# Supplementary Information

Identifying trade-offs and reference points in support of ecosystem approaches to managing Gulf of Mexico menhaden

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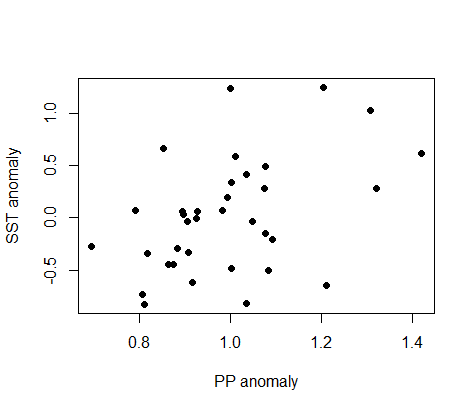
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# Supplementary Section S1: relationship between primary productivity anomaly and sea surface temperature anomaly

The primary productivity (PP) anomaly time series that was estimated by the Ecopath with Ecosim (EwE) fitting routine was significantly correlated to the Sea Surface Temperature (SST) anomaly time series (Pearson’s r=0.44, p<0.01). This suggests that warmer water temperatures resulted in higher levels of productivity for higher trophic levels (2-4) as shown in Heenan et al. (2020). This provides a possible mechanism that explains the anomaly obtained by EwE. Future modeling efforts will explore this relationship further by implementing SST as a direct forcing function. SST anomaly data were downloaded from the Gulf of Mexico Ecosystem Status Report data base (Karnauskas et al., 2017).



# Supplementary Figure S1: relationship between primary productivity anomaly and sea surface temperature anomaly.

# Supplementary Section S2: description of multisim routine use

To use the multisim routine the following steps should be taken:

* Create the appropriate input files for the simulation. The input file is a csv file that includes the forcing function values either at monthly or yearly resolution and includes the historical period that must be identical to the forcing function values, and projection period, which is manipulated according to the tested scenario (i.e., increase in fishing mortality, etc.). When multiple forcing functions are tested, they appear as separate columns, with the heading exactly as the heading in the EwE software. For environmental forcing functions, use the name provided by EwE e.g., “Forcing shape 1”. To test multiple scenarios, it is efficient to generate multiple files with R software. Place all the input files in a designated folder.
* Create an Ecosim time series file that excludes the forcing time series which you created for the multisim input files above, and that includes values for the projected period for all the other fishing related forcing functions (i.e., fishing mortality and effort). In our case, we used the geometric mean of the last three years (2014-2016) for these values.
* In the multisim plug in:
  + Choose the multisim input files folder.
  + Check the temporal resolution: either monthly or yearly.
  + Check the forcing functions that the simulations apply to- i.e., fishing mortality, and/or fishing effort.
  + Create and choose a designated output folder (empty folder) for the EwE software to write the output files of the analysis.
  + Check the desired output variables that you are interested in as output (e.g., biomass, catch).
  + Check the option for creating a unique folder for every run.

# Supplementary Tables

Supplementary Table 1. Marine taxa included in functional groups of the US Gulf-wide EwE model.

|  |  |  |
| --- | --- | --- |
| No | Functional group | Included taxonomic groups |
| 1 | Coastal dolphins | *Tursiops truncatus*, *Stenella* sp. |
| 2 | Offshore dolphins | Delphinidae |
| 3 | Baleen whales | *Balaenoptera* sp. |
| 4 | Seabird | Families of Phalacrocoracidae, Pelecanidae, Laridae, Gaviidae, Sternidae, Hydrobatidae, Procellariidae, Pandionidae, and Accipitridae. |
| 5 | Sea turtle | Cheloniidae and Dermochelyidae*.* |
| 6 | Blacktip shark | *Carcharhinus limbatus* |
| 7 | Dusky shark | *Carcharhinus obscurus* |
| 8 | Sandbar shark | *Carcharhinus plumbeus* |
| 9 | Large coastal sharks | Sphyrnidae, Odontaspididae, large Carcharhinidae. |
| 10 | Large oceanic sharks | Lamnidae, Alopiidae, *Prionace glauca* |
| 11 | Atlantic sharpnose shark | *Rhizoprionodon terraenovae* |
| 12 | Small coastal sharks | Carcharhinidae and Triakidae families, and *Sphyrna tiburo*. |
| 13 | Yellowfin tuna | *Thunnus albacares* |
| 14 | Bluefin tuna | *Thunnus thynnus* |
| 15 | Other tunas | *Katsuwonus pelamis, Thunnus obesus*, and *Thunnus Atlanticus* |
| 16 | Billfish | Istiophoridae |
| 17 | Swordfish | *Xiphias gladius* |
| 18 | Pelagic coastal piscivores | Coryphaenidae, Pomatomidae, Carangidae, Echeneidae, Belonidae, Lobotidae, *Sarda spp.*, *Euthynnus spp., Auxis spp., Acanthocybium solandri* |
| 19 | Amberjack | *Seriola dumerili, S. fasciata* |
| 20 | Cobia | *Rachycentron canadum* |
| 21 | King mackerel (0-1yr) | Age-0 to 1 year *Scomberomorus cavalla* |
| 22 | King mackerel (1+yr) | Age-1 and older *S. cavalla* |
| 23 | Spanish mackerel (0-1yr) | Age-0 to 1 year *S. maculatus* |
| 24 | Spanish mackerel (1+yr) | Age-1 and older *S. maculatus* |
| 25 | Skates-rays | Rajidae, Gymnuridae, Myliobatidae, Dasyatidae, Rhinobatidae, *Ginglymostoma cirratum* |
| 26 | Gag grouper (0-3yr) | Age-0 to 3 years *Mycteroperca microlepis* |
| 27 | Gag grouper (3+yr) | Age-3 and older years *M. microlepis* |
| 28 | Red grouper (0-3yr) | Age-0 to 3 years *Epinephelus morio* |
| 29 | Red grouper (3+yr) | Age-3 and older years *E. morio* |
| 30 | Yellowedge grouper (0-3yr) | Age-0 to 3 years *Hyporthodus flavolimbatus* |
| 31 | Yellowedge grouper (3+yr) | Age-3 and older years *H. flavolimbatus* |

Supplementary Table 1 Continued. Marine taxa included in functional groups of the US Gulf-wide EwE model.

|  |  |  |
| --- | --- | --- |
| No | Functional group | Included taxonomic groups |
| 32 | Goliath grouper | *E. itajara* |
| 33 | Deep-water grouper | *Hyporthodus niveatus, H. nigritus, E. drummondhayi, H. mystacinus* |
| 34 | Shallow-water grouper | *Epinephelus striatus, Mycteroperca venenosa, M. interstitialis, E. adscensionis, E. guttatus, M. phenax* |
| 35 | Red snapper (0yr) | Age-0 to 1 year *Lutjanus campechanus* |
| 36 | Red snapper (1-2yr) | Age-1 to 2 years *Lutjanus campechanus* |
| 37 | Red snapper (3+yr) | Age-3 and older years *Lutjanus campechanus* |
| 38 | Vermilion snapper | *Rhomboplites aurorubens* |
| 39 | Mutton snapper | *Lutjanus analis* |
| 40 | Other snapper | Lutjanidae |
| 41 | Coastal piscivores | Megalopidae, Elopidae, Centropomidae, Albulidae |
| 42 | Sea trout | *Cynoscion* spp. |
| 43 | Oceanic piscivores | Trichiuridae, Gempylidae, Bramidae, *Merluccius albidus* |
| 44 | Benthic piscivores | Paralichthyidae, Uranoscopidae, Synodontidae, Ophichthidae, Squatinidae |
| 45 | Reef piscivores | Holocentridae, Sphyraenidae, Muraenidae, Congridae, *Rypticus* spp. |
| 46 | Reef invertebrate feeders | Serranidae, Labridae, Scorpaenidae, Chaetodontidae, Priacanthidae, Haemulidae, Sparidae, *Ocyurus chrysurus* |
| 47 | Demersal coastal invertebrate feeders | Sciaenidae, Ariidae, Gerreidae, *Trachinotus* spp., *Chloroscombrus chrysurus, Oligoplites saurus, Pagrus pagrus, Haemulon aurolineatum, Orthopristis chrysoptera* |
| 48 | Red drum | *Sciaenops ocellatus* |
| 49 | Benthic coastal invertebrate feeders | Pleuronectiformes, Triglidae, Polynemidae, Gobiidae, Ophidiidae |
| 50 | Tilefish | Malacanthidae |
| 51 | Gray triggerfish | *Balistes capriscus* |
| 52 | Coastal omnivores | Tetraodontiformes, Ephippidae, *Lagodon rhomboides* |
| 53 | Reef omnivores | Pomacanthidae, Acanthuridae, Pomacentridae, Scaridae |
| 54 | Surface pelagics | Exocoetidae, Hemiramphidae |
| 55 | Large oceanic planktivores | *Manta birostris*, *Cetorhinus maximus*, *Rhincodon typus*, *Mola mola* |
| 56 | Oceanic planktivores | Argentinidae, Nomeidae |
| 57 | Sardine-herring-scad | Clupeidae, *Decapterus* spp. |
| 58 | Menhaden (0yr) | *Brevoortia* spp. Ages 0 to 1 year |
| 59 | Menhaden (1yr) | *Brevoortia* spp. Ages 1 to 2 years |
| 60 | Menhaden (2yr) | *Brevoortia* spp. Ages 2 to 3 years |

Supplementary Table 1 Continued. Marine taxa included in functional groups of the US Gulf-wide EwE model.

|  |  |  |
| --- | --- | --- |
| No | Functional group | Included taxonomic groups |
| 61 | Menhaden (3yr) | *Brevoortia* spp. Ages 3 to 4 years |
| 62 | Menhaden (4+yr) | *Brevoortia* spp. Ages 4 and older years |
| 63 | Anchovy-silverside-killifish | Engraulidae, Atherinidae, Fundulidae |
| 64 | Mullet | Mugilidae |
| 65 | Butterfish | Stromateidae |
| 66 | Cephalopod | Cephalopoda |
| 67 | Pink shrimp | *Farfantepenaeus duorarum* |
| 68 | Brown shrimp | *Farfantepenaeus aztecus* |
| 69 | White shrimp | *Litopenaeus setiferus* |
| 70 | Crab | Portunidae |
| 71 | Sessile epifauna | Porifera, Anthozoa, Tunicata, Bryozoa, Hydrozoa, Crinoidea, Mytilidae |
| 72 | Mobile epifauna | Malacostraca, Ostracoda, Echinoderma, Gastropoda, Pectinidae |
| 73 | Zooplankton | Copepoda, Euphausiacea, Scyphozoa, planktonic eggs/larvae |
| 74 | Infauna | Annelida, Nematoda, Bivalvia, Thalassinidea, Hippidae |
| 75 | Algae | Rhodophyta, Chlorophyta, Phaeophyta, Cyanophyta, Xanthophyta, Cyanobacteria |
| 76 | Seagrass | Marine angiosperms |
| 77 | Phytoplankton | Bacillariophyceae, Dinoflagellata, Protozoa |
| 78 | Detritus | Calcareous debris, mud, organic matter, fishery discards, detritus |

Supplementary Table 2. Basic inputs and estimates for the 1980 Gulf-wide Ecopath model including biomass (B, t km-2), biomass accumulation (BA, year-1), production to biomass ratio (P/B, year-1) or total mortality rate (Z, year-1), consumption to biomass ratio (Q/B, year-1), landings and discards (t km-2), trophic level (TL), ecotrophic efficiency (EE), fishing mortality (F, year-1, with the percent attributed to the menhaden purse seine (PS) given in parentheses), and predation mortality (M2, year-1). Note that a value of 0\* indicates either landings or discards < 0.00005 or *F* < 0.005.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | Functional group | B | BA | Z or P/B | Q/B | Landings | Discards | TL | EE | F (%PS) | M2 |
| 1 | Coastal dolphins | 0.021 | 0 | 0.16 | 15 | 0 | 0 | 3.44 | 0.82 | 0 | 0.131 |
| 2 | Offshore dolphins | 0.021 | 0 | 0.16 | 15 | 0 | 0 | 3.79 | 0.6 | 0 | 0.097 |
| 3 | Baleen whales | 0.021 | 0 | 0.16 | 15 | 0 | 0 | 3.47 | 0.07 | 0 | 0.011 |
| 4 | Seabird | 0.015 | 0 | 0.25 | 33 | 0 | 0 | 3.31 | 0.54 | 0 | 0.134 |
| 5 | Sea turtle | 0.013 | 0 | 0.12 | 3.5 | 0 | 0 | 3.42 | 0.83 | 0 | 0.1 |
| 6 | Blacktip shark | 0.095 | 0 | 0.32 | 3.2 | 0.0006 | 0.0004 | 3.37 | 0.21 | 0.01 (18.7) | 0.06 |
| 7 | Dusky shark | 0.009 | 0 | 0.28 | 2.8 | 0.0002 | 0\* | 3.75 | 0.26 | 0.03 (65.6) | 0.045 |
| 8 | Sandbar shark | 0.002 | 0 | 0.34 | 3.2 | 0.0001 | 0.0001 | 3.64 | 0.69 | 0.16 (11.6) | 0.071 |
| 9 | Large coastal sharks | 0.038 | 0 | 0.3 | 3 | 0.0006 | 0.0006 | 3.64 | 0.4 | 0.03 (22.9) | 0.091 |
| 10 | Large oceanic sharks | 0.028 | 0 | 0.29 | 2.7 | 0\* | 0 | 3.61 | 0.28 | 0 | 0.079 |
| 11 | Atlantic sharpnose shark | 0.020 | 0 | 0.58 | 5.8 | 0.0007 | 0.0067 | 3.39 | 0.94 | 0.38 (0.3) | 0.17 |
| 12 | Small coastal sharks | 0.002 | 0 | 0.5 | 5 | 0.0001 | 0.0002 | 3.47 | 0.97 | 0.15 (4.5) | 0.336 |
| 13 | Yellowfin tuna | 0.003 | 0 | 1.08 | 8.4 | 0.0022 | 0\* | 3.85 | 0.96 | 0.8 | 0.235 |
| 14 | Bluefin tuna | 0.001 | 0 | 0.43 | 4.3 | 0\* | 0\* | 3.71 | 0.8 | 0.11 | 0.234 |
| 15 | Other tunas | 0.006 | 0 | 0.89 | 8.9 | 0.0033 | 0\* | 3.62 | 0.83 | 0.56 | 0.179 |
| 16 | Billfish | 0.003 | 0 | 0.6 | 4.9 | 0.0014 | 0.0001 | 3.74 | 0.95 | 0.51 | 0.063 |
| 17 | Swordfish | 0.014 | 0 | 0.44 | 3.8 | 0.0055 | 0\* | 3.75 | 0.98 | 0.4 | 0.037 |
| 18 | Pelagic coastal piscivores | 0.062 | 0 | 0.76 | 6.3 | 0.0155 | 0.0010 | 3.33 | 0.84 | 0.27 (8.2) | 0.369 |
| 19 | Amberjack | 0.029 | 0 | 0.44 | 3.9 | 0.0061 | 0.0001 | 3.57 | 0.85 | 0.21 | 0.158 |
| 20 | Cobia | 0.011 | 0 | 0.62 | 4.1 | 0.0017 | 0.0006 | 3.66 | 0.57 | 0.21 | 0.149 |
| 21 | King mackerel (0-1yr) | 0.001 | 0 | 1.46 | 14.3 | 0 | 0.0001 | 3.35 | 0.37 | 0.12 | 0.418 |
| 22 | King mackerel (1+yr) | 0.140 | 0 | 0.22 | 3.5 | 0.0093 | 0\* | 3.36 | 0.9 | 0.07 (1.8) | 0.129 |
| 23 | Spanish mackerel (0-1yr) | 0.001 | 0 | 2 | 19.8 | 0.0001 | 0.0015 | 3.33 | 0.93 | 1.37 | 0.483 |
| 24 | Spanish mackerel (1+yr) | 0.063 | 0.0009 | 0.52 | 5.2 | 0.0060 | 0.0061 | 3.54 | 0.74 | 0.19 (11.2) | 0.189 |
| 25 | Skates-rays | 0.034 | 0 | 0.48 | 4.8 | 0.0004 | 0.0001 | 2.88 | 0.93 | 0.02 (63.9) | 0.433 |
| 26 | Gag grouper (0-3yr) | 0.003 | 0.0003 | 0.57 | 9.3 | 0.0006 | 0.0001 | 3.4 | 0.82 | 0.24 | 0.227 |
| 27 | Gag grouper (3+yr) | 0.018 | 0.0018 | 0.37 | 3.6 | 0.0044 | 0\* | 3.47 | 0.93 | 0.25 | 0.098 |
| 28 | Red grouper (0-3yr) | 0.003 | 0.0002 | 0.43 | 9.2 | 0 | 0\* | 3.38 | 0.79 | 0.01 | 0.332 |
| 29 | Red grouper (3+yr) | 0.027 | 0.0013 | 0.37 | 3.7 | 0.0069 | 0.0005 | 3.33 | 0.97 | 0.28 | 0.083 |
| 30 | Yellowedge grouper (0-3yr) | 0.000 | 0 | 0.32 | 18.1 | 0\* | 0 | 3.28 | 0.69 | 0 | 0.221 |
| 31 | Yellowedge grouper (3+yr) | 0.048 | 0.0005 | 0.1 | 3.7 | 0.0013 | 0 | 3.17 | 0.53 | 0.03 | 0.027 |
| 32 | Goliath grouper | 0.001 | 0 | 0.33 | 3.3 | 0.0003 | 0\* | 3.59 | 0.93 | 0.21 | 0.095 |
| 33 | Deep-water grouper | 0.007 | 0 | 0.4 | 4 | 0.0009 | 0 | 3.56 | 0.44 | 0.14 | 0.039 |
| 34 | Shallow-water grouper | 0.013 | 0 | 0.62 | 6.2 | 0.0041 | 0.0004 | 3.48 | 0.85 | 0.36 | 0.168 |

Supplementary Table 2 Continued. Basic inputs and estimates for the 1980 Gulf-wide Ecopath model.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | Functional group | B | BA | Z or P/B | Q/B | Landings | Discards | TL | EE | F (%PS) | M2 |
| 35 | Red snapper (0yr) | 0.003 | 0.0002 | 1 | 18.4 | 0\* | 0.0009 | 3.38 | 0.47 | 0.31 | 0.162 |
| 36 | Red snapper (1-2yr) | 0.020 | 0.0016 | 1.6 | 7.9 | 0.0021 | 0.0002 | 3.42 | 0.17 | 0.11 | 0.158 |
| 37 | Red snapper (3+yr) | 0.042 | 0.0034 | 0.33 | 3.3 | 0.0106 | 0.0002 | 3.32 | 0.84 | 0.26 | 0.024 |
| 38 | Vermilion snapper | 0.072 | 0 | 0.52 | 4.5 | 0.0006 | 0.0022 | 3.02 | 0.31 | 0.04 | 0.123 |
| 39 | Mutton snapper | 0.015 | 0 | 0.58 | 5.8 | 0.0009 | 0\* | 3.24 | 0.33 | 0.06 | 0.133 |
| 40 | Other snapper | 0.014 | 0 | 0.6 | 6 | 0.0022 | 0.0001 | 3.15 | 0.93 | 0.17 | 0.392 |
| 41 | Coastal piscivores | 0.085 | 0 | 0.67 | 6.5 | 0.0189 | 0.0004 | 3.13 | 0.96 | 0.23 (72.9) | 0.42 |
| 42 | Sea trout | 0.108 | 0 | 0.73 | 7 | 0.0451 | 0.0049 | 3.03 | 0.98 | 0.47 (29.3) | 0.25 |
| 43 | Oceanic piscivores | 0.036 | 0 | 1 | 8.5 | 0.0004 | 0\* | 3.36 | 0.99 | 0.01 (99.5) | 0.98 |
| 44 | Benthic piscivores | 0.027 | 0 | 0.7 | 5 | 0.0020 | 0.0003 | 3.32 | 0.97 | 0.09 (0.01) | 0.593 |
| 45 | Reef piscivores | 0.025 | 0 | 0.84 | 5.4 | 0.0050 | 0.0001 | 3.3 | 0.93 | 0.2 | 0.581 |
| 46 | Reef invertebrate feeders | 0.183 | 0 | 1.05 | 5.8 | 0.0128 | 0.0015 | 2.8 | 0.9 | 0.08 (1.4) | 0.867 |
| 47 | Demersal coastal invertebrate feeders | 0.255 | 0 | 1 | 5.9 | 0.0566 | 0.0183 | 2.81 | 0.9 | 0.29 (21.3) | 0.607 |
| 48 | Red drum | 0.115 | 0 | 0.5 | 5 | 0.0125 | 0.0003 | 3.18 | 0.35 | 0.11 (0.2) | 0.065 |
| 49 | Benthic coastal invertebrate feeders | 0.170 | 0 | 1.25 | 5.8 | 0.0003 | 0.0002 | 2.8 | 0.97 | 0\* (11.5) | 1.203 |
| 50 | Tilefish | 0.007 | 0 | 0.35 | 3.5 | 0.0003 | 0\* | 3.27 | 0.27 | 0.04 | 0.051 |
| 51 | Gray triggerfish | 0.055 | 0 | 0.59 | 5.9 | 0.0017 | 0.0062 | 2.79 | 0.38 | 0.14 | 0.082 |
| 52 | Coastal omnivores | 0.165 | 0 | 0.88 | 8.8 | 0.0027 | 0.0002 | 2.73 | 0.99 | 0.02 (3.8) | 0.851 |
| 53 | Reef omnivores | 0.020 | 0 | 1.4 | 8.4 | 0.0001 | 0\* | 2.68 | 0.95 | 0\* | 1.323 |
| 54 | Surface pelagics | 0.125 | 0 | 1.45 | 11.7 | 0.0003 | 0 | 2.86 | 0.91 | 0\* (8.9) | 1.322 |
| 55 | Large oceanic planktivores | 0.017 | 0 | 0.16 | 1.3 | 0 | 0 | 3.22 | 0.38 | 0 | 0.06 |
| 56 | Oceanic planktivores | 0.045 | 0 | 0.87 | 8.7 | 0 | 0 | 3.16 | 0.94 | 0 | 0.818 |
| 57 | Sardine-herring-scad | 0.630 | 0 | 1.05 | 10.5 | 0.0076 | 0\* | 2.77 | 0.91 | 0.01 (24.9) | 0.946 |
| 58 | Menhaden (0yr) | 1.893 | 0.6246 | 1.67 | 42.9 | 0.0024 | 0 | 2.25 | 0.04 | 0\* (55.2) | 0.057 |
| 59 | Menhaden (1yr) | 4.414 | 1.4565 | 1.51 | 22 | 0.7595 | 0 | 2.25 | 0.15 | 0.17 (99.9) | 0.059 |
| 60 | Menhaden (2yr) | 2.007 | 0.6623 | 1.73 | 15.4 | 1.2558 | 0 | 2.25 | 0.43 | 0.63 (99.9) | 0.108 |
| 61 | Menhaden (3yr) | 0.496 | 0.1635 | 1.52 | 12.7 | 0.2159 | 0 | 2.25 | 0.45 | 0.44 (99.9) | 0.246 |
| 62 | Menhaden (4+yr) | 0.143 | 0.0473 | 1.42 | 11.1 | 0.0317 | 0.0003 | 2.25 | 0.46 | 0.22 (99.1) | 0.423 |
| 63 | Anchovy-silverside-killifish | 0.705 | 0 | 1.59 | 15.9 | 0\* | 0 | 2.62 | 0.84 | 0\* (99.7) | 1.342 |
| 64 | Mullet | 0.287 | 0 | 0.8 | 8 | 0.0449 | 0\* | 2.41 | 0.6 | 0.16 (2.8) | 0.321 |
| 65 | Butterfish | 0.073 | 0 | 1.36 | 8.1 | 0.0012 | 0.0005 | 2.76 | 0.98 | 0.02 (68.8) | 1.31 |
| 66 | Cephalopod | 1 | 0 | 2.8 | 13.7 | 0.0002 | 0 | 2.97 | 0.82 | 0\* (45.7) | 2.283 |
| 67 | Pink shrimp | 0.080 | 0 | 3.77 | 19.2 | 0.0269 | 0 | 2.43 | 0.41 | 0.34 | 1.198 |
| 68 | Brown shrimp | 0.061 | 0 | 5.22 | 19.2 | 0.1306 | 0 | 2.06 | 0.64 | 2.15 (0.02) | 1.191 |
| 69 | White shrimp | 0.500 | 0 | 3.32 | 19.2 | 0.0652 | 0 | 2.05 | 0.18 | 0.13 (0.05) | 0.473 |
| 70 | Crab | 0.250 | 0 | 1.6 | 10.5 | 0.0640 | 0 | 2.86 | 0.94 | 0.26 (0.2) | 1.253 |
| 71 | Sessile epifauna | 12 | 0 | 1.6 | 9 | 0.0277 | 0 | 2.01 | 0.63 | 0\* | 0.998 |
| 72 | Mobile epifauna | 18 | 0 | 2.6 | 16 | 0.0341 | 0 | 2.13 | 0.35 | 0\* (0.1) | 0.92 |

Supplementary Table 2 Continued. Basic inputs and estimates for the 1980 Gulf-wide Ecopath model.

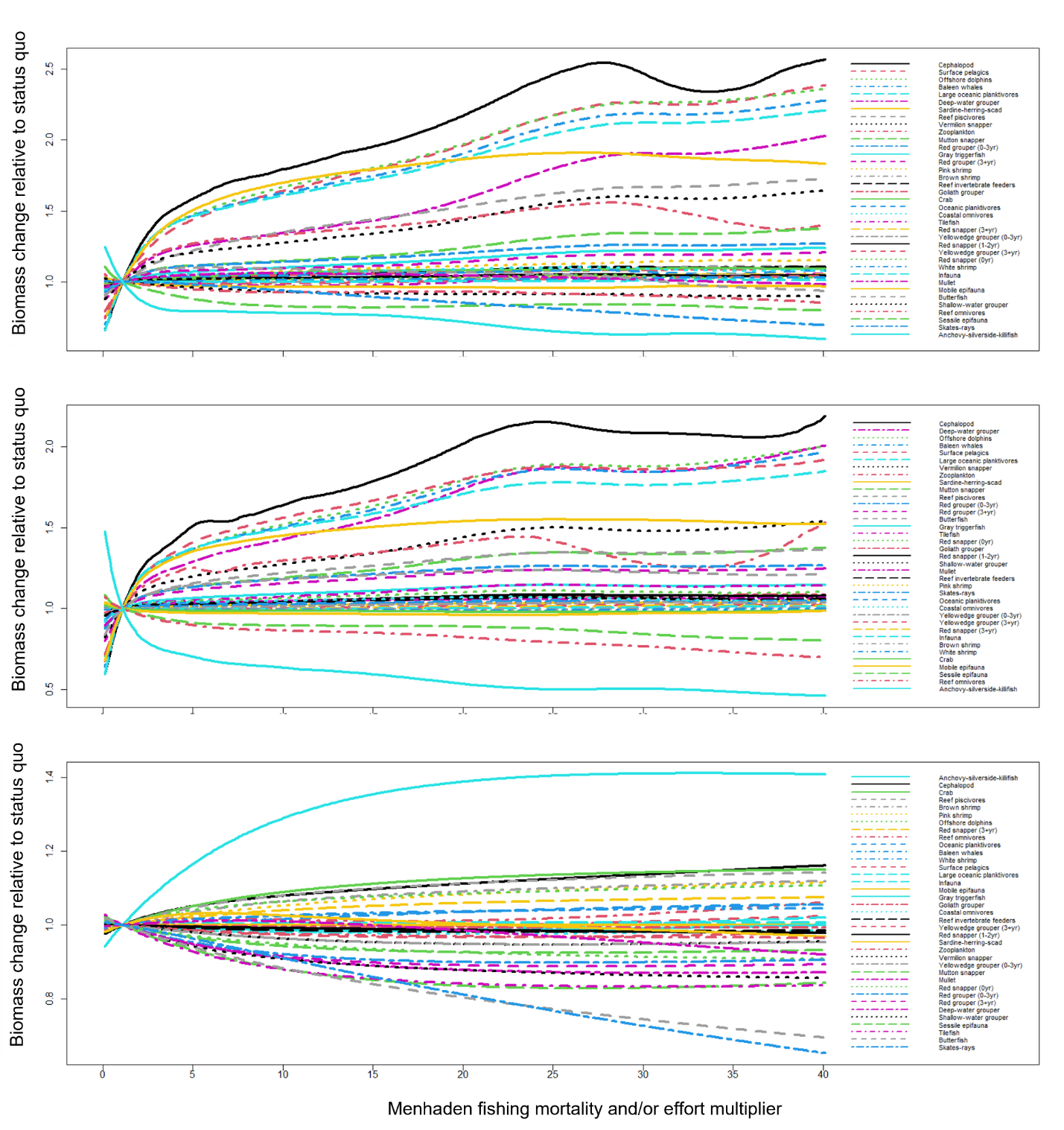
|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| No | Functional group | B | BA | Z or P/B | Q/B | Landings | Discards | TL | EE | F (%PS) | M2 |
| 73 | Zooplankton | 15 | 0 | 10 | 74 | 0.0020 | 0 | 2.05 | 0.72 | 0\* (100) | 7.246 |
| 74 | Infauna | 18.5 | 0 | 5.17 | 22 | 0\* | 0 | 2.04 | 0.49 | 0 | 2.528 |
| 75 | Algae | 29.8 | 0 | 27.5 | 0 | 0 | 0 | 1 | 0.07 | 0 | 2.049 |
| 76 | Seagrass | 150 | 0 | 25 | 0 | 0 | 0 | 1 | 0.01 | 0 | 0.162 |
| 77 | Phytoplankton | 25 | 0 | 160 | 0 | 0 | 0 | 1 | 0.3 | 0 | 48.079 |
| 78 | Detritus | 100 | 0 |  |  | 0 | 0 | 1 | 0.09 | - | - |

Supplementary Table 3. Time series for landings (i.e., catch), biomass, and fishing mortality for select EwE functional groups. NOAA refers to landings in weight from NOAA commercial and recreational sources. For Landings and Biomass, values in parentheses represent the weight assigned to each time series and the type (6 = landings, 61 = relative landings, 0 = relative biomass). Fishing mortality is always input as a driver (type = 4).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No | Functional group | Catch (*C*) | Biomass (*B*) | Fishing mortality (*F*) |
| 6 | Blacktip shark | NOAA (0.5, 6) | SEDAR 29 Update (1, 0) | SEDAR 29 Update |
| 7 | Dusky shark | NOAA (0.5, 61 - catches deemed unreliable for use in assessment) | SEDAR 21 Update (1, 0) | SEDAR 21 Update |
| 8 | Sandbar shark | NOAA (0.5, 6) | SEDAR 54 (HMS) (1, 0) | SEDAR 54 |
| 9 | Large coastal sharks | NOAA (0.5, 6) | SEDAR 11 (1, 0) | - |
| 10 | Large oceanic sharks | NOAA (0.5, 6) | ICCAT 2017a for shortfin mako (1, 0) | ICCAT 2017a for shortfin mako |
| 11 | Atlantic sharpnose shark | NOAA (0.5, 6) | SEDAR 34 (1, 0) | SEDAR 34 |
| 12 | Small coastal sharks | NOAA (0.5, 6) | SEDAR 34 for bonnethead (1, 0) | - |
| 13 | Yellowfin tuna | NOAA (1, 6) | Pelagic longline index (1, 0) | ICCAT 2019 |
| 14 | Bluefin tuna | NOAA (1, 6) | Pelagic longline index (1, 0) | ICCAT 2017c |
| 15 | Other tuna | NOAA (1, 6) | Pelagic longline index (1, 0) | - |
| 16 | Billfish | ICCAT (1, 6) | Pelagic longline index (3.78, 0) | ICCAT 2018 |
| 17 | Swordfish | NOAA (1, 61) | Pelagic longline index (9.04, 0) | ICCAT 2017b |
| 18 | Pelagic coastal piscivores | NOAA (1, 6) | SEAMAP Bottom trawl (0.55, 0) | - |
| 19 | Amberjacks | SEDAR 33 Update (7.85, 6) | SEDAR 33 Update (10.68, 0) | SEDAR 33 Update *C*/*B* |
| 20 | Cobia | SEDAR 28 (2.91, 6) | SEDAR 28 (7.88, 0) | SEDAR 28 *C*/*B* |
| 21 | King mackerel (0-1yr) | - | SEDAR 38 (12.29, 0) | - |
| 22 | King mackerel (1+yr) | SEDAR 38 (17.73, 6) | SEDAR 38 (15.03, 0) | SEDAR 38 *C*/*B* |
| 23 | Spanish mackerel (0-1yr) | - | SEDAR 28 (5.11, 0) | - |
| 24 | Spanish mackerel (1+yr) | SEDAR 28 (5.71, 6) | SEDAR 28 (10.78, 0) | SEDAR 28 *C*/*B* |
| 25 | Skates-rays | NOAA (1, 6) | SEAMAP Bottom trawl (2.61, 0) | - |
| 26 | Gag grouper (0-3yr) | - | SEDAR 33 Update (15.32, 0) | - |
| 27 | Gag grouper (3+yr) | SEDAR 33 Update (7.41, 6) | SEDAR 33 Update (22.12, 0) | SEDAR 33 Update *C*/*B* |
| 28 | Red grouper (0-3yr) | - | SEDAR 61 (4.54, 0) | - |
| 29 | Red grouper (3+yr) | SEDAR 61 (4.98, 6) | SEDAR 61 (7.23, 0) | SEDAR 61 Update *C*/*B* |
| 30 | Yellowedge grouper (0-3yr) | - | SEDAR 22 (7.79, 0) | - |
| 31 | Yellowedge grouper (3+yr) | SEDAR 22 (27.14, 6) | SEDAR 22 (20.71, 0) | SEDAR 22 *C*/*B* |
| 32 | Goliath grouper | NOAA (1, 6) | SEDAR 47 (13.17, 0) | SEDAR 47 |
| 33 | Deep-water grouper | NOAA (1, -6) | - | - |
| 34 | Shallow-water grouper | NOAA (1, -6) | SEDAR 49 video index for yellowmouth grouper (1, 0) | - |
| 35 | Red snapper (0-1yr) | - | SEDAR 52 (15.87, 0) | - |
| 36 | Red snapper (1-2yr) | SEDAR 52 (20, 61) | SEDAR 52 (14.57, 0) | SEDAR 52 *C*/*B* |
| 37 | Red snapper (3+yr) | SEDAR 52 (20, 6) | SEDAR 52 (13.27, 0) | SEDAR 52 *C*/*B* |
| 38 | Vermilion snapper | SEDAR 67 (10.24, 6) | SEDAR 67 (21.17, 0) | SEDAR 67 *C*/*B* |

Supplementary Table 3 Continued. Time series for landings, biomass, and fishing mortality for select EwE functional groups.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No | Functional group | Catch (*C*) | Biomass (*B*) | Fishing mortality (*F*) |
| 39 | Mutton snapper | SEDAR 15 Update (1, 6) | SEDAR 15 Update (13.17, 0) | SEDAR 15 Update *C*/*B* |
| 40 | Other snapper | NOAA (1, 6) | SEAMAP Bottom trawl (0.69, 0) | - |
| 41 | Coastal piscivores | NOAA (1, 6) | - | - |
| 42 | Seatrout | NOAA (1, 6) | SEAMAP Bottom trawl (5.57, 0) | - |
| 43 | Oceanic piscivores | NOAA (1, 6) | SEAMAP Bottom trawl (3.27, 0) | - |
| 44 | Benthic piscivores | NOAA (1, 6) | SEAMAP Bottom trawl (14.36, 0) | - |
| 45 | Reef piscivores | NOAA (1, 6) | SEAMAP Bottom trawl (3.05, 0) | - |
| 46 | Reef invertebrate feeders | NOAA (1, 6) | SEAMAP Bottom trawl (9.22, 0) | - |
| 47 | Demersal coastal invertebrate feeders | NOAA (1, 6) | SEAMAP Bottom trawl (5.06, 0) | - |
| 48 | Red drum | SEDAR 49 (1980-2013) and NOAA (2014+) (1, -6) | SEDAR 49 (Dauphin Island Sea Lab longline index) (1, 0) | - |
| 49 | Benthic coastal invertebrate feeders | NOAA (1, 6) | SEAMAP Bottom trawl (11.37, 0) | - |
| 50 | Tilefish | NOAA (3.21, 6) | SEDAR 22 (3.64, 0) | SEDAR 22 *C*/*B* |
| 51 | Gray triggerfish | SEDAR 43 (10.68, 6) | SEDAR 43 (5.74, 0) | SEDAR 43 *C*/*B* |
| 52 | Coastal omnivores | NOAA (1, 6) | SEAMAP Bottom trawl (10.39, 0) | - |
| 53 | Reef omnivores | NOAA (1, 6) | - | - |
| 54 | Surface pelagics | NOAA (1, 6) | - | - |
| 57 | Sardine-herring-scad | NOAA (1, 6) | SEAMAP Bottom trawl (3.03, 0) | - |
| 58 | Menhaden (0yr) | - | SEDAR 63 (1, 0) | - |
| 59 | Menhaden (1yr) | SEDAR 63 (5.5, 61) | SEDAR 63 (13.17, 0) | SEDAR 63 *C*/*B* |
| 60 | Menhaden (2yr) | SEDAR 63 (5.5, 6) | SEDAR 63 (13.17, 0) | SEDAR 63 *C*/*B* |
| 61 | Menhaden (3yr) | SEDAR 63 (5.5, 61) | SEDAR 63 (13.17, 0) | SEDAR 63 *C*/*B* |
| 62 | Menhaden (4+yr) | SEDAR 63 (5.5, 61) | SEDAR 63 (13.17, 0) | SEDAR 63 *C*/*B* |
| 63 | Anchovies-silversides-killifish | - | SEAMAP Bottom trawl (2.74, 0) | - |
| 64 | Mullet | NOAA (1, -6) | - | - |
| 65 | Butterfish | - | SEAMAP Bottom trawl (1.42, 0) | - |
| 66 | Cephalopods | - | SEAMAP Bottom trawl (4.99, 0) | - |
| 67 | Pink shrimp | 2018a Update (0.97, 6) | 2018a Update (13.17, 0) | 2018a Update *C*/*B* |
| 68 | Brown shrimp | 2018b Update (10.62, 6) | 2018b Update (13.17, 0) | 2018b Update *C*/*B* |
| 69 | White shrimp | 2018c Update (7.98, 6) | 2018c Update (13.17, 0) | 2018c Update *C*/*B* |
| 70 | Crab | NOAA (1, 6) | SEAMAP Bottom trawl (0.55, 0) | GDAR 01 |
| 72 | Mobile epifauna | NOAA (1, 6) | SEAMAP Bottom trawl (0.63, 0) | - |



Supplementary Figure 1. The change in biomass of groups that are not Gulf menhaden predators is in response to increasing (A) menhaden *F* and purse seine effort, (B) menhaden *F* only, and (C) purse seine effort only.

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