmann MPM, Patterson WF, III (2019) Application of three-dimensional acoustic telemetry to assess the effects of rapid recompression on reef fish discard mortality. ICES Journal of Marine Science

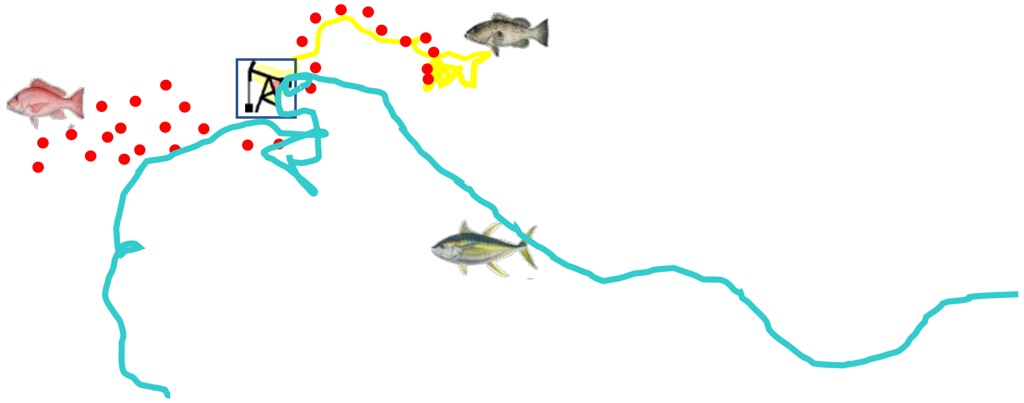
Atobelli A, Szedlmayer ST (2019) Acoustic Telemetry of Shark Movements and Residency Near Artificial Habitats in the Northern Gulf of Mexico. GCFI

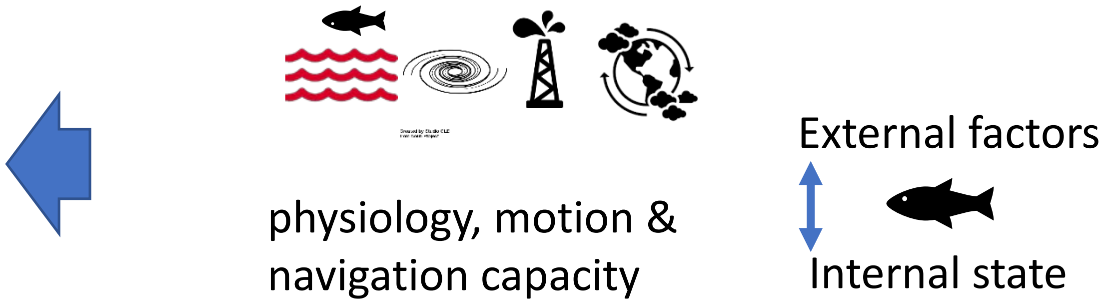
The network: needed next steps

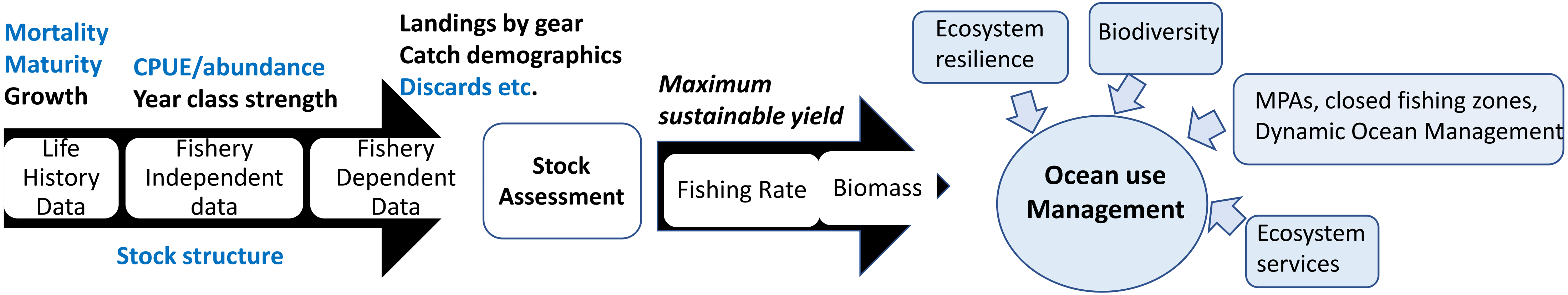


- **Funding for personnel to manage it, too big to handle on the side in a research lab**
- **Need to shift cost/benefit ratio to equally benefit people studying resident versus highly migratory species;**
- **Need to invest in arrays that are managed possibly through the states to provide long-term movement monitoring, as array locations change with new studies**
- **There is a need for a Gulfwide data base to standardize and archive data**

Examples of research using movement to inform management







Using telemetry to address mortality

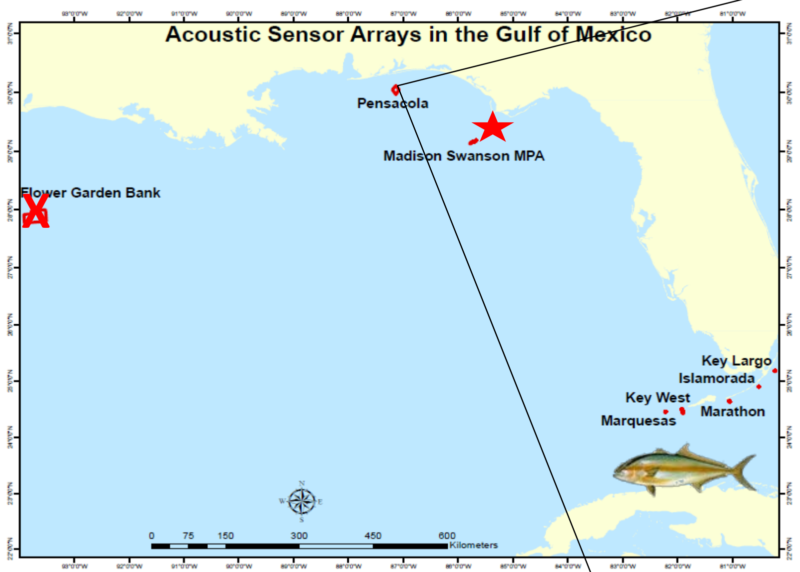
Curtis JM, Johnson MW, Diamond SL, Stunz GW (2015) Quantifying Delayed Mortality from Barotrauma Impairment in Discarded Red Snapper Using Acoustic Telemetry. Marine and Coastal Fisheries 7:434-449

Jackson LS, Drymon JM, Nelson TR, Powers SP (2018) Biotelemetry based estimates of greater amberjack (*Seriola dumerili*) post-release mortality in the northern Gulf of Mexico. Fisheries Research 208:239-246

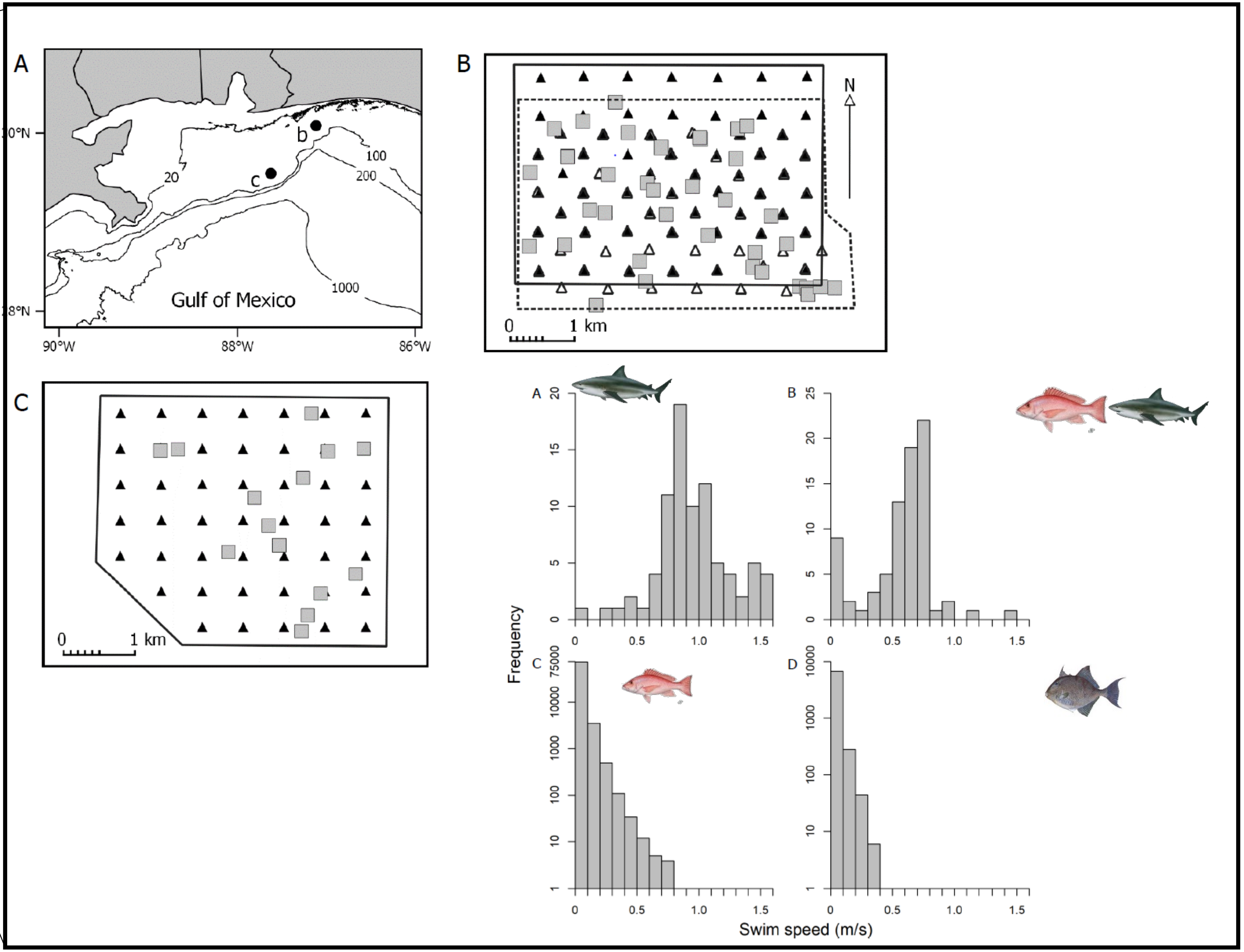
Bohaboy EC, Guttridge TL, Hammerschlag N, Van Zinnicq Bergmann MPM, Patterson WF, III (2019) Application of three-dimensional acoustic telemetry to assess the effects of rapid recompression on reef fish discard mortality. ICES Journal of Marine Science

Predation > cause of mortality and barotrauma, movement signatures to id prey event

- Will Patterson's lab

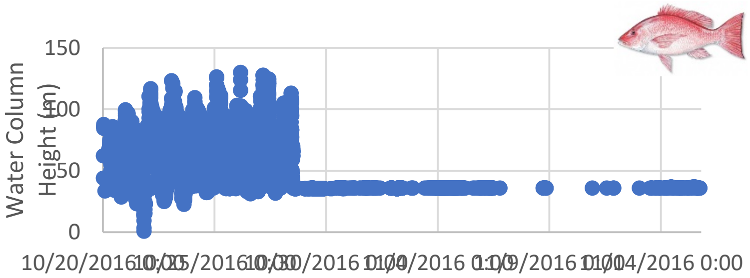


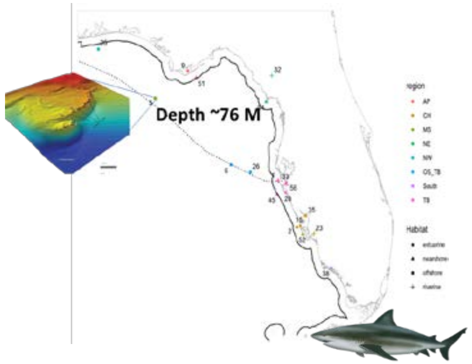
Bonaboy et al., 2019. Application of three-dimensional acoustic telemetry to assess the effects of rapid recompression on reef fish discard mortality. ICES

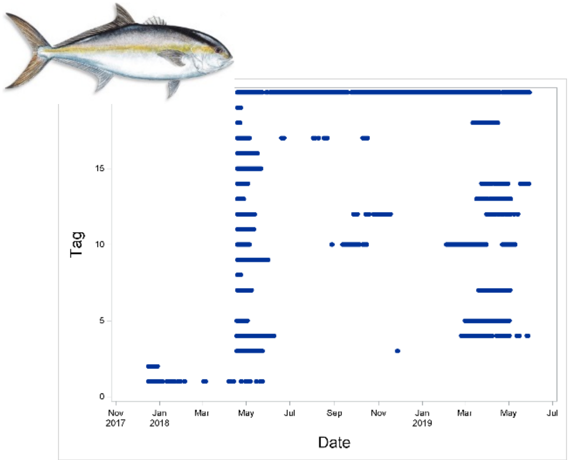


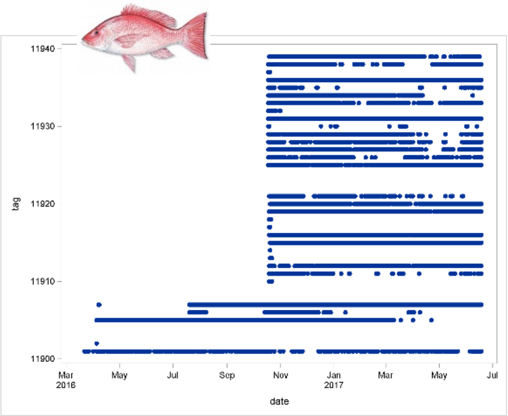
Site fidelity and discard mortality differ with species in the same habitat

- Caught by hook and line, acoustically tagged (with pressure sensors), & released with seaqualizers and cameras to confirm survival at release;
- Red snapper: 36% survival (28 out of 36 fish detected minimum 2 weeks)
- Greater amberjack: 74% survival (17 out of 20 fish detected 2 weeks or >)

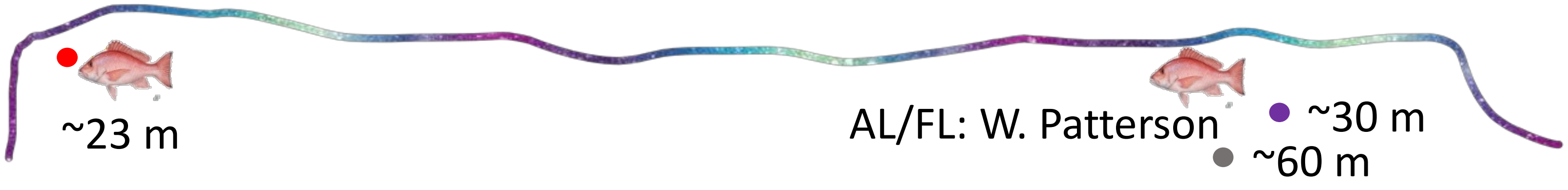


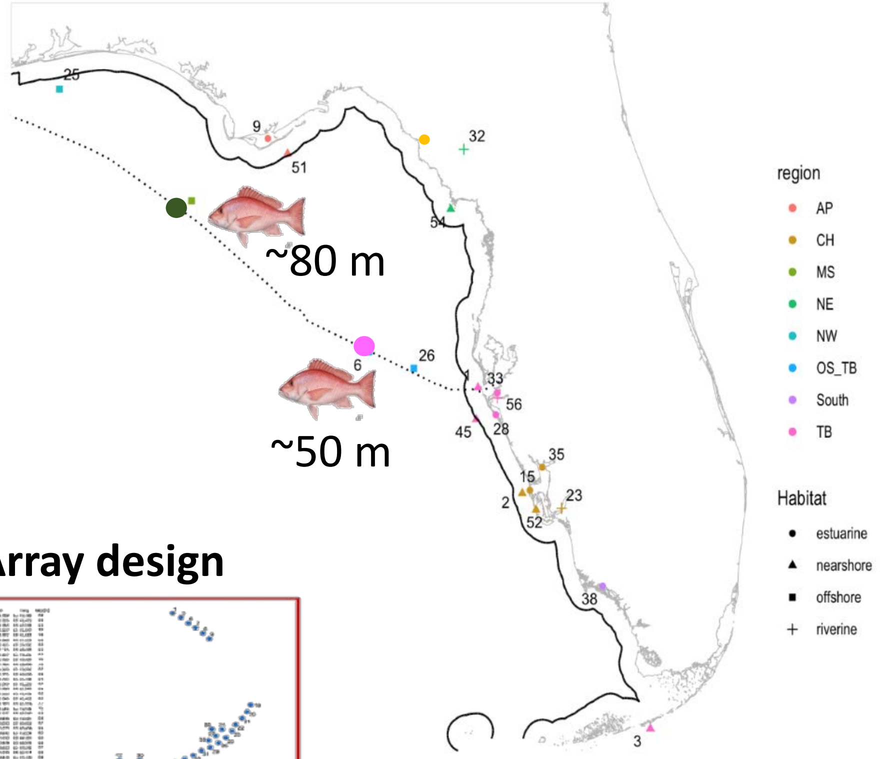






Discard mortality differs with habitat and ability to assign fate (dropped tags, array design)

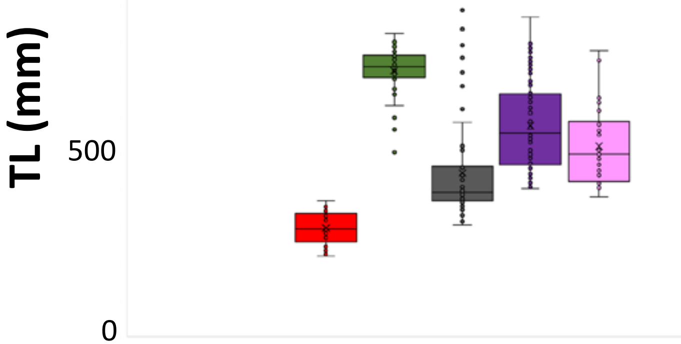




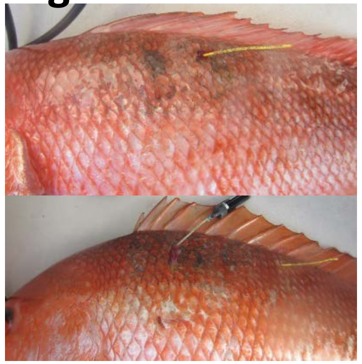
Factors affecting discard mortality & fate assignment in red snapper

Wall, K., Gibson, K., Curtis, J., Bohaboy, E., Patterson, W. Bickford, J., Lowerre-Barbieri, S.

Fish size



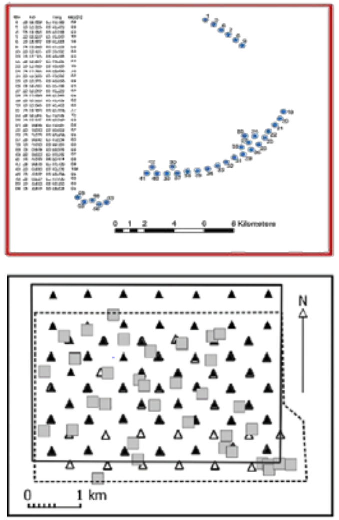
Tag loss



Depth

- ~23 m
- ~30 m
- ~50 m
- ~60 m
- ~80 m

Array design



Using telemetry to evaluate spawning and habitat use

Dance MA, Rooker JR (2015) Habitat- and bay-scale connectivity of sympatric fishes in an estuarine nursery. Estuarine, Coastal and Shelf Science

Lowerre-Barbieri SK, Walters S, Bickford J, Cooper W, Muller R (2013) Site fidelity and reproductive timing at a Spotted Seatrout spawning aggregation site: individual versus population scale behavior. Marine Ecology Progress Series 481:181-197

Lowerre-Barbieri S, Villegas-Rıos D, Walters S, Bickford J, Cooper W, Muller R (2014) Spawning Site Selection and Contingent Behavior in Common Snook, *Centropomus undecimalis*. PLoS ONE 9: e101809

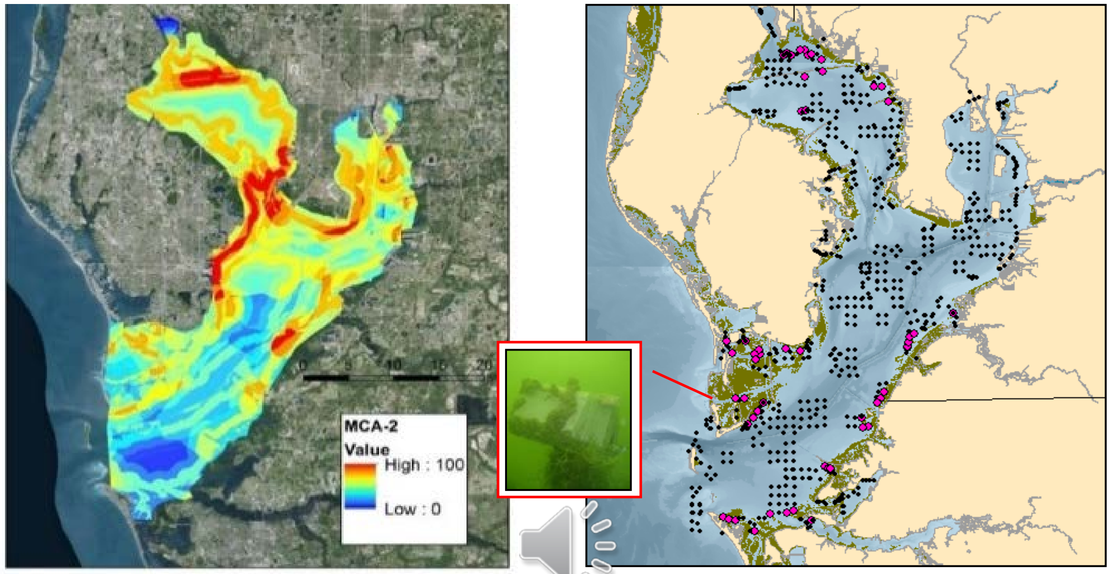
Lowerre-Barbieri SK, Walters Burnsed SL, Bickford JW (2016) Assessing reproductive behavior important to fisheries management: a case study with red drum, *Sciaenops ocellatus*. Ecological Applications 26:979-995

Zarada K, Walters Burnsed S, Bickford J, Ducharme-Barth N, Ahrens RNM, Lowerre-Barbieri S (2019) Estimating site-specific spawning parameters for a spawning aggregation: an example with spotted seatrout. Marine Ecology Progress Series 624:117-129

Examples with single species

2000

- Spawning sites well-distributed, but two patterns: within home range and at a pass spawning aggregation site
- Bunces pass: most consistently used and densely populated spawning site in Tampa Bay; fish there only at spawn times (dusk & spawning season)
- Daily spawning aggregation throughout the spawning season.



Walters et al. 2009

Ground-truthing with capture-based sampling

Fish move to this site to spawn (97% spawners); & virtually no fish here outside of spawn times

Sites just east of here: ~20% spawning and fish there year-round

Lowerre-Barbieri 2009

Passive acoustics to monitor aggregation and acoustic tracking to assess spawning frequency

Drawn from large catchment area (for seatrout); some fish moving > 100 km over a spawning season

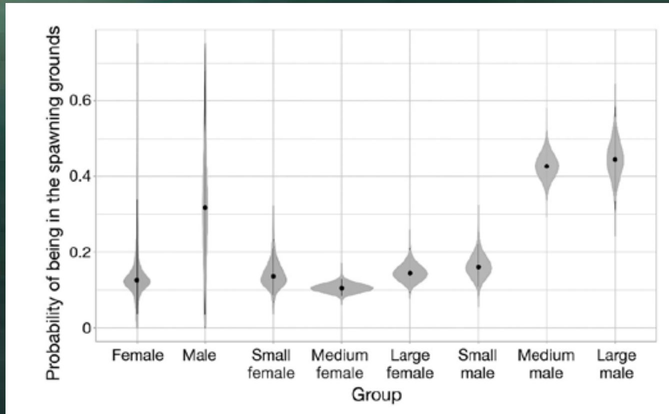
Zarada et al. 2019

Daily spawning aggregation but not the same individuals

Boucek et al., 2017

By tracking individuals we were able to calculate sex-specific spawning frequencies for the first time; showing males spawn > frequently and females spawn ~1/2 as often as previously believed

Zarada et al. 2019



Using telemetry to assess space use, recruitment, and to inform measures of abundance

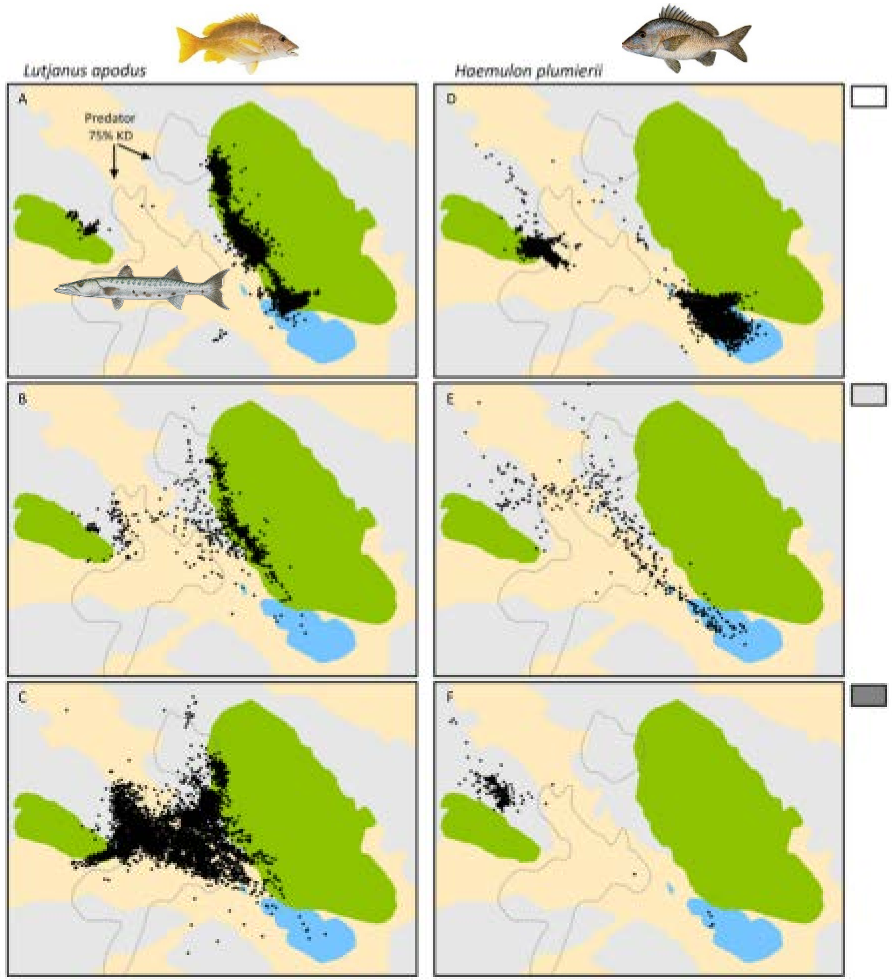
Rooker JR, Dance MA, Wells RJD, Ajemian MJ, Block BA, Castleton MR, Drymon JM, Falterman BJ, Franks JS, Hammerschlag N, Hendon JM, Hoffmayer ER, Kraus RT, McKinney JA, Secor DH, Stunz GW, Walter JF (2019) Population connectivity of pelagic megafauna in the Cuba-Mexico-United States triangle. Scientific reports 9:1663

Rooker JR, Dance MA, Wells RJD, Quigg A, Hill RL, Appeldoorn RS, Padovani Ferreira B, Boswell KM, Sanchez PJ, Moulton DL, Kitchens LL, Rooker GJ, Aschenbrenner A (2018) Seascape connectivity and the influence of predation risk on the movement of fishes inhabiting a back-reef ecosystem. Ecosphere 9:e02200

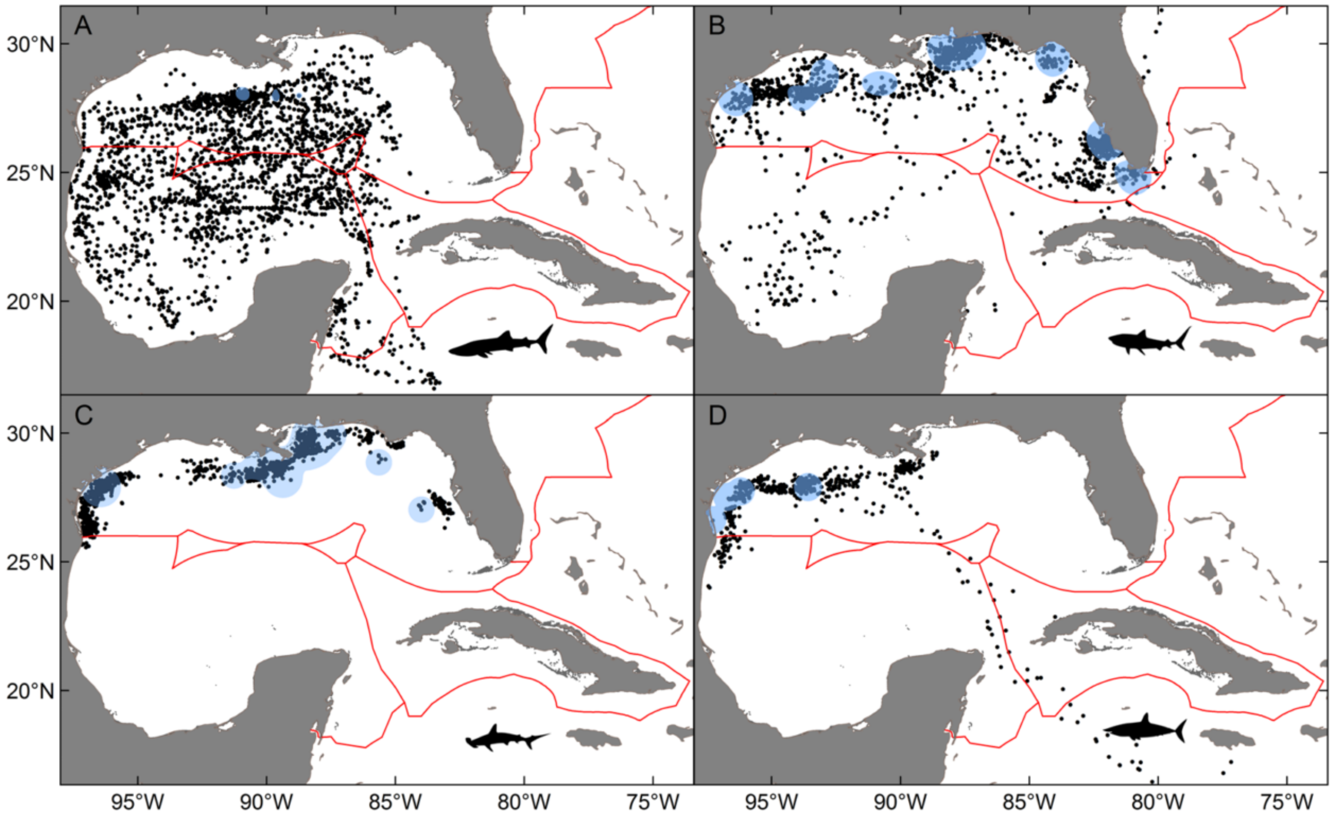
Walters Burnsed S, Lowerre-Barbieri S, Bickford J, Hoerl Leone E (2020) Recruitment and movement ecology of red drum *Sciaenops ocellatus* differs by natal estuary. Marine Ecology Progress Series 633:181-196

Lowerre-Barbieri SK, Tringali MD, Shea CP, Walters Burnsed S, Bickford J, Murphy M, Porch C, Handling editor: Caroline D (2018) Assessing red drum spawning aggregations and abundance in the Eastern Gulf of Mexico: a multidisciplinary approach. ICES Journal of Marine Science 76:516-529

Space use and trophic dynamics & national boundaries



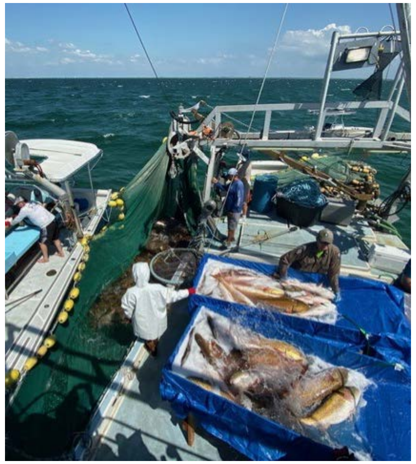
Rooker et al., 2018



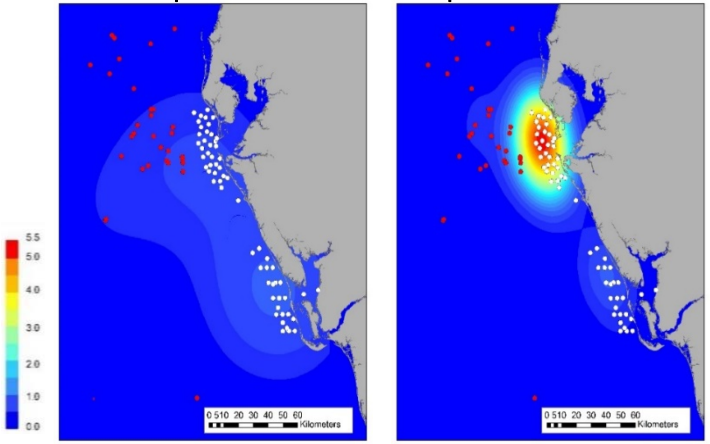
Rooker et al., 2019

Testing how availability to capture affects abundance estimates

- Stock structure: aggregate to spawn, high spawning site fidelity, form aggregations of up to 10,000 fish.
- Large home range; detected after the spawning season in an area of at least 150 km along the coast and 90 km offshore.
- Genetic tag/recapture (sampled 8,888 unique fish over 3 yrs); found a four-fold difference in annual abundance of spawners
- Integrating measures of temporary immigration/emigration into our Joly-Seber super population to address availability to capture reduced apparent abundance by 16%



Non-reproductive Reproductive



Lowerre-Barbieri et al., 2016; 2018

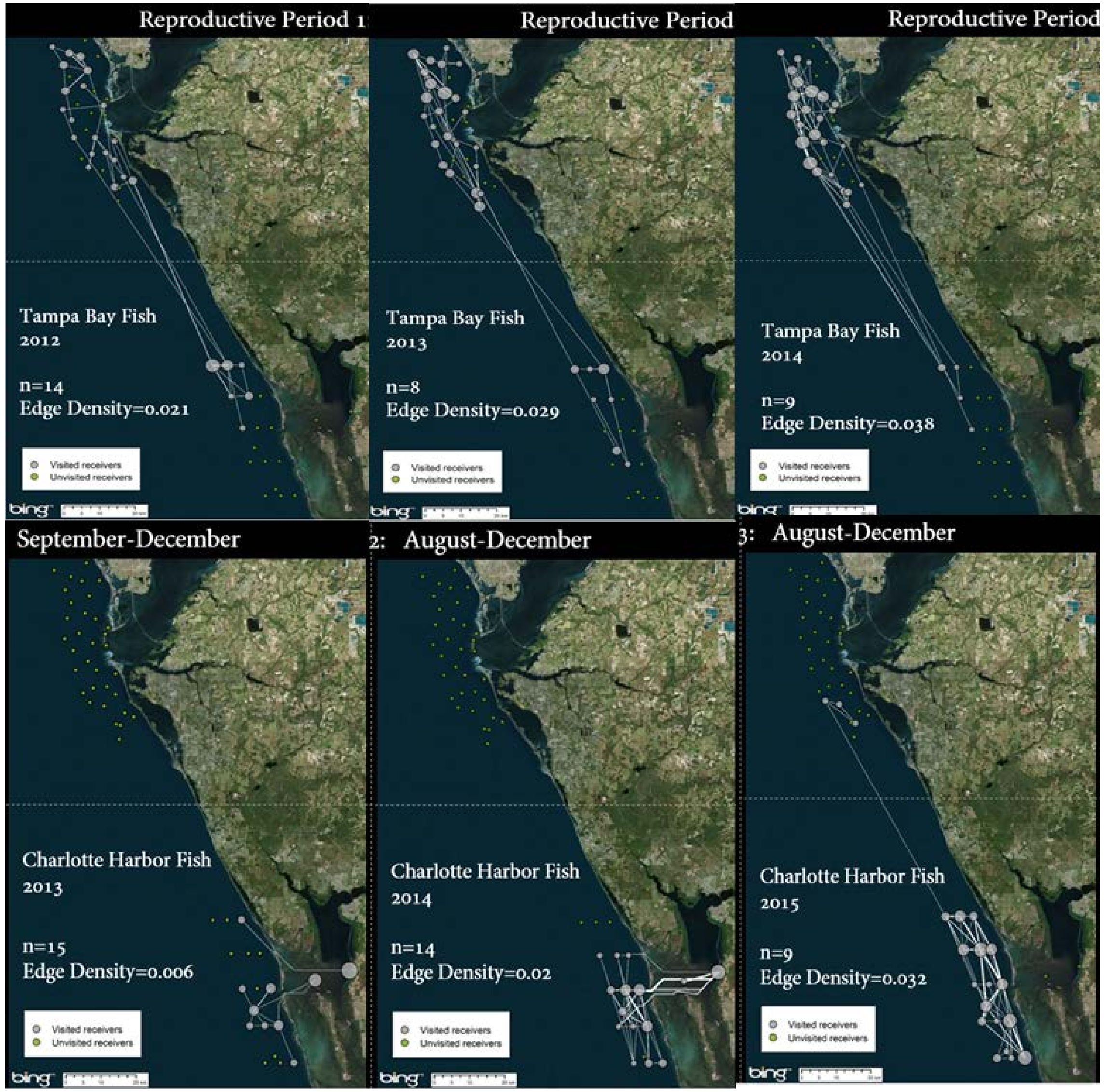
2014: JS model with immigration/emigration

Parameter	mean	sd	2.5%	50%	97.5%
mean.p	0.057	0.007	0.044	0.058	0.068
mean.phi	0.996	0.004	0.985	0.997	1.000
mean.imi	0.080	0.012	0.060	0.079	0.105
mean.emi	0.147	0.015	0.115	0.148	0.175
Nsuper	42530.289	3987.053	36196.975	41723.500	51089.100

2014: JS model without immigration/emigration

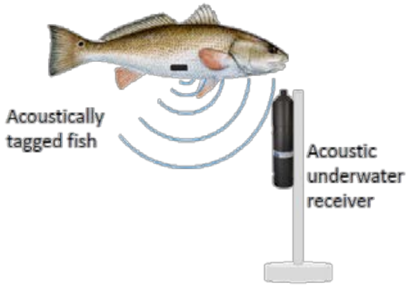
Parameter	mean	sd	2.5%	50%	97.5%
mean.p	0.045	0.004	0.038	0.045	0.056
mean.phi	0.915	0.005	0.905	0.915	0.923
Nsuper	51797.392	4878.351	42583.975	51494.000	61150.000

Tagged 20 subadults in Tampa Bay & 20 in Charlotte Harbor

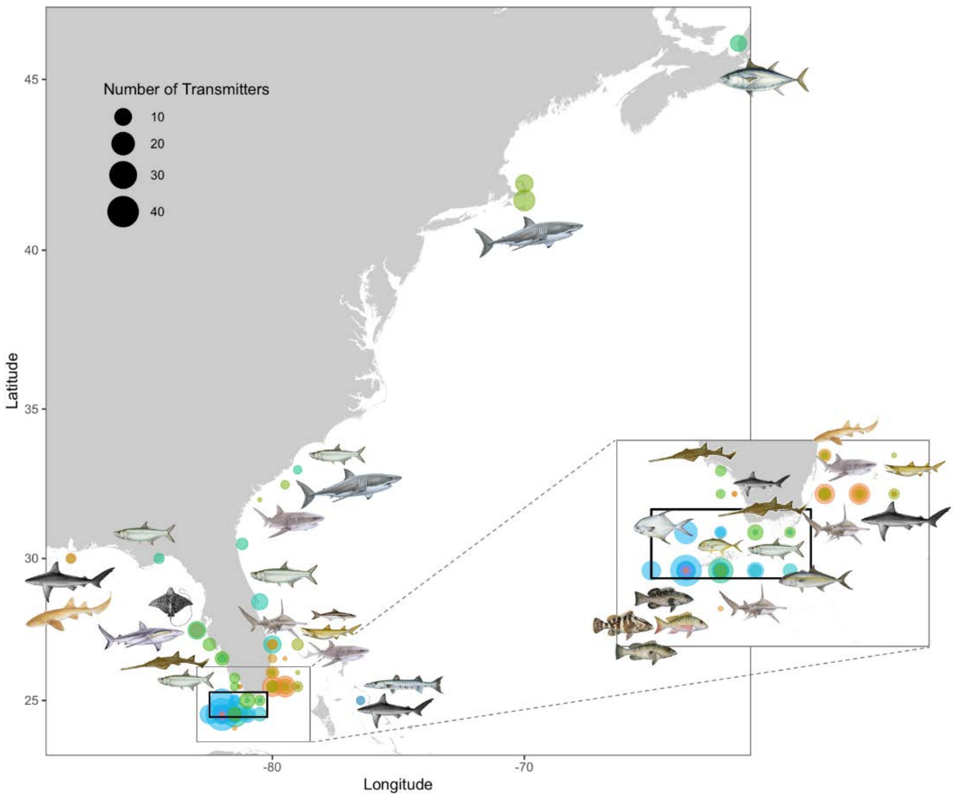


Burnsed et al., 2020

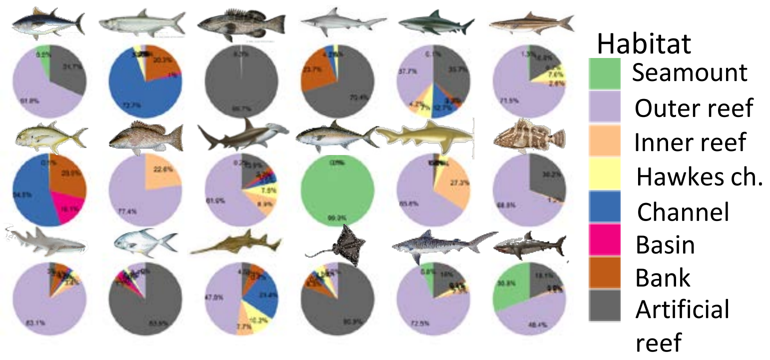
- Later recruitment by Charlotte Harbor fish & extreme within-estuary site fidelity
- Consequent movement ecology differed by natal estuary
- Natal homing, confirming Red Drum spawn off Charlotte Harbor
- Spatial scale of annual migration remains unknown



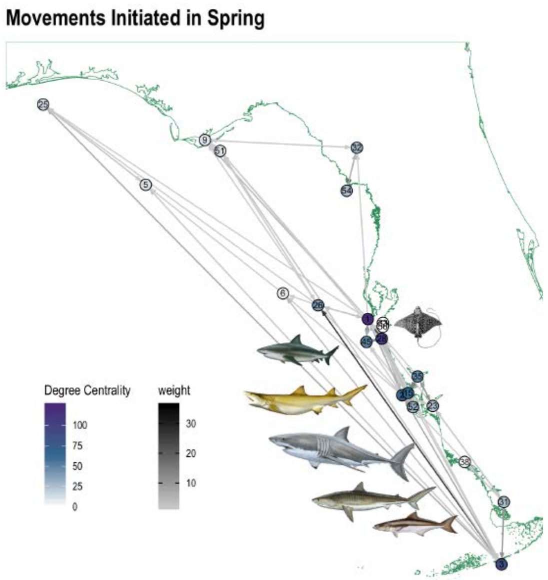
Papers in progress to demonstrate the new research possible

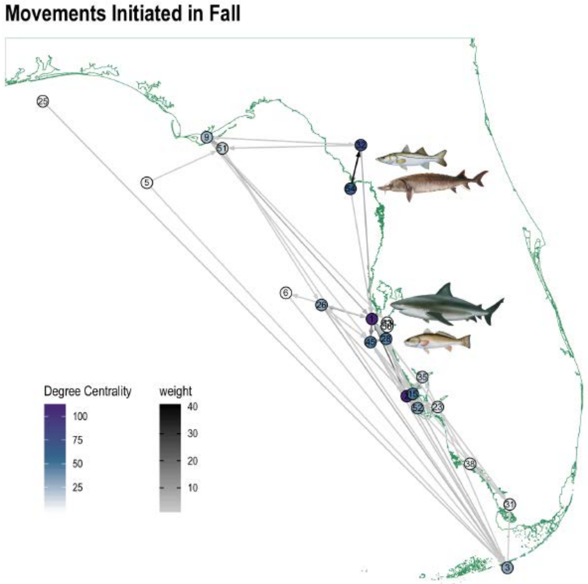


C. Friess, G. Alvarez, K. Bassos-Hull, E. Bohaboy, R.Boucek, A. Collins, A. Danylchuck, R. Ellis, A. Fox, J.Gardiner, L. Griffin, N. Hammerschlag, K. Hart, A. Hill, M. Kendall, J. Locascio, H. Menendez, P. O'Donnell, W. Patterson, C. Peterson, G. Poulakis, M. Price, C.Purtlebaugh, M. Randall, J. Rehage, R. Scharer, R.Schloesser, M. Smukall, K. Wilkinson, and S. Lowerre-Barbieri. **Using an integrative tracking network to monitor multi-species movement at the eco-region scale.**



Lowerre-Barbieri, S., Friess, C., Brownscombe, J., Morley, D., Bickford, J., Acosta, A., Addis, D., Block, B., Skomal, G., Grubbs, D., Hammershlag, N., Kroetz, A., Gervasi, C., Poulakis, G., Danylchuk, A., Griffin, L., Basso-Hull, K., Gardiner, J. and Whoriskey, F. **Monitoring movement to assess marine ecosystem health: an example in the Florida Keys**

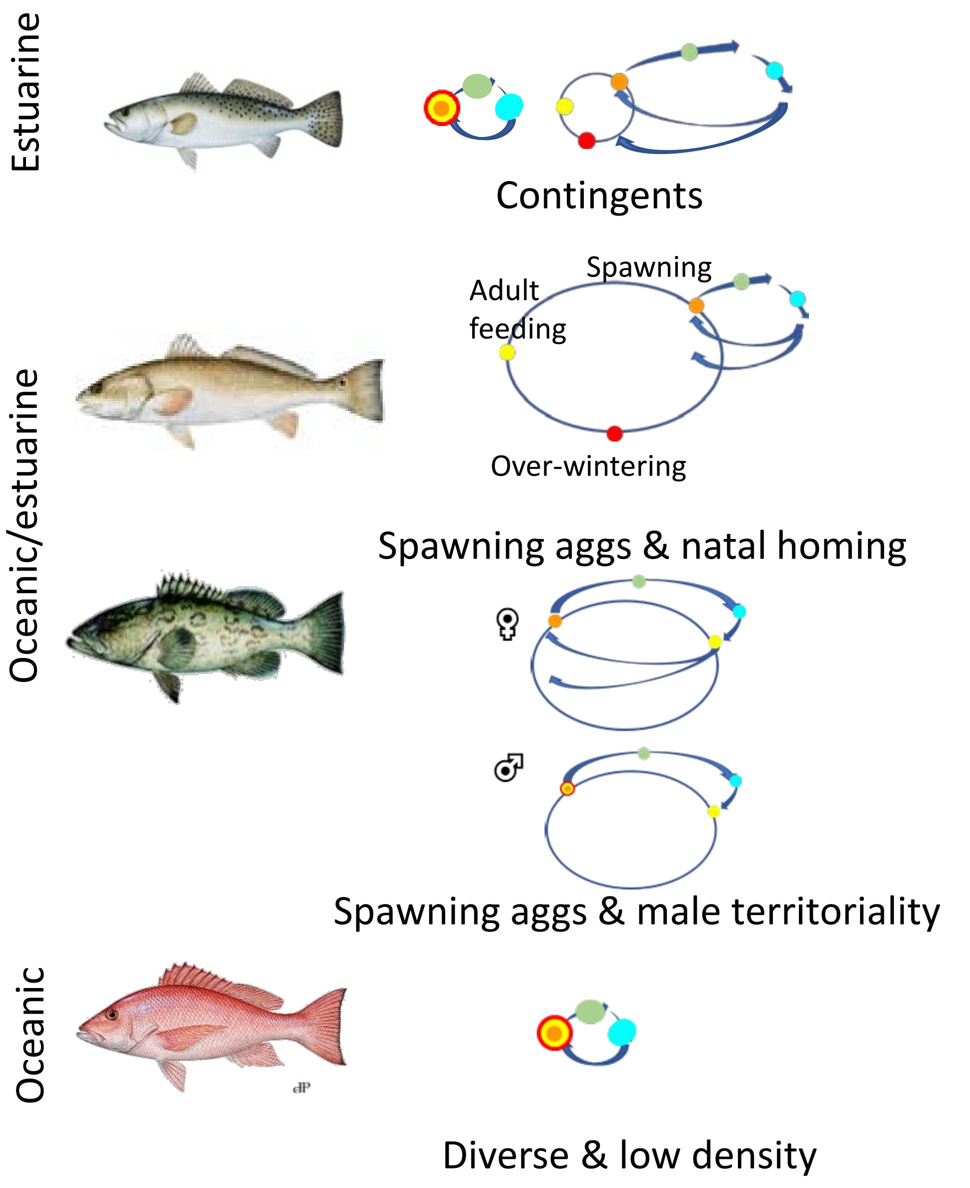


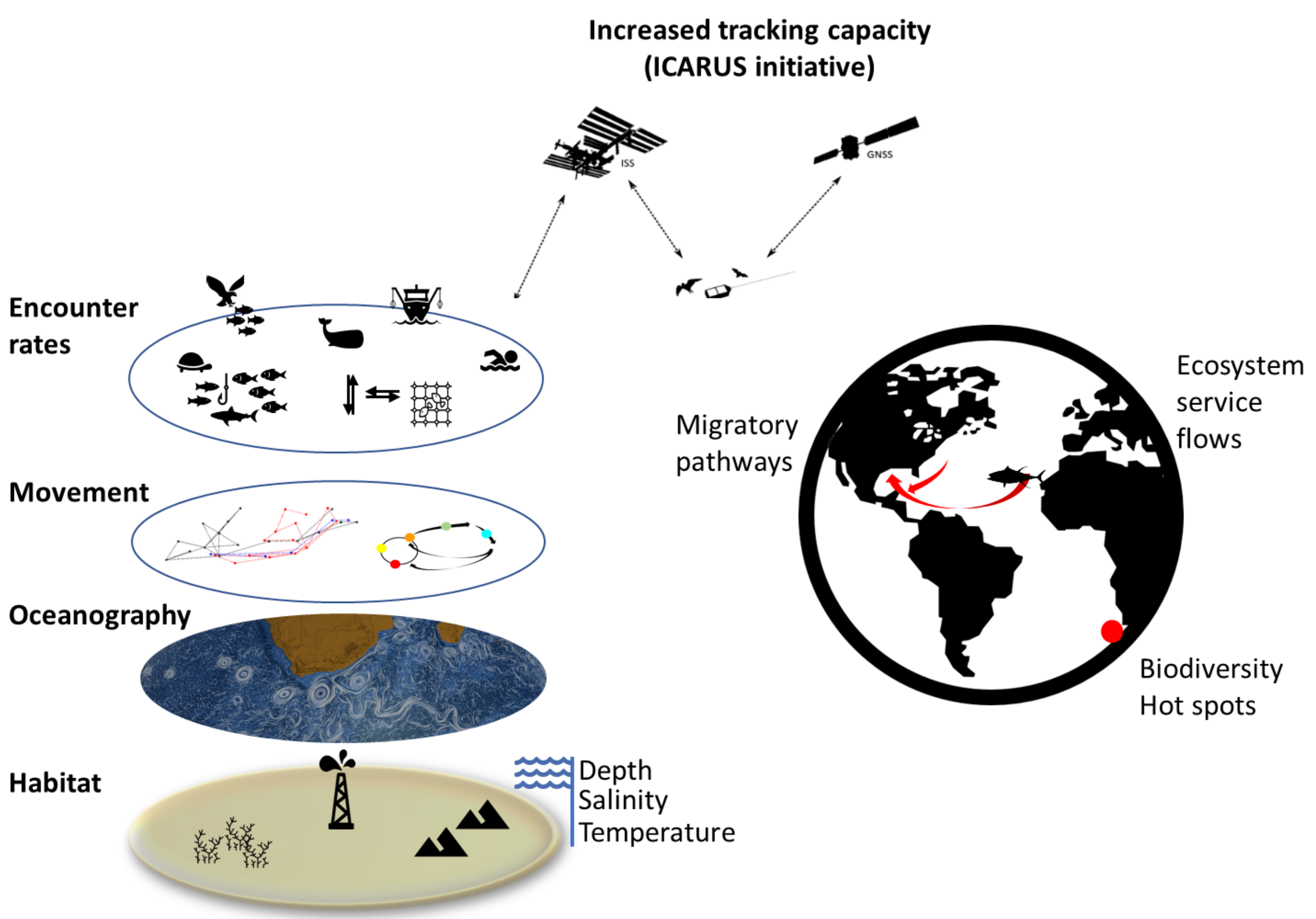


Wrapping it up

Movescapes are species-specific and drive encounter rates and ecosystem services

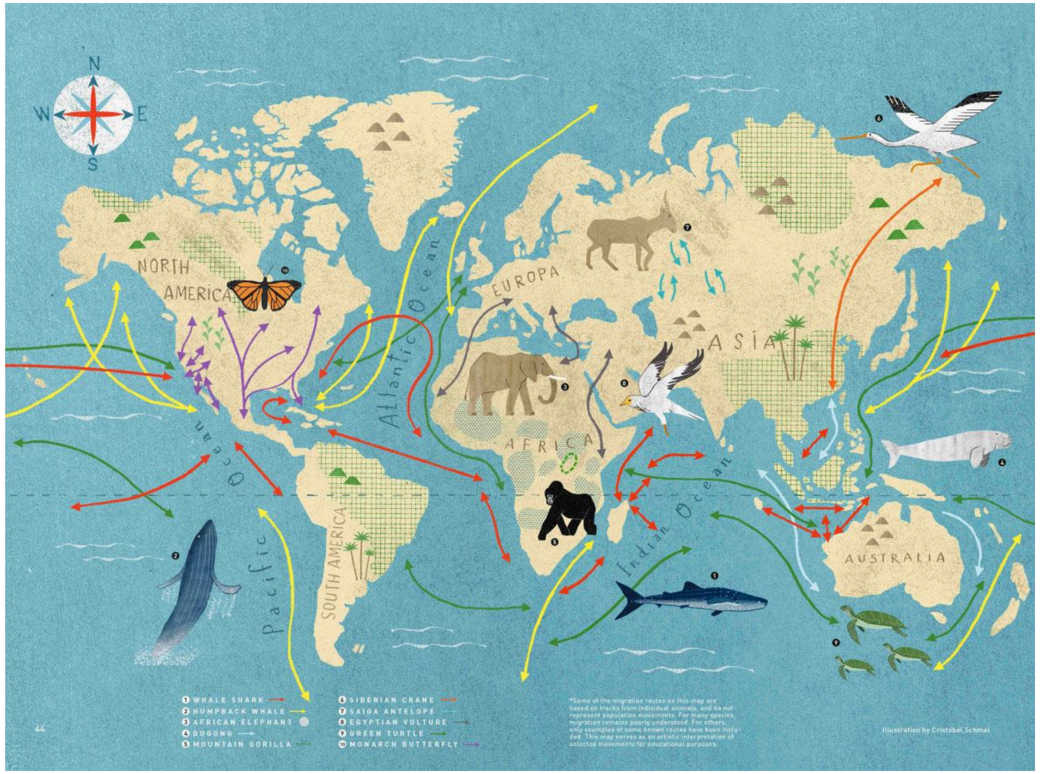
Spawning site & life cycle distributions:





Lowerre-Barbieri et al. 2019

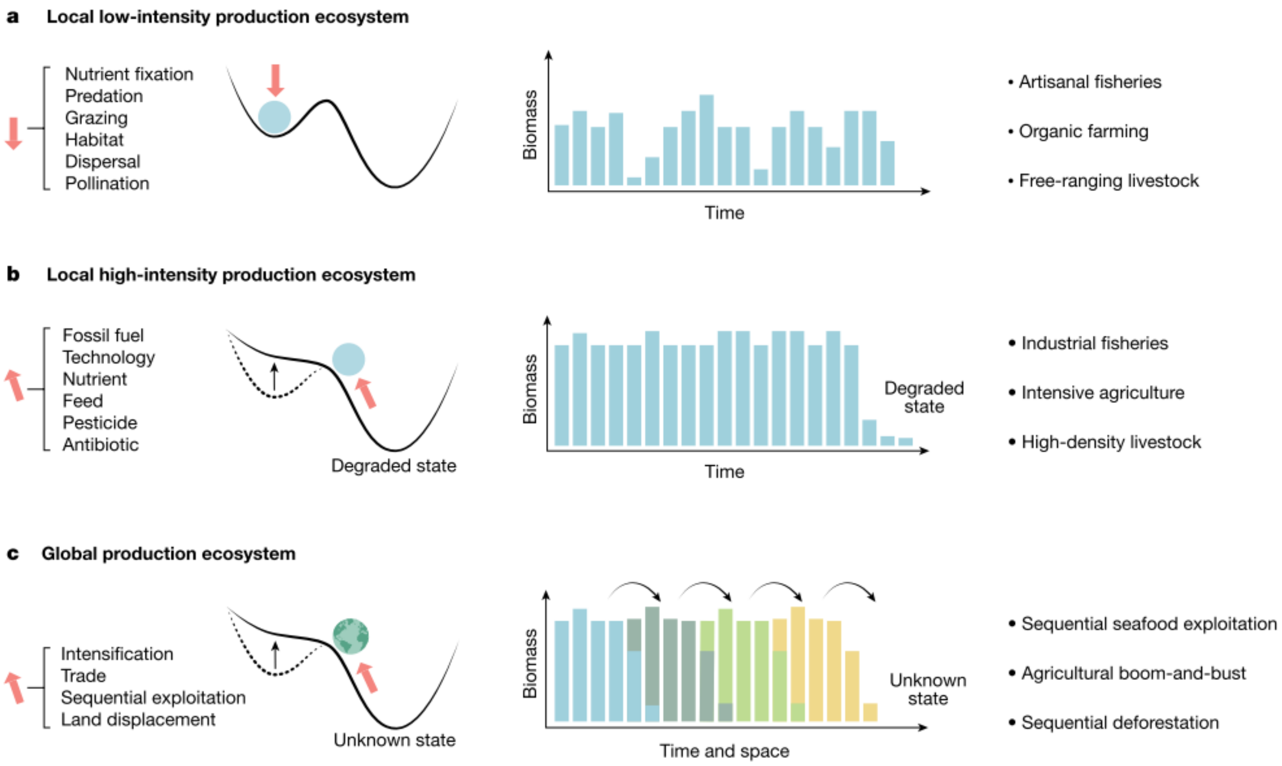
Ecosystems pushed to unnatural productivity, impacting long-term resilience



https://news.un.org/en/story/2020/02/1057511

- Concern migrating animals are more vulnerable to anthropogenic disturbances

- Productivity and risk are happening at different temporal scales

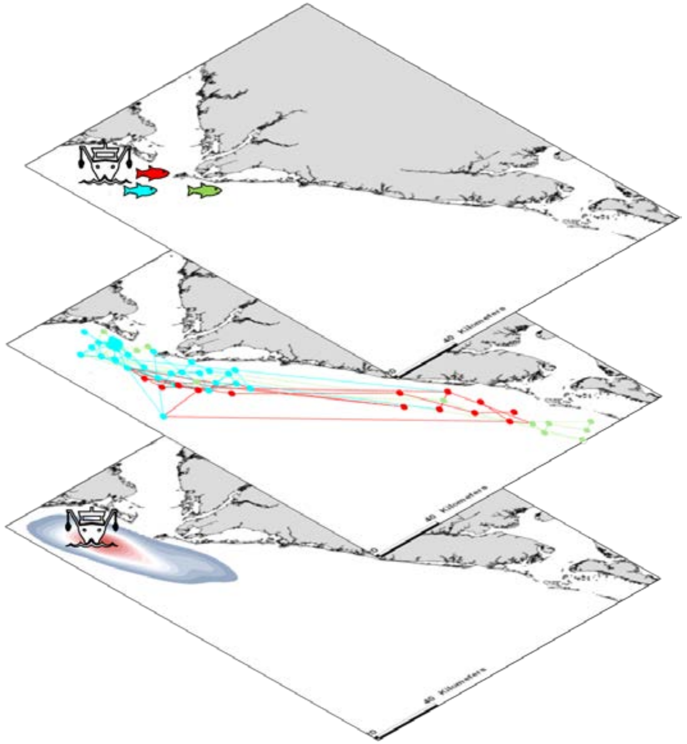


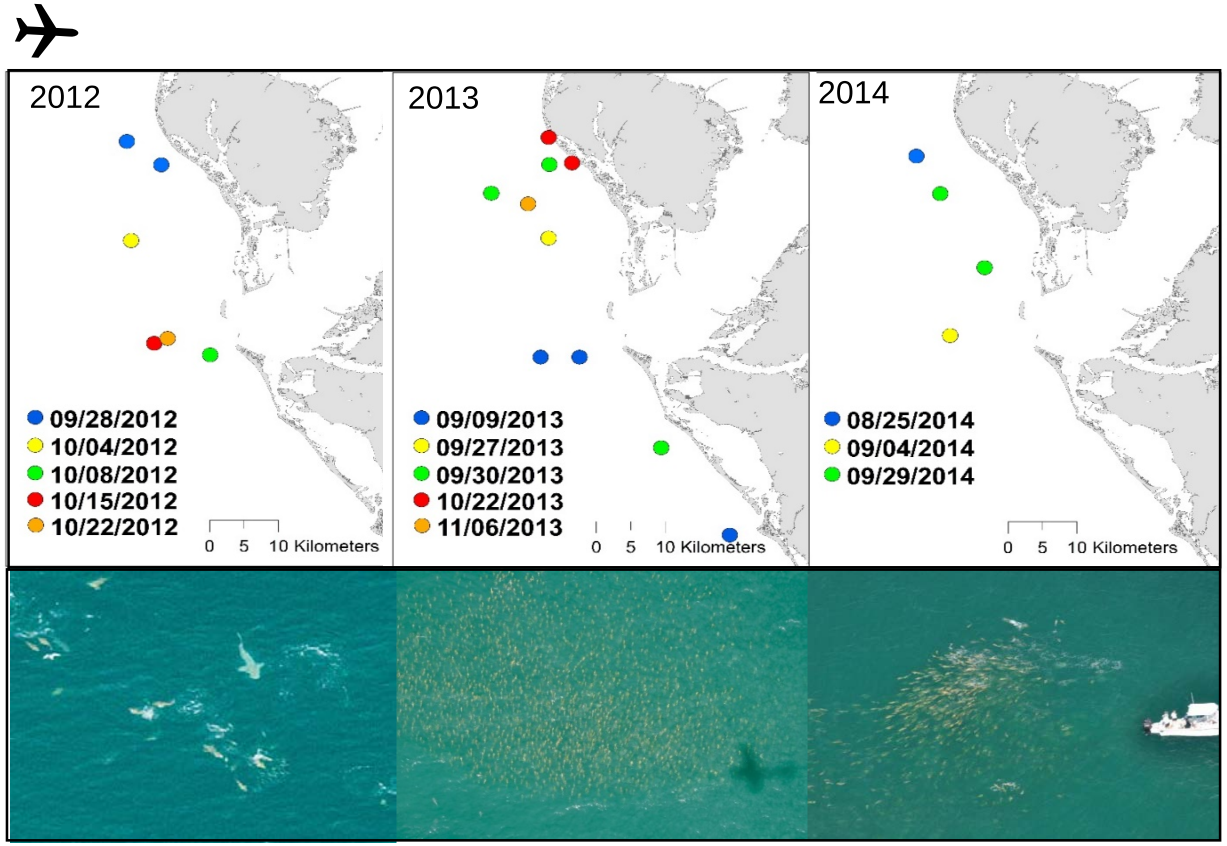
Nystrom et al., 2019. Nature **575**:98-108.

The Thirteenth Meeting of the Conference of the Parties to the Convention on the Conservation of Migratory Species of Wild Animals, or [CMS COP13](), was just completed as the world faces the threat of losing one million species to extinction unless protective efforts are increased.

Conclusions

We have an opportunity to build, test, and integrate new technology to build the research and data needed to lead the nation in integrating movement into management





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iTAG members

The MERR lab

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