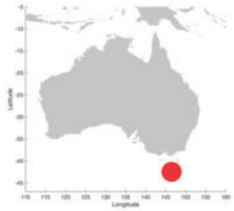
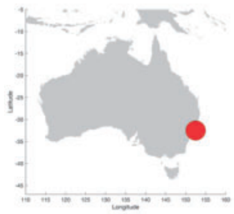
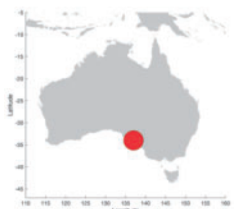
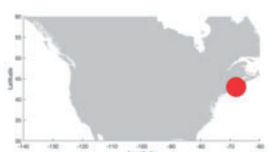
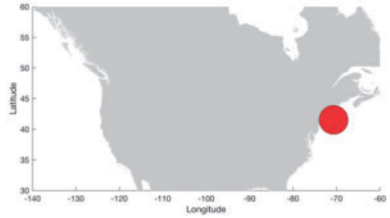
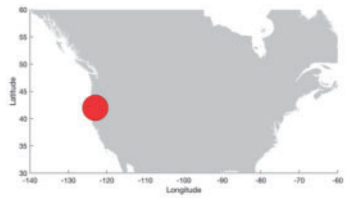
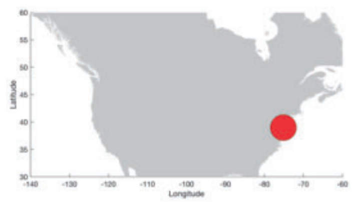
Table 1. Summary of ecological forecasting examples describing the context for each system (reprinted From Hobday et al. 2019; U.S. public domain)

Salmon aquaculture forecasts in Tasmania  **Funding:** Industry **Institution:** CSIRO/Bureau of Meteorology **Stakeholders:** Salmon Farmers	Dynamical seasonal forecasts to predict water temperatures for south-east Tasmanian Atlantic salmon (*Salmo salar*) farm sites several months into the future are used to manage production risk (Spillman and Hobday, 2014). High summer temperatures pose a significant risk to production systems of these farms. Based on 20 years of historical validation, the model shows useful skill for all months of the year at lead-times of 0–1 months. Model skill is highest when forecasting for winter months, and lowest for December and January predictions. The poorer performance in summer is due to increased variability due to the convergence of several ocean currents offshore from the salmon farming region. Accuracy of probabilistic forecasts exceeds 80% for all months at lead-time 0 month for the upper tercile (warmest 33% of values) and exceeds 50% at a lead-time of 3 months. Industry engagement is high, and delivery of forecasts is ongoing, supplemented by industry–scientist discussions (Hobday *et al.*, 2016).
Recreational dolphinfish forecasts in eastern Australia  **Funding:** Researchers (University PhD) **Institution:** CSIRO/Bureau of Meteorology/UNSW **Stakeholders:** Recreational Fishers/Managers	A seasonal forecast of the habitat and density of dolphinfish (*Coryphaena hippurus*), based on sea surface temperatures, was developed for the east coast of New South Wales (NSW) Australia (Brodie *et al.*, 2017). Two prototype forecast products were created; geographic spatial forecasts of dolphinfish habitat and a latitudinal summary identifying the location of fish density peaks. The less detailed latitudinal summary was designed to limit the resolution of habitat information to prevent potential resource over-exploitation by fishers in the absence of total catch controls. The dolphinfish habitat forecast was accurate at the start of the annual dolphinfish migration in NSW (December) but other months (January–May) showed poor performance due to spatial and temporal variability in the catch data used in model validation. Habitat forecasts for December were useful up to 5 months ahead, with performance decreasing as forecasts were made further into the future.
Commercial tuna forecasts in the Great Australia Bight  **Funding:** Industry/FRDC **Institution:** CSIRO/Bureau of Meteorology **Stakeholders:** Fishing industry	A habitat forecast system based on a seasonal ocean model and electronic tagging data was developed in collaboration with the Southern Bluefin Tuna (SBT, *Thunnus maccoyii*) fishery in Australia to overcome challenges posed by novel environmental conditions (Eveson *et al.*, 2015). A dramatic change in the distribution of SBT compromised the ability of the fishery to efficiently locate and harvest the species. In partnership with industry representatives, a seasonal forecasting system was implemented to project the likely distribution of SBT several months into the future (Eveson *et al.*, 2015). Forecasts are delivered daily via an industry-specific website, which has assisted fishers to efficiently catch SBT under variable climatic conditions. There is a cap on catches so this system does not contribute to over-exploitation.
Lobster forecasts in Maine  **Funding:** Research agency **Institution:** GMRI **Stakeholders:** Fishing Industry/Managers	The American lobster (*Homarus americanus*) fishery is currently the highest-valued commercial fishery in the United States, worth nearly $670 million in landed value in 2016. Over 80% of the value is landed in the state of Maine. The 2012 Northwest Atlantic heat wave disrupted this fishery by prompting early warming of the ocean and an earlier-than-normal large influx of lobster landings. Since readiness for the product was not aligned throughout the supply chain, a glut of lobsters developed, resulting in a price collapse (Mills *et al.*, 2013). At that time, managers and key industry members in Maine questioned whether the early onset of the high-landings period could have been predicted, with the expectation that such information would give valuable early notice for the fishery and supply chain to prepare appropriately for the upcoming season. A regression-based seasonal forecast was developed to provide the expected timing of the summer uptick in landings (June–July) based on ocean temperatures in March–April (Mills *et al.*, 2017). This forecast was formally issued to the industry in 2015 and 2016 via a public website. While it proved technically reliable at predicting the summer uptick timing, it also created unexpected challenges and was not perceived as useful to the industry (Pershing *et al.*, 2018).

Northwest Atlantic industry–science collaborative research programme  **Funding:** Research agency **Institution:** NOAA **Stakeholders:** Fishing Industry	Inefficiencies in fisheries science and governance produce regulatory environments that can lag rapidly changing northwest Atlantic marine ecosystems and fisheries by 2–5 years (Hennessey and Healey, 2000; Pinsky and Fogarty, 2012). This pilot programme uses sustained embedding of collaborative research and ecosystem scale hindcasting and now-casting within operational fisheries, with the goal of developing products accounting for socioecological change in fishery assessments and management (NEFSC, 2014, 2018; Turner *et al.*, 2017). Fishery and ocean data and ocean model output are used in science–industry partnerships that co-develop, evaluate, and refine habitat nowcast models describing occupancy dynamics of species and fishing fleets. The primary goal is to develop models that can be applied in population assessments and tactical management to account for the effects of changing habitat dynamics on observed abundances, fishery landings, and productivity. The programme is also designed to increase fishing precision by reducing costs of harvesting quotas, including externalities such as bycatch and habitat impacts. Sustained engagement with industry experts provides important collateral benefits including the timely transfer of information about the socioecological dimensions currently impacting specific fisheries that are required for practical ecosystem-based fisheries assessment and management.
Northeast Pacific Ocean ecological forecasts  **Funding:** Research agency **Institution:** NOAA **Stakeholders:** Fishing Industry and Managers	In the northeast Pacific Ocean, marine resource managers at the state, federal, and tribal levels make decisions on a weekly to quarterly basis, and fishers operate on a similar timeframe. To determine the potential of a support tool for these efforts, a seasonal forecast system known as J-SCOPE (JISAO's Seasonal Coastal Ocean Prediction of the Ecosystem) has been developed (Kaplan *et al.*, 2016; Siedlecki *et al.*, 2016). This system features dynamical downscaling of regional ocean conditions in Washington and Oregon waters using a combination of a high-resolution regional model with biogeochemistry and forecasts from NOAA's Climate Forecast System). Model performance and predictability have been determined for sea surface temperature, bottom temperature, bottom oxygen, pH, and aragonite saturation state through model hindcasts, reforecast, and forecast comparisons with observations. Results indicate J-SCOPE forecasts have measurable skill on seasonal timescales (Siedlecki *et al.*, 2016).
Delaware Bay Atlantic sturgeon by-catch forecasts  **Funding:** University **Institution:** NGO/Government/University **Stakeholders:** Fishing Industry	Atlantic sturgeon (*Acipenser oxyrinchus*) is a long-lived anadromous species found on the east coast of North America (Vladykov and Greeley, 1963). Overfishing for caviar and flesh in the late 19th and early 20th century (Cobb, 1900; Borodin, 1925; Smith and Clugston, 1997), combined with habitat loss and degradation, severely diminished Atlantic sturgeon populations, and there has been little to no recovery despite a moratorium on directed fishing and improved water quality (Billard and Lecointre, 2000). The Delaware River and Bay historically supported the largest spawning population of Atlantic sturgeon in the world as well as the largest fishery. The Delaware River Atlantic sturgeon fishery was short lived; peak landings dropped more than 90% by the turn of the century (Cobb, 1900). Although directed harvest of Atlantic sturgeon ended in 1998, the results of historic overharvest, coupled with habitat change and ongoing issues of bycatch mortality, have resulted in a $>$99% decline from historic abundance of 360 000 spawning adults (Secor and Waldman, 1999) to $<$300 spawning adults annually (ASSRT, 2007). As a result, the National Marine Fisheries Service listed Atlantic sturgeon under the Endangered Species Act (ESA) on 6 April 2012 (United States Office of the Federal Registry, 2012) with incidental bycatch (Stein *et al.*, 2004) and vessel strikes (Simpson and Fox, 2009) identified as risk factors for the Delaware River. The ESA listing has the potential to have major impacts on commercial fisheries, shipping, and other industries that interact with Atlantic sturgeon during their coastal migration. These fishers are also motivated to avoid Atlantic sturgeon because interactions severely damage legal fishing gear, resulting in costly downtime. This action created the need for a short-term forecasting system to alert fishers in the Delaware Bay of their potential risk of interacting with an Atlantic sturgeon. The model was developed by fusing remote sensed data and historic acoustic telemetry observations (Breece *et al.*, 2017), and distributes a nowcast, 1, 2, and 3 days statistical forecasts. Recent satellite observations are not always available to constrain the model, so forecasts are flagged with a warning for users. Forecasts are distributed daily via web applications, and via SMS text messages to users.