

Climate risk assessment of the fisheries in Namibia

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Supplementary materials

Supplementary Table S1. Approximate allocation of fishing effort by Namibia's fishery sectors across 12 geographic zones, defined based on depth (<100m, 100–200m, 200–1000m, and >1000m) and latitudinal regions (North: 19°–21°S; Central: 21°–25°S, and South: 25°–31°S).

		Oceanic >1000m	Slope 200-1000m	Shelf 100-200m	Coastal <100m
Hake trawlers	North	0	0.3	0	0
	Central	0	0.2	0	0
	South	0	0.5	0	0
Hake liners	North	0	0.1	0	0
	Central	0	0.5	0	0
	South	0	0.4	0	0
Midwater trawlers	North	0.02	0.54	0.03	0
	Central	0	0.4	0.01	0
	South	0	0	0	0
Monk & sole trawlers	North	0	0.3	0	0
	Central	0	0.4	0	0
	South	0	0.3	0	0
Large pelagic liners	North	0.25	0.15	0	0
	Central	0.3	0.05	0	0
	South	0.2	0.05	0	0
Small pelagic fishery	North	0	0	0.2	0.2
	Central	0	0	0.25	0.2
	South	0	0.05	0.05	0.05
Crab fishery	North	0.05	0.9	0.05	0
	Central	0	0	0	0
	South	0	0	0	0
Rock lobster fishery	North	0	0	0	0
	Central	0	0	0	0
	South	0	0	0	1
Recreational fishery	North	0	0	0	0.1
	Central	0	0	0	0.8
	South	0	0	0	0.1
Small-scale fishery	North	0	0	0	0
	Central	0	0	0	0.8
	South	0	0	0	0.2

Supplementary Table S2. Impact scores for eight component hazards in 12 geographic zones, defined based on depth (<100m, 100–200m, 200–1000m, and >1000m) and latitudinal regions (North: 19°–21°S; Central: 21°–25°S, and South: 25°–31°S). Within each region, hazard impact scores may range between 0 (negligible risk of impact) and 4 (very high risk of impact).

		Oceanic >1000m	Slope 200-1000m	Shelf 100-200m	Coastal <100m
Benguela Niños	North	2.00	3.00	4.00	4.00
	Central	1.50	2.25	3.00	3.00
	South	0.50	0.75	1.00	1.00
General temperature rise	North	0.75	1.50	2.25	2.25
	Central	0.50	1.00	1.50	1.50
	South	0.00	0.00	0.00	0.00
Ocean acidification (OA)	North	0.00	0.50	0.75	1.00
	Central	0.00	1.00	1.50	2.00
	South	0.00	2.00	3.00	4.00
Extreme weather & offshore winds	North	0.50	0.50	1.00	2.00
	Central	0.75	0.75	1.50	3.00
	South	1.00	1.00	2.00	4.00
Low-oxygen water	North	0.00	0.00	0.00	0.00
	Central	0.00	0.00	0.00	2.25
	South	0.00	0.00	0.00	1.00
Sea level rise & storm surges	North	0.00	0.00	0.00	0.00
	Central	0.00	0.00	0.00	1.00
	South	0.00	0.00	0.00	0.50
Jellyfish blooms	North	0.00	1.00	1.50	2.00
	Central	0.00	1.00	1.50	2.00
	South	0.00	1.00	1.50	2.00
Harmful algal blooms	North	0.00	0.00	0.00	0.00
	Central	0.00	0.00	0.00	0.25
	South	0.00	0.00	0.00	0.00

Supplementary Table S3. Leave-one-out analysis to assess the robustness of climate hazard exposure scores by fishery sector, dependent on inclusion or exclusion of 2 component hazards that may or may not be linked to climate change: jellyfish blooms, and harmful algal blooms (HABs). The upper half of the table shows the scores of component hazards by sector (identical to Table 3 of main manuscript). The lower half of the table shows the overall hazard exposure by sector, and the relative rankings by sector, for all hazards minus jellyfish blooms; all hazards minus HABs; and all hazards minus jellyfish blooms and HABs. Note that the relative rankings of climate hazard exposure by sector remain unchanged.

	Hazard exposure by sector									
Hazard	Hake trawlers	Hake liners	Mid-water trawlers	Monk-fish trawlers	Large pelagic liners	Small pelagic fishery	Crab fishery	Rock lobster fishery	Recreational fishery	Small-scale fishery
Benguela Niños	1.73	1.73	0.67	2.03	1.65	3.09	3	1	2.9	2.6
General temperature rise	0.65	0.65	0.32	0.85	0.61	1.58	1.5	0	1.43	1.2
Ocean acidification (OA)	1.35	1.35	0.16	1.15	0.23	1.58	0.49	4	2.1	2.4
Extreme weather & offshore winds	0.8	0.83	0.14	0.75	0.71	1.93	0.53	4	3	3.2
Low-oxygen water	0	0	0	0	0	0.5	0	1	1.9	2
Sea level rise & storm surges	0	0	0	0	0	0.23	0	0.5	0.85	0.9
Jellyfish blooms	1	1	0.24	1	0.25	1.70	0.98	2	2	2
Harmful algal blooms (HABs)	0	0	0	0	0	0.05	0	0	0.2	0.2
Overall hazard exposure	0.69	0.69	0.19	0.72	0.43	1.33	0.81	1.56	1.80	1.81
Leave-one-out analysis:										
All 8 hazards	0.691	0.695	0.192	0.723	0.431	1.333	0.812	1.563	1.798	1.813
All hazards minus jellyfish	0.647	0.651	0.184	0.683	0.457	1.280	0.789	1.500	1.769	1.786
All hazards minus HABs	0.790	0.794	0.219	0.826	0.493	1.516	0.928	1.786	2.026	2.043
All minus jellyfish and HABs	0.755	0.760	0.215	0.797	0.533	1.485	0.920	1.750	2.030	2.050
Rank all 8 hazards	8	7	10	6	9	4	5	3	2	1
Rank all hazards minus jellyfish	8	7	10	6	9	4	5	3	2	1
Rank all hazards minus HABs	8	7	10	6	9	4	5	3	2	1
Rank all minus jellyfish and HABs	8	7	10	6	9	4	5	3	2	1

Supplementary Table S4. Biological traits describing tolerance of high temperatures, and temperature specificity for 38 key fish and shellfish species in Namibia. The scores of high temperature tolerance are based on the maximum preferred temperature (TP90), ranging from 1 ('very high') to 4 ('low'). The scores for temperature specificity are based on the range of preferred temperatures (TP90 – TP10), here ranging from 1 ('low') to 4 ('very high') (see Table 2 for full details). Species relevant to recreational and/or small-scale fisheries are marked with *.

		<i>High temperature tolerance</i>		<i>Temperature specificity</i>		
Common name	Scientific name	Maximum preferred temperature (TP90, °C)	High temperature tolerance score	Minimum preferred temperature (TP90, °C)	Range of preferred temperatures (°C)	Temperature specificity score
Horse mackerel, Cape	<i>Trachurus capensis</i>	22.85	3	15.23	7.62	3
Hake, Deep-water	<i>Merluccius paradoxus</i>	21.21	3	16.20	5.01	3
Hake, Shallow-water	<i>Merluccius capensis</i>	19.92	4	15.02	4.90	3
Sardine (Pilchard)	<i>Sardinops sagax</i>	24.66	2	11.77	12.89	1
Snoek	<i>Thyrsites atun</i>	20.68	3	11.70	8.98	2
Crab, Deep-sea Red	<i>Chaceon maritae</i>	17.38	4	13.50	3.88	4
Kingklip	<i>Genypterus capensis</i>	19.49	4	14.64	4.85	3
Anglerfish (Monkfish)	<i>Lophius vomerinus</i>	20.59	3	15.18	5.41	3
Shark, Blue	<i>Prionace glauca</i>	28.13	1	14.64	13.49	1
Seabream, Panga	<i>Pterogymnus lanarius</i>	23.42	3	14.86	8.56	2
Squid, Angola Flying	<i>Todarodes angolensis</i>	24.51	2	16.08	8.43	2
Tuna, Albacore	<i>Thunnus alalunga</i>	27.91	2	16.68	11.23	2
Swordfish	<i>Xiphias gladius</i>	28.02	1	17.36	10.66	2
Mako, Shortfin	<i>Isurus oxyrinchus</i>	28.18	1	16.43	11.75	2
Sole, West Coast	<i>Austroglossus microlepis</i>	17.78	4	14.61	3.17	4
Tuna, Bigeye	<i>Thunnus obesus</i>	28.15	1	18.23	9.92	2
Alfonsino, Splendid	<i>Beryx splendens</i>	27.58	2	15.38	12.20	1
Orange Roughy	<i>Hoplostethus atlanticus</i>	24.94	2	9.80	15.14	1
Dory, Cape	<i>Zeus capensis</i>	23.34	3	14.86	8.48	2
Lobster, West Coast Rock	<i>Jasus lalandii</i>	18.51	4	14.52	3.99	4
Sardinella, Round	<i>Sardinella aurita</i>	27.93	2	18.58	9.35	2
Tuna, Yellowfin	<i>Thunnus albacares</i>	28.34	1	19.21	9.13	2
Gurnard, Cape	<i>Chelidonichthys capensis</i>	23.21	3	14.83	8.38	2
Dentex, Large-eye	<i>Dentex macrophthalmus</i>	27.70	2	18.40	9.30	2
Marlin, Blue	<i>Makaira nigricans</i>	27.96	2	20.97	6.99	3
Oilfish	<i>Ruvettus pretiosus</i>	27.80	2	17.23	10.57	2
Shark, Thresher	<i>Alopias vulpinus</i>	28.15	1	14.45	13.70	1
Tuna, Southern Bluefin	<i>Thunnus maccoyii</i>	23.35	3	9.25	14.10	1
Tuna, Skipjack	<i>Katsuwonus pelamis</i>	28.32	1	19.62	8.70	2
Cardinalfish, Black	<i>Epigonus telescopus</i>	27.13	2	13.71	13.42	1
Kob, Silver*	<i>Argyrosomus inodorus</i>	20.67	3	16.20	4.47	3
Steenbras, West Coast*	<i>Lithognathus aureti</i>	19.00	4	13.50	5.50	3
Galjoen*	<i>Dichistius capensis</i>	23.57	3	14.49	9.08	2
Seabream, Blacktail*	<i>Diplodus capensis</i>	25.83	2	15.73	10.10	2
Barbel*	<i>Galeichthys feliceps</i>	23.73	3	16.03	7.70	3
Shark, Bronze Whaler*	<i>Carcharhinus brachyurus</i>	27.10	2	17.03	10.07	2
Shark, Spotted Gully*	<i>Triakis megalopterus</i>	22.26	3	16.03	6.23	3
Shark, Smooth-hound*	<i>Mustelus mustelus</i>	27.16	2	11.03	16.13	1

Supplementary Table S5. Population resilience traits and scores for 38 key fish and shellfish species in Namibia. This trait was scored as either ‘high’ (score 1: minimum population doubling time estimated <15 months), ‘medium’ (score 2: minimum population doubling time estimated 1.4–4.4 years), ‘low’ (score 3: minimum population doubling time estimated 4.5–14 years), or ‘very low’ (score 4: minimum population doubling time estimated >15 years). Species that are important for recreational and/or small-scale fisheries are marked with *.

Common name	Scientific name	Population resilience	Population resilience score
Horse mackerel, Cape	<i>Trachurus capensis</i>	Medium	2
Hake, Deep-water	<i>Merluccius paradoxus</i>	Low	3
Hake, Shallow-water	<i>Merluccius capensis</i>	Low	3
Sardine (Pilchard)	<i>Sardinops sagax</i>	Medium	2
Snoek	<i>Thysites atun</i>	Medium	2
Crab, Deep-sea Red	<i>Chaceon maritae</i>	Medium	2
Kingklip	<i>Genypterus capensis</i>	Low	3
Anglerfish (Monkfish)	<i>Lophius vomerinus</i>	Low	3
Shark, Blue	<i>Prionace glauca</i>	Low	3
Seabream, Panga	<i>Pterogymnus lanarius</i>	Low	3
Squid, Angola Flying	<i>Todarodes angolensis</i>	High	1
Tuna, Albacore	<i>Thunnus alalunga</i>	Medium	2
Swordfish	<i>Xiphias gladius</i>	Medium	2
Mako, Shortfin	<i>Isurus oxyrinchus</i>	Low	3
Sole, West Coast	<i>Austroglossus microlepis</i>	Low	3
Tuna, Bigeye	<i>Thunnus obesus</i>	Medium	2
Alfonsino, Splendid	<i>Beryx splendens</i>	Low	3
Orange Roughy	<i>Hoplostethus atlanticus</i>	Very low	4
Dory, Cape	<i>Zeus capensis</i>	Very low	4
Lobster, West Coast Rock	<i>Jasus lalandii</i>	Low	3
Sardinella, Round	<i>Sardinella aurita</i>	High	1
Tuna, Yellowfin	<i>Thunnus albacares</i>	Medium	2
Gurnard, Cape	<i>Chelidonichthys capensis</i>	Low	3
Dentex, Large-eye	<i>Dentex macrophthalmus</i>	Medium	2
Marlin, Blue	<i>Makaira nigricans</i>	Medium	2
Oilfish	<i>Ruvettus pretiosus</i>	Low	3
Shark, Thresher	<i>Alopias vulpinus</i>	Low	3
Tuna, Southern Bluefin	<i>Thunnus maccoyii</i>	Low	3
Tuna, Skipjack	<i>Katsuwonus pelamis</i>	Medium	2
Cardinalfish, Black	<i>Epigonus telescopus</i>	Very low	4
Kob, Silver*	<i>Argyrosomus inodorus</i>	Medium	2
Steenbras, West Coast*	<i>Lithognathus aureti</i>	Low	3
Galjoen*	<i>Dichistius capensis</i>	Low	3
Seabream, Blacktail*	<i>Diplodus capensis</i>	Medium	2
Barbel*	<i>Galeichthys feliceps</i>	Medium	2
Shark, Bronze Whaler*	<i>Carcharhinus brachyurus</i>	Very low	4
Shark, Spotted Gully*	<i>Triakis megalopterus</i>	Very low	4
Shark, Smooth-hound*	<i>Mustelus mustelus</i>	Very low	4

Supplementary Table S6. Metrics used to calculate socio-economic vulnerability for the eight sectors of the large-scale fishing fleet (2nd to 5th columns), and the indices derived from these (6th to 9th columns), scaled to range between 0 (lowest) and 1 (highest). The final column shows the overall socio-economic vulnerability by sector, based on the average of the four indices.

	Average value of landings 2018-2020 ('000 N\$)	Average landings value per employee 2018-2020 (N\$)	% permanent positions 2020	Annual employment change 2018-2021	Total landed value index	Per-capita revenue index	% permanent positions index	Annual employment change index	Overall socio-economic vulnerability
Hake trawlers	3620	319	20%	4%	0.00	0.85	0.87	0.66	0.59
Hake liners	231	473	28%	17%	0.94	0.76	0.78	0.47	0.74
Midwater trawlers	3066	921	66%	9%	0.15	0.52	0.35	0.60	0.40
Monkfish trawlers	157	403	88%	3%	0.96	0.80	0.09	0.67	0.63
Large pelagic liners	228	1,277	89%	-20%	0.94	0.32	0.08	1.00	0.59
Small pelagic fishery	25	43	8%	-9%	1.00	1.00	1.00	0.84	0.96
Crab fishery	169	1,867	97%	51%	0.96	0.00	0.00	0.00	0.24
Rock lobster fishery	34	348	9%	-12%	1.00	0.83	0.98	0.88	0.92