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Marine recreational fishing and the implications of climate change

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Abstract

Marine recreational fishing is popular globally and benefits coastal economies and people's well-being. For some species, it represents a large component of fish landings. Climate change is anticipated to affect recreational fishing in many ways, creating opportunities and challenges. Rising temperatures or changes in storms and waves are expected to impact the availability of fish to recreational fishers, through changes in recruitment, growth and survival. Shifts in distribution are also expected, affecting the location that target species can be caught. Climate change also threatens the safety of fishing. Opportunities may be reduced owing to rougher conditions, and costs may be incurred if gear is lost or damaged in bad weather. However, not all effects are expected to be negative. Where weather conditions change favourably, participation rates could increase, and desirable species may become available in new areas. Drawing on examples from the UK and Australia, we synthesize existing knowledge to develop a conceptual model of climate-driven factors that could impact marine recreational fisheries, in terms of operations, participation and motivation. We uncover the complex pathways of drivers that underpin the recreational sector. Climate changes may have global implications on the behaviour of recreational fishers and on catches and local economies.

KEYWORDS
adaptation, angling, catch, distribution shifts, motivation, tourism

1 | INTRODUCTION

Climatic change is projected to affect the marine and coastal environment through rising sea levels, increased sea temperatures, changes in salinity, pH and oxygen, changes in the frequency and magnitude of wind, rainfall, waves, storms and currents, with subsequent changes in turbidity levels (IPCC, 2013). The impacts of climate change in commercial fishing are beginning to be considered in management of commercial stocks, with many countries and regions developing risk assessments or adaptation frameworks (e.g. Australia, 2010; Garrett, Buckley, & Brown, 2015a; German Government, 2008; Government of Canada, 2005; Miller, Ota, Sumaila, Cisneros-Montemayor, & Cheung, 2018). However, the effects of climate change on recreational fishing are only starting to be considered (e.g. Kerr et al., 2017 reviewed the effects on recreational fisheries in the US Atlantic), despite the Intergovernmental

Panel on Climate Change (IPCC) recognizing as early as 1997 that climate change could impact this activity (IPCC, 1997).

Around the world, it has been estimated that around 121 million people a year participate in recreational fishing, although participation varies greatly across countries (Cisneros-Montemaier & Sumala, 2010). With such high participation and significant catches in some places (Radford et al., 2018), climate change impacts on the sector could have wide implications for ecosystems, the economy and more generally on people's well-being.

The UK and Australia represent two countries with widely differing participation rates. Around a million people in the United Kingdom (1.8% of all adults) participate in recreational sea fishing (Hyder et al., 2018). In the UK, an average of 6.8 million days of sea angling per year was recorded in 2015–2017 with shore fishing being the most common (Arkenford, 2017), but with more fish caught from boats (Armstrong et al., 2013). Sea angling is economically and socially important in England with resident sea anglers spending £1.23 billion on the sport, equivalent to £831 million direct spend (excluding tax and imports), and supporting 10,400 full-time equivalent jobs and almost £360 million of gross value added (Roberts et al., 2017). More than 5 million Australians participate in recreational fishing (Australian Bureau of Statistics, 2010), with the highest fishing participation rates in the Northern Territory (31.6%), Tasmania (29.3%) and Western Australia (28.5%; Henry & Lyell, 2003). The sector supports around 90,000 Australian jobs, and each recreational fisher is estimated to spend approximately $1,000 per annum on their fishing activities, including tackle, boats, travel and accommodation (Queensland Department of Primary Industries, 2019).

For commercial fisheries, climate change impacts are predicted to mainly result from changes to catch potential (Garrett, Buckley, Brown, & Townhill, 2015b), changing weather conditions and storm and flood frequency (e.g. Sainsbury et al., 2018). Climate change is anticipated to affect the socio-ecological systems of marine recreational fisheries in similar ways, but with some differences owing to the different motivation for participating in commercial and recreational fishing; pleasure and consumption being two of the main drivers for recreational fishing (ICES, 2018a). In northern Australia (Queensland), the strongest motivations for recreational fishing were for rest and recreation, to enjoy nature and to be outdoors (Ormsby, 2004). In southern Australia, both catch and non-catch aspects of the fishing experience are motivators. Importantly, recreational fishing can be satisfying regardless of whether any fish are caught (Beardmore, Haider, Hunt, & Arlinghaus, 2011; Fedler & Ditton, 1994). Even though resource-related aspects are not unimportant or incidental, there are other drivers and motivations of recreational fishers (Fijlink & Lyell, 2010).

This paper uses the United Kingdom and Australia as examples to consider the different aspects of climate change that might positively or negatively affect the marine recreational fishing sector globally, those who participate in the activity and businesses that rely on it for income. The two countries have ongoing surveys of recreational fishing. The UK has a lot of data are available on participation, catches and expenditure, and Australia has extensive research about climate change. In both the UK and Australia, there are coastal regions that are

considered "hot spots" of climate warming (Hobday & Pecl, 2014). The latter is relevant since adaptive responses to climate change are greatest where the climate has changed the most (Poloczanska et al., 2013). The responses already witnessed in these hotspot areas (Pecl et al., 2019) and the anticipated future responses, provide examples of impacts and adaptation strategies relevant to other regions of the world.

The aims of this paper were to identify the different aspects of climate change that may have potential effects on marine recreational fishing and to discuss the implications for fisher behaviour and adaptation. The paper draws on literature from global studies on past and future climate change, fisheries and recreational fishing, with a focus on the well-studied UK and Australia, to demonstrate how recreational fishers may be affected.

2 | CLIMATE IMPACT PATHWAYS

There are many potential effects of climate change in fish species considered important for recreational fisheries. Such effects are manifested via a range of interlinked pathways (shown in the conceptual model in Figure 1). Physical changes in the marine environment, such as temperature rise (in Figure 1 listed in the Climate box), are expected to cause various changes in the fish targeted by recreational fishers. These include impacts on adult production, recruitment, growth and survival (Dutil & Brander, 2003; Rätz & Lloret, 2003; Simpson et al., 2011), which affect the availability of preferred
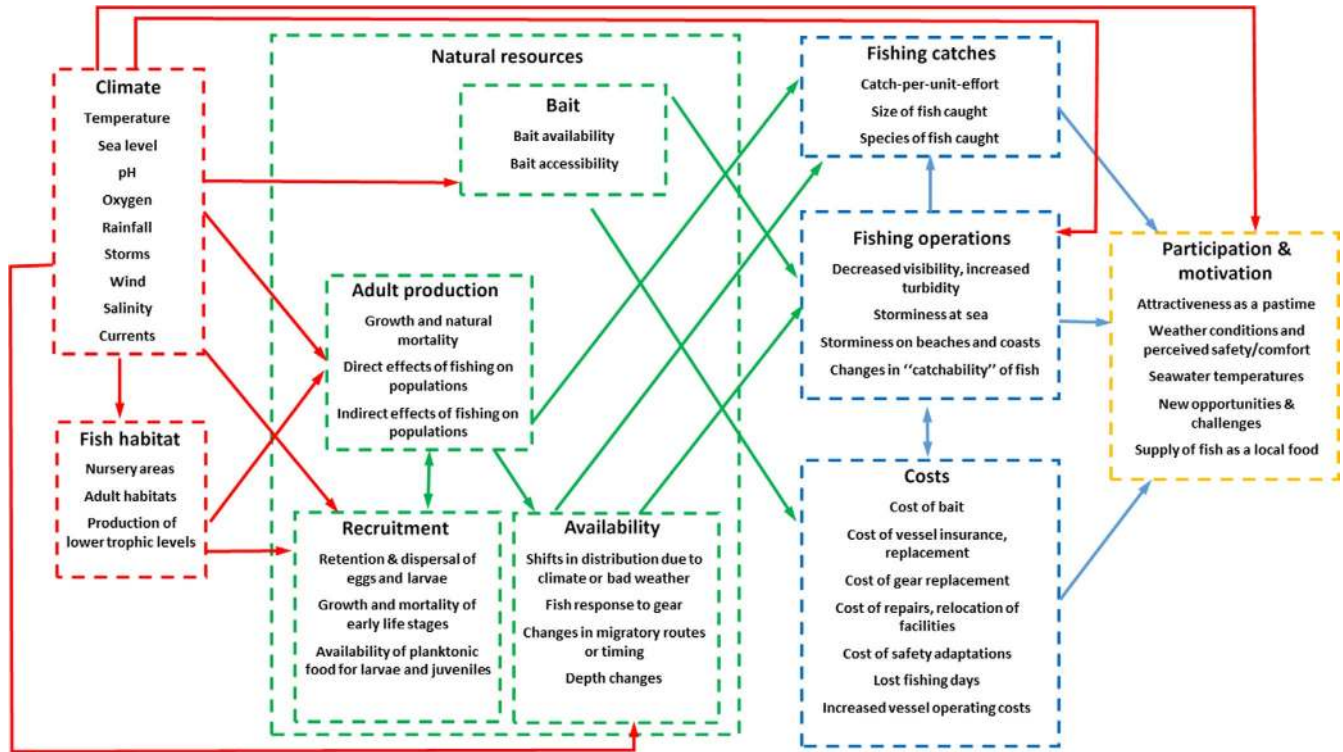
FIGURE 1 The pathways by which each aspect of marine recreational fishing can be affected by climate change, from the climate drivers, to changes in natural resources, catches, fishing operations, costs and fisher behaviour

fish and of baitfish (box labelled Natural resources). This in turn affects the size and species (e.g. Last et al., 2011; Sunday et al., 2015) available to fishers, and the fishing effort required (box labelled Fishing Catches).

Safety at sea or on shore may be affected by adverse weather, and recreational fishing may become a less desirable activity (box labelled Fishing operations). In addition, catchability of fish may be affected if the marine conditions change, and for example, turbidity, current or wave action increases (Garrett et al., 2015b). Fishing could become more costly if gear is lost or damaged (Costs box). Costs will also be affected if recreational fishers have to travel further to fish for their preferred species, if these become locally unavailable or the weather conditions or infrastructure no longer promote recreational fishing in that area. Fishers who use boats will be affected differently to those who fish from the shore or dive.

The many different potential impacts and changes in recreational fisheries could lead to changes in fisher motivation and behaviour, and subsequent participation levels, as the rewards of fishing change (box labelled Participation & motivation). Further, more active management of recreational fishing may be required in some instances, particularly where recreational catches need to be explicitly considered in stock management (Hyder et al., 2018; Radford et al., 2018). Arguably, resources can be best managed if the response of a system can be predicted (Szuwalski & Hollowed, 2016), and so understanding how fish availability and catchability will change, and the likely responses of recreational fishers, is essential in ensuring that effective fisheries management is put in place under a changing climate.

3 | DISTRIBUTION SHIFTS

The spatial range of a marine species is strongly influenced by their environment, and any changes in the environmental conditions may result in a redistribution of fish (Hollowed et al., 2013; Pecl et al., 2017) for which there is already ample empirical evidence (e.g. Last et al., 2011; Sunday et al., 2015). As climate change endures, changes in distribution will likely continue or even be exacerbated. The species location shift is predominantly poleward (Pecl et al., 2017), with, overall, a northerly shift in the temperate northern hemisphere (Jones, Dye, Pinnegar, Warren, & Cheung, 2012; Montero-Serra, Edwards, & Genner, 2015; Perry, Low, Ellis, & Reynolds, 2005) and a southerly shift in the southern hemisphere. On average, marine species are shifting by 72 km a decade, however, some shifts are much faster (Poloczanska et al., 2013).

Currently in the UK, the most species caught by marine recreational fishers by weight are Atlantic cod, Atlantic mackerel (*Scomber scombrus*, Scombridae), lesser spotted dogfish (*Scyliorhinus canicular*, Scyliorhinidae), European sea bass (*Dicentrarchus labrax*, Moronidae) and whiting (*Merlangius merlangus*, Gadidae; Armstrong et al., 2013; Table 1). The top recreational species caught in Australia are flatheads (Platycephalidae), mackerels (Scombridae) and breams (Sparidae; Henry & Lyle, 2003; Table 2). Recreational fishers in Australia also harvest non-fish species, predominantly lobsters and abalone, but also squid and cuttlefish, blue swimmer crabs (*Portunus pelagicus*, Portunidae) and mud crabs (*Scylla* spp.).

TABLE 1 The total weight of the top ten species caught by total weight by British marine recreational fishers calculated from a 2012 survey (Armstrong et al., 2013)

Species	Scientific name	Total caught weight/t (RSE)	Abundance response to temperature	Shift in distribution (km poleward)
Cod	*Gadus morhua*, Gadidae	636 (0.39)	–[a]	149–343[b]
Mackerel	*Scomber scombrus*, Scombridae	539 (0.27)	Na	97–337[b]
Lesser spotted dogfish	*Scyliorhinus canicula*, Scyliorhinidae	420 (0.31)	+	Na
Sea bass	*Dicentrarchus labrax*, Moronidae	381 (0.32)	Na	224–399[b]
Whiting	*Merlangius merlangus*, Gadidae	370 (0.26)	–[a]	–14 (south) –190 (north)[b]
Skates and rays	Batoidea	338 (0.42)	Thornback ray – Cuckoo ray +[a] Common skate –[c] Spotted ray decline since 1970s[c] Starry ray ±[c]	Common skate ~0–200[d] Thornback ray ~50–700[d]
Smooth-hound	*Mustelus mustelus*, Triakidae	265 (0.32)	+[c]	Na
Pollack	*Pollachius pollachius*, Gadidae	260 (0.22)	–[c]	Na
Flounder	*Platichthys flesus*, Pleuronectidae	122 (0.48)	Na	Na
Conger	*Conger conger*, Congridae	116 (0.25)	Na	Na

Note. The total weights have been raised using a national participation survey and different raising methods give slightly different total values.
[a]Simpson et al. (2011).
[b]Defra (2013).
[c]Sguotti, Lynam, García-Carreras, Ellis, and Engelhard (2016).
[d]Jones et al. (2013) (approximate values).

About 41% of the total recreational fishing effort occurs in coastal waters and only around 4% in offshore waters (Henry & Lyle, 2003). Climate-induced changes in distribution may impact the potential for recreational fishers to target their traditionally caught species (Tables 1 and 2).

3.1 | United Kingdom

Changing sea temperatures have caused some species to increase in numbers around the UK and some to decrease. In the north-east Atlantic, between 1980 and 2008, some species with a more cool water affinity have reduced in abundance. This included species of importance for recreational fishing such as Atlantic cod, whiting, thornback ray (*Raja clavate*, Rajidae), common skate (*Dipturus batis*, Rajidae) and spurdog (*Squalus acanthias*, Squalidae; Simpson et al., 2011; Sguotti et al., 2016). In the future, these cold-adapted species are expected to shift poleward and follow the colder conditions and their range around the UK is likely to reduce (Pinnegar, Garrett, Simpson, Engelhard, & Kooij, 2017). Modelled future species distributions of important recreational fish, such as haddock (*Melanogrammus aeglefinus*, Gadidae), Atlantic cod, common sole (*Solea solea*, Soleidae), lemon sole (*Microstomus kitt*, Pleuronectidae), whiting, thornback ray and common skate, suggest all of these species will shift poleward by the end of the century to habitats more suitable (Jones et al., 2013, 2012).

The top two recreational species in the UK (cod and mackerel) have been the focus of several studies on climate change and fishing.

Atlantic mackerel has recently expanded in range further north around northern Europe. There has been an increase in numbers in the northern North Sea (van der Kooij et al., 2016a), and large quantities are now caught around Iceland and Norway (Berge et al., 2015). Cod has been found to be significantly impacted by climate change by multiple studies; for example, a significant northern shift in North Sea cod stocks has been observed as temperature has increased in recent decades (Engelhard, Righton, & Pinnegar, 2014). Additionally, the complete collapse of Celtic and Irish Sea cod stocks has been predicted by 2,100, but increases are predicted in north Norway (Drinkwater, 2005). These data suggest that recreational anglers in Britain will struggle to catch cod in the future as the effects of climate change become more pronounced. Moreover, growth rates decrease and fewer fish are observed when sea temperatures rise (Dutil & Brander, 2003; Rätz & Lloret, 2003), exacerbating the possible reduction in the availability of large cod to recreational fishers due to climate change.

Conversely, warm-adapted species may be more available to recreational fishers than they were in the last century because of recent warming. Overall, the majority of the seas around the UK have a higher abundance of warm-affinity fish with past warming with regional variations (Simpson et al., 2011). If these trends continue, there may be a higher abundance of fish overall for recreational fishers, but not necessarily the traditionally caught species.

Interannual fluctuations in sea bass are frequently considered to be caused by fluctuations in sea temperature, and the species is expected to expand further north around the UK with climate change

TABLE 2 The total weight of the top ten species caught by total weight by Australian marine recreational fishers (Henry & Lyell, 2003)

Family or species	Scientific name	Total caught weight/t	Key climate drivers[a]	Resilience to climate change (resilient or vulnerable), and sensitivity score (1 (low) –10 (high))
Flatheads	Platycephalidae (including sand flathead *Platycephalus bassensis*, dusky flathead *P. fuscus*, tiger flathead *Neoplatycephalus richardsoni*)	2,326	Temperature, salinity, winds and currents, pH?, nutrients/plankton, freshwater flows, seagrass	Dusky flathead resilient[e], 4.75–5.67, sand flathead 5.75[b]
Mackerels	Scombridae	1,789	Na	Spotted mackerel (*Scomberomorus munroi*) resilient[e], 4.63–5.79[c], Spanish mackerel (*S. commerson*) resilient[e], 4.88–5.5, blue mackerel 5[b], jack mackerel 5.75[b], grey mackerel (*S. semifasciatus*) 5.25–5.92[c], school mackerel (*S. queenslandicus*) 6.25[c]
Breams	Sparidae (including yellowfin bream *Acanthopagrus australis*, black bream *A. butcheri*, northern bream *A. berda*, tarwhine *Rhabdosargus sarba*)	1,706	Black bream – temperature, salinity, pH?, freshwater flows, yellowfin bream, HABs	Black bream vulnerable[e], 6.5–6.75
Pink snapper	*Pagrus auratus*, Sparidae	1,422	Temperature, winds and currents, pH?	5.5–6
Tuna/bonitos	*Thunnus* and *Sarda* spp. (Scombridae)	1,328	Temperature, upwelling, winds and currents, pH?, small pelagics	Bigeye tuna (*T. sagax*) 4.74[b], southern bluefin (*T. maccoyii*) 5.25[b], yellowfin tuna (*T. albacores*)4.75[b], longtail tuna (*T. tonggol*) 4[c]
Whitings	Sillaginidae (mainly sand whiting *Sillago ciliata* and winter whiting *S. maculata*)	1,172	Na	Sand whiting 3[c], 5.5[c]
Australian salmon	*Arripis trutta* and *A. truttaceus*, Arripidae	1,113	Temperature, winds and currents, pH?	Vulnerability uncertain[e], 5.5[b]
Emperors	Lethrinidae	1,036	Na	Bluespotted emperor (*Lethrinus punctulatus*) 6.5[d], grass emperor (*L. laticaudis*) 5.5–7.75, spangled emperor (*L. nebulosus*) 5.75–7.75, red throat emperor (*L. miniatus*) 6.38[c], red emperor (*Lutjanus sebae*) 7.75[c]
Red emperor	*Lutjanus sebae*, Lutjanidae	984	Na	Resilient[e], 5.25–6.5
Molloway/jewfish	Sciaenidae	975	Na	Na

[a]Pecl et al. (2014).
[b]Pecl et al. (2011).
[c]Welch et al. (2014).
[d]Caputi et al. (2015).
[e]Creighton et al. (2011).

(Pinnegar et al., 2017). Anglers targeting sea bass may benefit from climate change in this case, or more anglers may turn to sea bass fishing. However, there has been an increase in commercial and recreational fishing in recent years, and sea bass stocks around the UK have declined over the past decade due to a combination of fishing pressure and weak recruitment (ICES, 2017, 2018b). This emphasizes that fish population responses to climate change are not easy to predict and are very dependent upon other factors such as fishing pressure.

3.2 | Australia

In Australia, several studies have estimated the sensitivity and vulnerability of the top fisheries species to climate change (Caputi et al., 2015; Creighton et al., 2011; Fulton et al., 2018; Pecl et al., 2014, 2011; Welch et al., 2014), many of which are also recreationally fished species. Combined information from these studies is shown in Table 2.

In Australia, at least 195 marine species have undergone a change in distribution since 2003, including 67 fish and 58 invertebrates, many of which are recreationally fished (Pecl, unpub. data). Most shifts have been recorded in south-east Australia and for species of a temperate affinity (e.g. Last et al., 2011; Robinson et al., 2015; Sunday et al., 2015), although this pattern may possibly reflect the greater research effort in this region (). Additionally, the dependence of many tropical fish species on coral may hinder their ability to expand (Feary et al., 2014; Munday, Jones, Pratchett, & Williams, 2008).

3.3 | Limitations to movement

Some species and stocks may be able to shift their distribution as modelling may suggest, but others that are at the warm limit of their range may simply decline. Movement of marine fish species spatially (e.g. Perry et al., 2005; Simpson et al., 2011) can only facilitate the avoidance of adverse conditions caused by a changing climate to a limited degree. There is also evidence that fish have shifted deeper on average with climate change, and this effect has been more marked than the latitudinal response in the North Sea (Audzijonyte & Pecl, 2018; Baudron, Pecl, Gardner, Fernandes, & Audzijonyte, 2019; Dulvy et al., 2008).

As with inland fish, which can be considered "canaries in a coal mine" with regard to detecting changes in the environment (Lynch et al., 2016), changes in assemblages of sensitive marine fish species may be some of the first climate change impacts that are seen. For certain species, the amount of suitable habitat could become even less with time, leading to additional issues such as increased mortality (Hixon & Jones, 2005) and decreased growth rates (Lorenzen & Enberg, 2002) owing to the greater density of individuals being squeezed into smaller areas of suitable habitat. Moreover, due to the rapid velocity of climate change (Loarie et al., 2009), many species

will not be able to adapt to the conditions within the timeframe available and may therefore ultimately perish.

3.4 | Arrival of novel species

Climate velocity trajectories, that is the speed and direction of temperature isotherms moving over the seascape, outline the shortest pathways that shifting species may follow to track their preferred thermal niches as global climate warms and is emerging as a consistent predictor for range shifts in the ocean (Pinsky, Worm, Fogarty, Sarmiento, & Levin, 2013; Poloczanska et al., 2013; Burrows et al., 2014). However, climate sink areas where conditions locally disappear might potentially block the movement of shifting species. "Out-of-range" fish observations in sink areas could represent the "arrival" stage of range-extending species that are prevented from shifting further (Fogarty, Burrows, Pecl, Robinson, & Poloczanska, 2016). With sinks being found along coastlines in particular, recreational fishers may be the first to see such arrivals. The assumption that fish can change their distributions based on suitable habitat assumes that the fish have the ability to freely move to new locations. In addition, changing strength and direction of ocean currents may have more influence on fish population movements as well as affecting connectivity between populations, potentially impacting on recruitment and distribution (van Gennip et al., 2017).

In countries with slightly warmer climates than the UK, such as France and Spain, some of the main species targeted by recreational fishers are also common to the UK. Others include albacore (*Thunnus alalonga*, Scombridae), ballan wrasse (*Labrus bergylta*, Labridae), conger eel (*Conger conger*, Congridae), horse mackerel (*Trachurus trachurus*, Carangidae), common octopus (*Octopus vulgaris*, Octopodidae), squid (*Loligo* spp., Loliginidae), cuttlefish (*Sepia officinalis*, Sepiidae) and sea breams Sparidae (Hyder et al., 2018). It might be hard to imagine some of these latter species being targeted around UK shores, but the warmer sea temperatures projected with climate change might be favourable for squid (van der Kooij, Engelhard, & Righton, 2016b) and bluefin tuna (*Thunnus thynnus*, Scombridae; MacKenzie, Payne, Boje, Høyer, & Siegstad, 2014; Pinnegar et al., 2017) and fishing magazines in the UK regularly feature articles about how to catch novel species, for example, triggerfish (*Balistes capriscus*, Balistidae). In fact, squid fishing is a popular activity for anglers in southern Europe and could become so around northern Europe if they are more easily caught. It is starting to be offered on charter boat trips in the south of England (e.g. VMO, 2019).

Bluefin tuna are now being caught around the south-west coast of the UK (Pinnegar et al., 2017) and are found as far north as Greenland (MacKenzie et al., 2014). These highly prized fish are likely to attract large numbers of sport fishers. Currently, there is no UK quota for bluefin tuna and there are calls for a catch and release recreational fishery for the species in the UK (Angling Trust, 2018; Bluefin Tuna UK, 2019). Other species of note which might spread around northern Europe are gurnards (Triglidae), John Dory (*Zeus faber*, Zeidae), red mullet (*Mullus surmuletus*, Mullidae) and the

splendid alfonsino (*Beryx splendens*, Berycidae) which is used in sushi (Simpson et al., 2011).

For many species, migration patterns are tied to prevailing currents, and the duration that preferred environmental conditions are present in particular regions can facilitate or hinder the movements of many pelagic and coastal species that are fished recreationally (Briscoe et al., 2017). Yellowtail kingfish (*Seriola lalandi*, Carangidae) for example is a species caught in eastern Australian fisheries, where the recreational catch exceeds that of the commercial catch (Lowry, Molony, Keag, & Penney, 2016), and where the distribution of oceanographic habitat has rapidly shifted poleward over the past 20 years (Champion, Hobday, Tracey, & Pecl, 2018a). In the south-east region of Australia, several "new" highly prized recreational species have been recorded, including mahi mahi or dolphin fish (*Coryphaena hippurus*, Coryphaenidae), yellowtail kingfish, snapper and others, creating some excitement among recreational fishers (2019).

Australia operates a national citizen science programme the Range Extension Database and Mapping project, or Redmap Australia (www.redmap.org.au), through which recreational fishers and SCUBA divers send in photographs of species they catch or observe further polewards than expected, that is, species that might be undergoing range shifts. Over 3,000 "out-of-range" photographic observations have been submitted by over 800 citizen scientists and verified by more than 60 scientists around Australia (2019). These photographic observations have recorded kingfish up to 200 km poleward of the previous southernmost occurrence record for this species (Stuart-Smith et al., 2016).

3.5 | Depth changes

An analysis of climate change-induced depth changes in North Sea fisheries by Dulvy et al. (2008) found significant depth increases for several key recreational species, such as plaice and whiting, with species moving 5–15 m deeper per decade. Since angling from the shore is the most common form of UK recreational fishing (Armstrong et al., 2013), fishers' access to these species could be greatly reduced, if the increase in depth preference means that these species will be located further offshore. Conversely, sole and pout (*Trisopterus luscus*, Gadidae) were found to move to shallower waters (between 6 and 7 m per decade; Dulvy et al., 2008; Engelhard, Pinnegar, Kell, & Rijnsdorp, 2011), which may increase access to these species closer to the shore. For sole in particular, the shallowing trend seems to be related to fewer extremely cold winters in recent years. Prior to this, sole typically migrated offshore each winter to seek out deeper, less cold, waters. Now sole are able to persist in shallow waters all year round (Engelhard et al., 2011).

The movement of species to either deeper or shallower waters could induce an increase in offshore angling as anglers attempt to target species they have historically caught. Alternatively, anglers may choose to change their target species to those moving inshore, such as sole, increasing the fishing pressure on these species. Of course, there are limits to how deep a species can go, particularly in the shallow shelf seas of north-west Europe, and many moved

into deeper waters in the 1980s, allowing little scope to move even deeper (Rutterford et al., 2015).

3.6 | Global changes

Research in other parts of the world shows similar changes in distribution and habitat restriction, with implications for anglers. Mirroring changes seen in Europe, over the last two decades of the 20th century, the composition of nearshore reef fish in the Southern California Bight, has shifted from northern- to southern-affinity species (Holbrook, Schmitt, & Stephens, 1997). There was also a 15%–25% reduction biodiversity overall. This was attributed to declining recruitment correlated with the biomass of microzooplankton in the California Current, associated with a climate regime shift. Studies on bonefish (*Albula Vulpes*, Albulidae), a popular sportfish in the Gulf of Mexico, show that they will be very vulnerable to temperature changes in the future, and in particular, they may not be able to inhabit nearshore environments, compared with species more able to acclimatize, such as schoolmaster snapper (*Lutjanus apodus*, Lutjanidae) or yellowfin mojarra (*Gerres cinereus*, Gerreidae; Shultz, Zuckerman, Stewart, & Sucki, 2014; Shultz, Zuckerman, & Suski, 2016).

Other important recreational fish that have been widely studied include tuna and billfish. The future distributions of the Pacific skipjack tuna (*Katsuwonus pelamis*, Scombridae) were modelled into the coming century, and biomass is projected to increase in the Western Central Pacific Ocean until 2050, and then stabilize and start to decrease after 2060 (Lehodey, Senina, Calmettes, Hampton, & Nicol, 2013). The models showed that feeding and spawning habitat becomes more favourable in the eastern Pacific and also extends to higher latitudes, while the western equatorial warm pool becomes less suitable for spawning. Atlantic bluefin tuna will also likely experience habitat loss in the northern Gulf of Mexico as temperatures increase this century, while the habitat will become more suitable for skipjack tuna (Muhling et al., 2015). Higher temperatures in the Gulf of Mexico may impact egg survival and larval development of Atlantic bluefin tuna and yellowfin tuna (*Thunnus albacares*, Scombridae), and larval abundance of blue marlin (*Makaira nigricans*, Istiophoridae; Dell'Apa, Carney, Davenport, & Vernon Carle, 2018). Blue marlin habitat will change, and they may move deeper, as warm water extends deeper (Dell'Apa et al., 2018).

Recreational anglers fishing in southern Europe may also see a substantial change in their catch as the surface air and sea temperatures are predicted to rise (Bethoux, Gentili, Raunet, & Tailliez, 1990; Giorgi & Lionello, 2008; Lejeusne, Chevaldonné, Pergent-Martini, Boudouresque, & Perez, 2010). Recreational and small-scale commercial fishers in the Mediterranean Sea have reported 75 species that have recently arrived or are increasing in abundance, and these are mostly warm-adapted species, both native and non-native (Azzurro et al., 2019). The expected rise in Mediterranean temperature may cause several commonly caught species, such as frigate tuna (*Auxis thazard*, Scombridae), herring (*Clupea harengus*, Clupeidae), sardines (*Sardina pilchardus*,

Clupeidae) and Atlantic horse mackerel (*Trachurus trachurus*, Carangidae; Khalfallah, Dimech, Ulman, Zeller, & Pauly, 2017; Matíc-Skoko, Soldo, Stagličić, Blažević, & Iritani, 2014) to shift in distribution to the point where the catchability of these species by recreational anglers declines to zero. Climate change is likely to cause a decline in many Mediterranean species, including shad (*Alosa alosa*, Clupeidae), flounder, plaice and Fusca drum (*Umbrina ronchus*, Sciaenidae) that are important for recreational spearfishing and angling, because ranges cannot easily shift in this enclosed sea (Albouy et al., 2013). Alternatively, the increased temperatures expected in the Mediterranean could increase the catchability of other species because of an increased reproductive success and distribution range, as has already been observed in round sardinella (*Sardinella aurita*, Clupeidae; Sabates, Martin, Lloret, & Raya, 2006).

Species currently only significantly prevalent in the Mediterranean could "spill-out" via the Strait of Gibraltar and head northwards, increasing the chances of recreational anglers in northern Europe encountering them on fishing trips. Projections for the end of the century suggest that 54 fish species are expected to lose their climatically suitable habitat by 2080–99, and that species richness is predicted to decrease across 70.4% of the continental shelf area, especially in the western Mediterranean Sea and several parts of the Aegean Sea (Albouy et al., 2013). Species projected to lose all of their climatically suitable conditions by 2080–99 are more commonly targeted by commercial fleets (18 species out of 54) than by recreational fleets (4 species out of 54; Albouy et al., 2013).

Interestingly, most studies on climate change focus on how a temperature increase will affect distributions, whereas there is a lack of research on the impact of cold shock events (Szekeres et al., 2016). Cold events have caused mass mortalities of important recreational fish species in the past, including of billfish, permit (*Trachinotus falcatus*, Carangidae) and snook (*Centropomus undecimalis*, Centropomidae) in Florida, and models should be developed that investigate how climate could impact cold anomalies and how these can affect fish (Szekeres et al., 2016). In contrast, modelling has found that cold snaps in offshore areas have decreased in recent decades (Schlegel, Oliver, Wernberg, & Smit, 2017). In the UK in the winter of 2018, large numbers of invertebrates including lobsters (*Homarus Gammarus*, Nephropidae) and crabs washed up on the North Sea coast after a very cold period, and this event was widely reported in the media (e.g. Guardian, 2018).

4 | BODY SIZE

Capturing large individuals of a target species is one of the main motivators for recreational fishers (Beardmore, Hunt, Haider, Dorow, & Arlinghaus, 2014). Many fishing tournaments for example have prizes specifically for the largest catch. Increases in sea temperature could impact the body size of fish with decreases in ectotherm body sizes considered as a universal response to global warming (e.g. Daufresne, Lengfellner, & Sommer, 2009;

Fonds, Cronie, Vethaak, & Puyl, 1992; Imsland, Sunde, Folkvord, & Stefansson, 1996; Peck, Buckley, Caldarone, & Bengtson, 2003; Pörtner & Farrel, 2008; Yamashita, Tanaka, & Miller, 2001). For temperate species, experimental work suggests that fish body size decreases by 3%–5% per degree Celsius (Forster, Hirst, & Atkinson, 2012). Studies currently underway around Australia indicate that warming is correlated with declines in body size within this range (Audzijonjyte, pers com).

In the western English Channel, there was an interannual increase in mean temperatures of over 2°C between 1911 and 2007 (Genner et al., 2010). A decline was found in the larger body size classes in all 30 species examined, including common recreational species like cod, pollack and ray species. Lower numbers of larger size classes could cause smaller, younger fish to be at greater risk of being caught which may reduce populations in the long term (Lewin et al., 2018). A reduced chance of catching highly desired large individuals may cause recreational fishers to lose interest in the sport, although research in the United States has suggested that this is not always the case (McClenachan, 2009).

5 | FISHING OPERATIONS

5.1 | Weather

Weather conditions may affect the desirability of recreational fishing as a pastime in the future, both positively and negatively. The impacts can be categorized mainly in terms of increasing air temperatures and changes in the timing and extent of sunny or rainy periods, rainfall intensity and changes in frequency and intensity of storms and waves. The UK is expected to experience an increase in air temperatures, with projections for southern England showing a mean summer temperature increase of 4.2°C by 2080, and the Scottish islands an increase of 2.5°C (Jenkins et al., 2010). Daily minimum winter temperatures are also projected to increase across the country (Jenkins et al., 2010). These increases in temperature may make recreational fishing more attractive as a hobby throughout the year. On very hot days, fishers may choose to fish during the evening or night, rather than stop fishing completely, as found to be the case in a study in the Atlantic and Gulf Coasts of the United States (Dundas & von Haewfen, 2015).

Rainfall changes could also affect fishing participation. In New England and the North Atlantic United States, participation is expected to decrease with increasing rainfall, but overall participation in shoreline recreational fishing may increase with climate change (Dundas & von Haewfen, 2015). Rainfall projections vary around the UK, and so fishers in some parts of the country will be affected more than others. The biggest change in winter precipitation is a 33% increase along the west of the UK. However, in the Scottish Highlands, rainfall may decrease (Jenkins et al., 2010), potentially making recreational fishing more appealing.

In southern Australia, fishers will be affected by rising sea levels and sea surface temperatures. Fishers who fish from the shore will be particularly impacted by near-coastal sea surface temperature rise

of typically around 0.4–1.0°C by 2030 and around 2–4°C by 2090 (CSIRO, 2015). Rainfall in this region is projected to decrease in the spring with the winter declines potentially as high as 50% by 2090. Changes in summer and autumn rainfall cannot be reliably projected, but there is medium confidence in a decrease (CSIRO, 2015). Models project heatwaves, on land and in the ocean, to become more frequent, hotter and last longer across Australia by the end of the 21st century (Perkins-Kirkpatrick et al., 2016). Again, fishers may choose to fish in the evening or at night, rather than stop fishing altogether (Dundas & von Haewfen, 2015).

5.2 | Storms and waves

Climate projections on storms and waves are complex and do not paint a clear picture globally (Church et al., 2013); however since 1948, waves and wind speeds have been getting stronger around the globe (Reguero, Losada, & Méndez, 2019; Young & Ribal, 2019). There is uncertainty in the projections of storminess around northern Europe, although seasonal mean and extreme wave heights are projected to increase around the south-west of the UK, change little in the southern North Sea and reduce to the north of the UK (Jenkins et al., 2010).

There has been an increase in extreme weather events since the 1980s in Australia. It is likely that the intensity of tropical cyclones will increase (e.g. Abbs, 2012; Walsh et al., 2016). Climate models also suggest that cyclones are moving south affecting the southern parts of the country (Sharmila & Walsh, 2018). Although investigation into determining which climate mechanisms control variability of Australia's wave climate is continuing (Hemer, Church, & Hunter, 2007), it is evident that because storms are occurring in an environment with higher sea levels the storm surge impacts can be much worse.

Changes in storm conditions and sea level rise are expected to increase the risk of damage to commercial fishing infrastructure such as harbours, landing sites and jetties, and boats themselves in certain areas (Garrett et al., 2015b). This is likely to be the same for infrastructure on which recreational fishers rely, such as piers, harbour walls and sea defences, and marinas for recreational boats.

The number of days at sea may be reduced in commercial fisheries if storms become more frequent or intense and conditions are unsafe (Garrett et al., 2015b), and the same bad weather conditions are likely to impact the recreational sector. If weather conditions affect either safety or comfort, both in boats and on shore, then this is likely to reduce the number of suitable fishing days per year. There is also potential that rougher conditions could cause more gear to be lost, causing higher replacement and insurance costs for fishers, and increasing ghost fishing and marine litter. Conversely, in areas where wave heights may decrease (as projected for the north of the UK), conditions for fishing from boats are likely to improve.

Models have been used to predict the location choice of commercial fishing vessels based on operating costs (e.g. Giardin et al., 2017) and also predict when a vessel owner might choose to enter or leave the industry altogether (Tidd, Hutton, Kell, & Padda, 2011). Comparable methods have not yet been applied to recreational fisheries and modelling fisher motivations. However, a model developed to explore decision-making in the recreational squid fishery of Palma Bay in the Balearic Islands, Spain, found that poor sea conditions caused a marked decrease in the number of recreational boats operating (Cabanellas-Reboredo et al., 2014). Despite unexplained variability in the model, the probability that a boat departed from port decreased, on average, to 0.5 at a wave height of 0.8 m. The probability that a boat would go out fishing was negligible if the wave height was >1.5 m.

In commercial fisheries, an anticipated effect of any increase in storm or waves is an increase in water turbidity which could reduce the catchability of fish by hooks and lines (Garrett et al., 2015b). Marine recreational anglers will likely face the same challenges, as fish which rely on sight over smell are less able to find bait. Experiments on Atlantic cod have shown that they reduce their activity at intermediate turbidities (i.e. they are more active in high and low turbidity waters) and so take longer to find prey (Meager & Batty, 2007), and this may indeed also be the case for finding baited hooks.

5.3 | Sea level change

Projections show that 70% of the world's coasts are likely to experience a rise in sea level in the coming century, with regional differences (Church et al., 2013). Sea levels are expected to be between 12 and 76 cm higher by 2095 around the UK (Jenkins et al., 2010). Sea level rise may narrow beaches towards cliffs or sea defences (i.e. coastal squeeze) or cover rocky areas (Baglee, Haworth, & Anastasi, 2012), thus reducing the number or suitability of fishing sites. If people's preferred or favourite fishing sites become less unavailable or less suitable, or if people have to travel further to find good sites, this again could reduce the desirability of recreational fishing.

6 | COSTS, PARTICIPATION AND MOTIVATION

Recreational fishers observe changes in the environment (van Putten et al., 2017) and so are in a good position to respond to those changes and adapt their behaviour, whether they consider them as climate change related or not. While many natural resource managers and governments are unsure of how to respond to climatic changes (Miller et al., 2018), individuals in fast-changing regions of the world are already adjusting their behaviour to accommodate these (Pecl et al., 2019). Recreational fishers generally have four behavioural substitution strategies (temporal, species, location and activity) to deal with changing environmental or management conditions (Sutton, 2006).

If changing a target species requires the purchase of new equipment or baits, the cost could prevent some people from
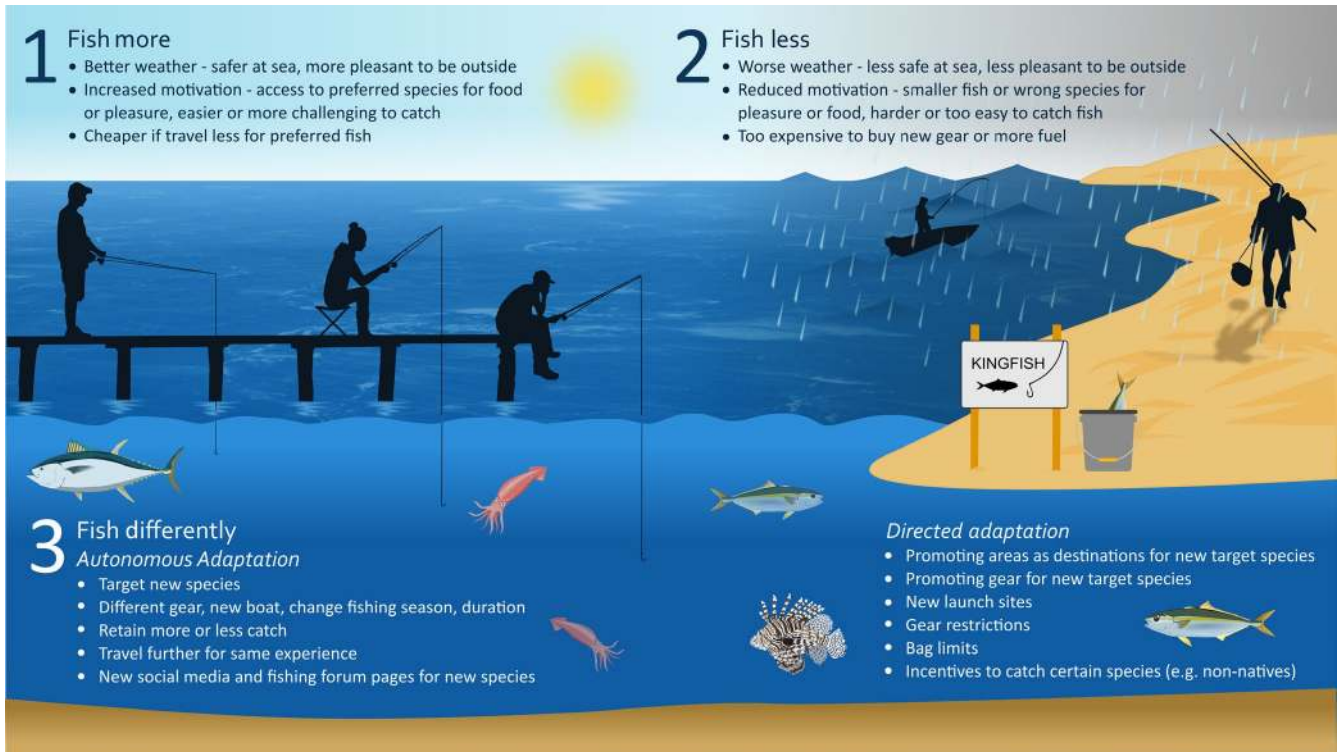
FIGURE 2 Four different types of response that recreational fishers may take as climate change affects their fishing operation

switching species. Fuel and travel costs of moving location could also be a deterrent. Conversely, fishers may have to travel shorter distances, reducing fuel and travel costs. Other important considerations are seasonal shifts, which may not coincide with people's annual holidays, affecting convenience and ability to fish. All of these trade-offs in costs and behavioural changes are complex, and there is likely to be a mixed response from fishers to the effects of climate change.

Fishers may fish less, fish more, some may stop fishing altogether, while others will adapt their behaviour to fish differently. These changes are illustrated in Figure 2, showing how various climate change effects could impact fishers' motivation and behavioural choices. As a consequence, some regions may experience an increase in marine recreational fishing activity, while others a decrease, and many will see changes relating to the main species targeted, types of gear used and modes of fishing.

6.1 | Behavioural changes

Australian marine recreational fishers would change their fishing behaviour if there was a large decline in fish abundance (van Putten et al., 2017). Behavioural changes include switching to fish for other species which are more abundant and using different gear types or technologies. If there was a 50% decline in abundance, only 16% of survey respondents would stop fishing altogether; the rest would change their behaviour. 40% of fishers responded that they would not stop fishing, no matter how much

fish abundance declined (van Putten et al., 2017). For many recreational fishers, stopping fishing is not an option and the authors suggest that to help people who are less likely, or slower, to adapt, they could be linked up with those who are faster to adopt adaptation strategies through fora or networks and therefore share knowledge and experiences. Angling organizations and magazines may have an important role to play in facilitating information sharing opportunities to promote adaptation.

6.2 | Autonomous adaptation

In response to climate change, off the east coast of Tasmania, several "bottom-up" or autonomous adaptations are already occurring, that is, changes without any government or management intervention (Pecl et al., 2019). Increasing availability of several desirable species has led to a proliferation of social media pages and online fora dedicated to targeting the species and has increased fisher interactions. In contrast, for other "new" species, some fishing groups have been very secretive about the new species making it difficult for local resource managers to understand what changes are occurring. Several charter operators have also advertised the opportunity to target new species for the first time, and SCUBA divers have shifted locations due to climate-driven habitat changes that have then reduced availability of lobster and abalone. Local tackle shops have also started stocking particular lures specifically for the new species.

Since the increase in yellowtail kingfish numbers in southern Australia, local charter operators in Tasmania have started

advertising for fishing trips (Pecl et al., 2019). The poleward range extension of yellowtail kingfish (Champion, Hobday, Tracey, et al., 2018a; Robinson et al., 2015) means that fishers and managers will need to adapt to these changes in future. Marine resource users require information relevant to their activities at decision-making timescales in order to adapt effectively. For coastal regions with changing currents, temporal habitat persistence (e.g. months per year) could be an important metric for climate change adaptation because it provides fishery-relevant information that socially and economically may equate to shifts in recreational fishing opportunity (Champion, Hobday, Zhang, Pecl, & Tracey, 2018b). When communicated as a measure of "fishing opportunity," future predictions of increased habitat persistence may support sustained investment from fishers, such as the purchase of gear or licences.

6.3 | Directed adaptation

Where recreational fishers do not adapt without intervention, directed adaptation can take place, with new areas being promoted as destinations, new launch sites being advertised, incentives put in place to catch certain species, such as non-native or invasive species, and management measures can be imposed where necessary. For example, the Florida Fish and Wildlife Conservation Commission encourages fishers to catch the highly predatory lionfish and provides tips on how to catch them, to limit their negative impacts on native marine life (FFWCC, 2019). Management measures for recreational fishing include bag limits, licences, size limits, gear restrictions and seasonal or spatial moratoria. These could be employed alongside commercial fisheries management, if climate change causes stocks to decline or shift. For freshwater angling, detailed studies have been conducted to determine the optimal management actions, which consider angler motivation and species ecology (e.g. Johnston, Arlinghaus, & Dieckmann, 2012) which could be employed for marine recreational fishing.

In some countries, recreational fishing is already included in stock assessments and quota management. This is possible where there are reliable time series of recreational catches (e.g. using licence and bag limit data for Southern rock lobster (*Jasus edwardsii*, Palinuridae) and abalone (*Haliotis* spp., Haliotidae) in Australia) and is included in some European stock assessments (e.g. European sea bass (ICES, 2018b), western Baltic cod (Atlantic cod; ICES, 2016)). Management measures are generally not popular with recreational fishers; however, they can be necessary if commercial and recreational fishers compete for resources. In some cases, management has been driven by communities, such as calls to ensure humane treatment of rays in Victoria, Australia, or to simplify rules in Western Australia. In Australia, stocks can shift and require management across state boundaries, whereas in Europe, the situation is more complex because fisheries management is undertaken with neighbouring European countries, with particular implications for stocks that cross international boundaries.

7 | CONCLUSIONS

Climate change will continue to cause complex changes to occur in the marine socio-ecological environment, with consequences for marine recreational fishing. In the UK, some shifts in important recreational species are currently being observed. In Australia, fishers and tackle shops are already beginning to adapt to environmental change. In some communities, fishing-related businesses are able to take advantage of some changes that have led to desirable species moving into an area and becoming available for recreational fishing. In some locations, autonomous adaptation has taken place. In other locations, directed assistance from governments, angling member organizations or marine managers might be needed to encourage fishers to target other species of fish or target them in different ways, or with different gear. Not all climate-driven changes will occur at once, and changes in species availability are likely to be gradual in many cases, with recreational fishers making incremental changes in behaviour. However, changing storm patterns and sea level rise could cause significant changes to coastlines or operating practices in short periods of time. Such changes would require faster, potentially more substantial and proactive responses by fishers and communities.

Globally, shifts in the distribution and migration of recreational fish species are expected, but management implications will vary for different situations. Species distribution shifts, changes in migration patterns and changing abundances could cause or aggravate competition for marine resources and lead to sectoral tensions between the marine recreational fishing and commercial fishing sectors. This will require careful management to ensure that the catches of both sectors are taken into account in stock management, and that the needs of participants in both sectors are considered.

Recreational fishing is often excluded from climate change assessments on fish and fisheries, and future research should include consideration of combined catches and any implications for recreational fishers. This includes ecological, but also social and economic studies, as recreational fishing has a large part to play in well-being and in contributing to coastal economies. Applied research could be focused on how to enable recreational fishers to adapt to changes in species availability, such as the use of different gears, how best to promote new locations and whether fishing for specific species should be encouraged or discouraged. Some management measures could be very unpopular, and finding the best ways to encourage voluntary cooperation and minimise non-compliance of recreational fishers should be a priority (Mackay, Jennings, Putten, Sibly, & Yamazaki, 2018). In many cases, recreational fishers have decades of knowledge of how fish species, size and seasonality have changed in their local area, and research which captures this local knowledge would be very valuable (e.g. Azzurro et al., 2019). Similarly, ongoing monitoring to capture future changes can help scientists understand climate effects and how to best manage them (2019).

There are clearly recreational fishing opportunities in regions where charismatic novel target species are expanding or shifting their range. In some cases, marine managers or communities could help facilitate the realization of these opportunities. There is evidence that in some cases, the fishers themselves (and fishing-related businesses) have naturally altered their activities and autonomously adapted to the fishing opportunities that have presented themselves (Pecl et al., 2019). Examples from Australia in particular have shown that recreational fishers are resilient and adaptive and can take advantage of some changing conditions and new species. Some local economies could be big winners from climate change if they can take advantage of the increased high-value tourism opportunities which sport fishing offers. However, taking advantage of opportunities should be managed carefully to avoid the potential of over-exploitation. Especially since the exact recreational catches are often not recorded or monitored, consideration of the recreational catch in the Total Allowable Catch estimates is essential. Only if the autonomous and assisted adaptive behaviours of recreational fishers are monitored and considered as part of a marine socio-ecological system, will they continue to be able to benefit from this activity and ensure sustainable exploitation of the marine environment at the same time.

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REFERENCES

Abbs, D. (2012). *The impact of climate change on the climatology of tropical cyclones in the Australian region*. CSIRO Climate Adaptation Flagship Working Paper, No, 11.

Albouy, C., Guilhaumon, F., Leprieur, F., Lasram, F. B. R., Somot, S., Aznar, R., … Mouillot, D. (2013). Projected climate change and the changing biogeography of coastal Mediterranean fishes. *Journal of Biogeography*, 40, 534–547. https://doi.org/10.1111/jbi.12013

Angling Trust (2018). *Bluefin Tuna. Bluefin Tuna are back in Britain – let's give them a future*. Retrieved from: https://www.anglingtrust.net/page.asp?section=1829&sectionTitle=Bluefin+Tuna

Arkenford (2017). *Watersports Participation Survey Full Report* (98 pp). Surrey, UK: Arkenford https://www.britishmarine.co.uk/Resources/Publications/2018/April/Watersports-Participation-Survey-2017-Full-Report

Armstrong, M., Brown, A., Hargreaves, J., Hyder, K., Munday, M., Proctor, S., & Roberts, A. (2013). *Sea Angling 2012 – a survey of recreational sea angling activity and economic value in England*. Crown copyright 2013, London, UK, 16 pp.

Audzijonyte, A., & Pecl, G. T. (2018). Deep impact of fisheries. *Nature Ecology and Evolution*, 2(9), 1348–1349. https://doi.org/10.1038/s41559-018-0653-9

Australia (2010). *National Climate Change and Fisheries Action Plan 2009–2012*. Australian Fisheries Management Forum (for the) Natural Resource Management Ministerial Council. http://www.tarfish.org/documents/National-climate-change-action-plan-fisheries-aquaculture-nov-2010.pdf

Australian Bureau of Statistics (2010). *Australian Fisheries Statistics 2009*. ABARE–BRS 2010 Canberra, August.

Azzurro, E., Sbragaglia, V., Cerri, J., Bariche, M., Bolognini, L., Souissi, J. B., … Modschella, P. (2019). Climate change, biological invasions, and the shifting distribution of Mediterranean fishes: A large-scale survey based on local ecological knowledge. *Global Change Biology*, https://doi.org/10.1111/gcb.14670

Baglee, A., Haworth, A., & Anastasi, S. (2012). *Climate change risk assessment for the business, industry and services sector*. UK2012 Climate Change Risk Assessment. Retrieved from http://randd.defra.gov.uk/Document.aspx?Document=CCRAfortheBusiness,IndustryandServicesSector.pdf

Baudron, A., Pecl, G. T., Gardner, C., Fernandes, P. G., & Audzijonyte, A. (2019). Ontogenetic deepening of Northeast Atlantic fish stocks is not driven by fishing exploitation. *Proceedings of the National Academy of Sciences*, 116, 2390–2392. https://doi.org/10.1073/pnas.1817295116

Beardmore, B., Haider, W., Hunt, L. M., & Arlinghaus, R. (2011). The importance of trip context for determining primary angler motivations: Are more specialized anglers more catch-oriented than previously believed? *North American Journal of Fisheries Management*, 31, 861–879. https://doi.org/10.1080/02755947.2011.629855

Beardmore, B., Hunt, L. M., Haider, W., Dorow, M., & Arlinghaus, R. (2014). Effectively managing angler satisfaction in recreational fisheries requires understanding the fish species and the anglers. *Canadian Journal of Fisheries and Aquaculture Sciences*, 72, 500–513. https://doi.org/10.1139/cjfas-2014-0177

Berge, J., Heggland, K., Lønne, O. J., Cottier, F., Hop, H., Gabrielsen, G. W., … Misund, O. A. (2015). First records of Atlantic Mackerel (*Scomber scombrus*) from the Svalbard Archipelago, Norway, with possible explanations for the extension of its distribution. *Arctic*, 68, 54–61. https://doi.org/10.14430/arctic4455

Bethoux, J. P., Gentili, B., Raunet, J., & Tailliez, D. (1990). Warming trend in the western Mediterranean deep water. *Nature*, 347, 660–662. https://doi.org/10.1038/347660a0

Bluefin Tuna UK (2019). *Bluefin tuna are back in Britain – Let's give them a future*. Retrieved from: https://bluefintuna.co.uk

Briscoe, D. K., Hobday, A. J., Carlisle, A., Scales, K., Eveson, J. P., Arrizabalaga, H., … Fromentin, J.-M. (2017). Ecological bridges and barriers in pelagic ecosystems. *Deep Sea Research – II. Topical Studies in Oceanography*, 140, 182–192. https://doi.org/10.1016/j.dsr2.2016.11.004

Burrows, M. T., Schoeman, D. S., Richardson, A. J., Molinos, J. G., Hoffmann, A., Buckley, L. B., … Poloczanska, E. S. (2014). Geographical limits to species-range shifts are suggested by climate velocity. *Nature*, 507, 492–495 https://doi.org/10.1038/nature12976

Cabanellas-Reboredo, M., Alós, J., March, D., Palmer, M., Jordà, G., & Palmer, M. (2014). Where and when will they go fishing? Understanding fishing site and time choice in a recreational squid fishery. *ICES Journal of Marine Science*, 71, 1760–1773. https://doi.org/10.1093/icesjms/fst206

Caputi, N., Feng, M., Pearce, A., Benthuysen, J., Denham, A., Hetzel, Y., … Chandrapavan, A. (2015). *Management implications of climate change effect on fisheries in Western Australia. Part 1. Environmental change and risk assessment*. Fisheries Research Report 260, Department of Fisheries Western Australia, September 2015.

Champion, C., Hobday, A. J., Tracey, S. R., & Pecl, G. T. (2018a). Rapid shifts in distribution and high-latitude persistence of oceanographic habitat revealed using citizen science data from a climate change hotspot. *Global Change Biology*, *24*(11), 5440–5453 https://doi.org/10.1111/gcb.14398

Champion, C., Hobday, A. J., Zhang, X., Pecl, G. T., & Tracey, S. R. (2018b). Changing windows of opportunity: Past and future climate-driven shifts in temporal persistence of kingfish (*Seriola lalandi*) oceanographic habitat within south-eastern Australian bioregions. *Marine and Freshwater Research*, *70*(1), 33 https://doi.org/10.1071/MF17387

Church, J. A., Clark, P. U., Gregory, J. M., Jevrejeva, S., Levermann, A., Merrifield, M. A., ... Unnikrishnan, A. S. (2013). Sea level change. In T. F. Stocker, D. Qin, F.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. M. Midgley (Eds.). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY: Cambridge University Press.

Cisneros-Montemayor, A. M., & Sumaila, U. R. (2010). A global estimate of benefits from ecosystem-based marine recreation: Potential impacts and implications for management. *Journal of Bioeconomics*, *12*, 245–268. https://doi.org/10.1007/s10818-010-9092-7

Creighton, C., Sawynok, B., Sutton, S., D'Silva, D., Stagles, I., Pam, C., ... Spooner, D. (2011). *Climate change and recreational fishing: Implications of climate change for recreational fishers and the recreational fishing industry*. Australian Government Project 2011/037. Recfishing Research 2013.

CSIRO and Bureau of Meteorology (2015). *Climate Change in Australia Information for Australia's Natural Resource Management Regions: Technical Report*. Australia: CSIRO and Bureau of Meteorology.

Daufresne, M., Lengfellner, K., & Sommer, U. (2009). Global warming benefits the small in aquatic ecosystems. *Proceedings of the National Academy of Sciences*, *106*, 12788–12793. https://doi.org/10.1073/pnas.0902080106

Defra (2013). *Economics of Climate Resilience (ECR) – CA0401*. Final Report: CA0401 – Natural Environment Theme: Sea Fish. Retrieved from: http://randd.defra.gov.uk/Default.aspx?Module=More&Location=None&ProjectID=18016

Dell'Apa, A., Carney, K., Davenport, T., & Vernon Carle, M. (2018). Potential medium-term impacts of climate change on tuna and billfish in the Gulf of Mexico: A qualitative framework for management and conservation. *Marine Environmental Research*, *141*, 1–11. https://doi.org/10.1016/j.marenvres.2018.07.017

Drinkwater, K. F. (2005). The response of Atlantic cod (*Gadus morhua*) to future climate change. *ICES Journal of Marine Science*, *62*, 1327–1337. https://doi.org/10.1016/j.icesjms.2005.05.015

Dulvy, N. K., Rogers, S. I., Jennings, S., Stelzenmüller, V., Dye, S. R., & Skjoldal, H. R. (2008). Climate change and deepening of the North Sea fish assemblage: A biotic indicator of warming seas. *Journal of Applied Ecology*, *45*, 1029–1039. https://doi.org/10.1111/j.1365-2664.2008.01488.x

Dundas, S. J., & von Haefen, R. H. (2015). *Weather effects on the demand for coastal recreational fishing: Implications for a changing climate*. (CEnREP Working Paper No 15–015). Raleigh, NC: Center for Environmental and Resource Economic Policy.

Dutil, J. D., & Brander, K. (2003). Comparing productivity of North Atlantic cod (*Gadus morhua*) stocks and limits to growth production. *Fisheries Oceanography*, *12*, 502–512. https://doi.org/10.1046/j.1365-2419.2003.00243.x

Engelhard, G. H., Pinnegar, J. K., Kell, L. T., & Rijnsdorp, A. D. (2011). Nine decades of North Sea sole and plaice distribution. *ICES Journal of Marine Science*, *68*, 1090–1104. https://doi.org/10.1093/icesjms/fsr031

Engelhard, G. H., Righton, D. A., & Pinnegar, J. K. (2014). Climate change and fishing: A century of shifting distribution in North Sea cod. *Global Change Biology*, *20*, 2473–2483. https://doi.org/10.1111/gcb.12513

Feary, D. A., Pratchett, M. S., J Emslie, M., Fowler, A. M., Figueira, W. F., Luiz, O. J., ... Booth, D. J. (2014). Latitudinal shifts in coral reef fishes: Why some species do and others do not shift. *Fish and Fisheries*, *15*, 593–615. https://doi.org/10.1111/faf.12036

Fedler, A. J., & Ditton, R. B. (1994). Understanding angler motivations in fisheries management. *Fisheries*, *19*, 6–13. https://doi.org/10.1577/1548-8446(1994)019<0006:UAMIFM>2.0.CO;2

FFWCC (2019). *Lionfish*. Retrieved from: https://myfwc.com/fishing/saltwater/recreational/lionfish/

Fogarty, H. E., Burrows, M. T., Pecl, G. T., Robinson, L. M., & Poloczanska, E. S. (2016). Are fish outside their usual ranges early indicators of climate-driven range shifts? *Global Change Biology*, *23*, 2047–2057. https://doi.org/10.1111/gcb.13635

Fogarty, H., Cvitanovic, C., Hobday, A. J., & Pecl, G. T. (accepted) Prepared for a change? An assessment of the current state of knowledge to support climate adaptation for Australian fisheries. *Reviews in Fish Biology and Fisheries*.

Fonds, M., Cronie, R., Vethaak, A. D., & Van der Puyl, P. (1992). Metabolism, food consumption and growth of plaice (*Pleuronectes platessa*) and flounder (*Platichthys flesus*) in relation to fish size and temperature. *Netherlands Journal of Sea Research*, *29*, 127–143. https://doi.org/10.1016/0077-7579(92)90014-6

Forster, J., Hirst, A. G., & Atkinson, D. (2012). Warming-induced reductions in body size are greater in aquatic than terrestrial species. *Proceedings of the National Academy of Sciences*, *109*, 19310–19314. https://doi.org/10.1073/pnas.1210460109

Frijlink, S., & Lyle, J. M. (2010). *An evaluation of motivations, attitudes and awareness of Tasmania recreational fishers*. Hobart: Tasmanian Aquaculture and Fisheries Institute, University of Tasmania.

Fulton, E. A., Hobday, A. J., Pethybridge, H., Blanchard, J., Bulman, C., Butler, I., ... Zhang, X. (2018). *Decadal scale projection of changes in Australian fisheries stocks under climate change*. CSIRO Report to FRDC. FRDC Project No: 2016/139.

Garrett, A., Buckley, P., & Brown, S. (2015a). *Understanding and responding to climate change in the UK seafood industry: Climate change risk adaptation for wild capture seafood*. A Seafish report to the UK Government under the Climate Change Adaptation Reporting Power.

Garrett, A., Buckley, P., Brown, S., & Townhill, B. (2015b). *Climate change adaptation in UK seafood: Understanding and responding to climate change in the UK wild capture seafood industry*. A joint Seafish/MCCIP summary, 16 pp. https://doi.org/10.14465/2015.sarps.001-016

Genner, M. J., Sims, D. W., Southward, A. J., Budd, G. C., Masterson, P., McHugh, M., ... Hawkins, S. J. (2010). Body size-dependent responses of a marine fish assemblage to climate change and fishing over a century-long scale. *Global Change Biology*, *16*, 517–527. https://doi.org/10.1111/j.1365-2486.2009.02027.x

German Government (2008). *German Strategy for Adaptation to Climate Change adopted by the German federal cabinet on 17th December 2008*. Retrieved from: http://www.bmub.bund.de/fileadmin/bmu-import/files/english/pdf/application/pdf/das_gesamt_en_bf.pdf

Giorgi, F., & Lionello, P. (2008). Climate change projections for the Mediterranean region. *Global and Planetary Change*, *63*, 90–104. https://doi.org/10.1016/j.gloplacha.2007.09.005

Girardin, R., Hamon, K. G., Pinnegar, J., Poos, J. J., Thébaud, O., Tidd, A., ... Marchal, P. (2017). Thirty years of fleet dynamics modelling using discrete-choice models: What have we learned? *Fish and Fisheries*, *18*, 638–655. https://doi.org/10.1111/faf.12194

Government of Canada (2005). *Climate change risk assessment for fisheries Canada*. Fisheries and Oceans Canada. Retrieved from: http://www.dfo-mpo.gc.ca/science/oceanography-oceanographie/accasp-psaccma/profile-2005-eng.html#ac

Guardian (2018). *Mass die-off of sea creatures follows freezing of UK weather*. Retrieved from: https://www.theguardian.com/environment/2018/mar/05/mass-die-off-of-sea-creatures-follows-freezing-uk-weather?CMP=fb_gu

Hemer, M. A., Church, J. A., & Hunter, J. R. (2007). Waves and climate change on the Australian coast, SI 50. *Proceedings of the 9th International Coastal Symposium*, 432–437. Gold Coast, Australia, ISSN 0749.0208.

Henry, G. W., & Lyle, J. M. (2003). *The National Recreational and Indigenous Fishing Survey July 2003*. FRDC Project No. 99/158. Australian Government Department of Agriculture, Fisheries and Forestry, Canberra

Hixon, M. A., & Jones, G. P. (2005). Competition, predation, and density-dependent mortality in demersal marine fishes. *Ecology*, 86, 2847–2859. https://doi.org/10.1890/04-1455

Hobday, A. J., & Pecl, G. T. (2014). Identification of global marine hotspots: Sentinels for change and vanguards for adaptation action. *Reviews in Fish Biology and Fisheries*, 24, 415–425. https://doi.org/10.1007/s11160-013-9326-6

Holbrook, S. J., Schmitt, R. J., & Stephens, J. S. Jr (1997). Changes in an assemblage of temperate reef fishes associated with a climate shift. *Ecological Applications*, 7, 1299–1310. https://doi.org/10.1890/1051-0761(1997)007[1299:CIAAOT]2.0.CO;2

Hollowed, A. B., Barange, M., Beamish, R. J., Brander, K., Cochrane, K., Drinkwater, K., ... Yamanaka, Y. (2013). Projected impacts of climate change on marine fish and fisheries. *ICES Journal of Marine Science*, 70, 1023–1037. https://doi.org/10.1093/icesjms/fst081

Hyder, K., Weltersbach, M. S., Armstrong, M., Ferter, K., Townhill, B., Ahvonen, A., ... Strehlow, H. V. (2018). Recreational sea fishing in Europe in a global context—Participation rates, fishing effort, expenditure, and implications for monitoring and assessment. *Fish and Fisheries*, 19, 225–243. https://doi.org/10.1111/faf.12251

ICES (2016). *ICES Advice on fishing opportunities, catch, and effort Baltic Sea Ecoregion*. Version 3, 6 October 2016.

ICES (2017). *Report of the Data Evaluation meeting for the Benchmark Workshop on Sea Bass (DEWKBASS)*. 10–12 January 2017, Copenhagen, Denmark. ICES CM 2017/ACOM:32. 139 pp.

ICES (2018a). *Report from the Working Group on Recreational Fisheries Surveys (WGRFS)*. 11–15 June 2018, Faro, Portugal. ICES CM 2018/EOSG:19. 111 pp.

ICES (2018b). *Report of the Benchmark Workshop on Seabass (WKBASS), 20–24 February 2017 and 21–23 February 2018, Copenhagen, Denmark*. ICES CM 2018/ACOM:44. 283 pp.

Imsland, A. K., Sunde, L. M., Folkvord, A., & Stefansson, S. O. (1996). The interaction of temperature and fish size on growth of juvenile turbot. *Journal of Fish Biology*, 49, 926–940. https://doi.org/10.1111/j.1095-8649.1996.tb00090.x

IPCC (1997). *The Regional Impacts of Climate Change: An assessment of vulnerability*. R.T. Watson, M.C. Zinyowera, R.H. Moss (Eds.), (pp. 517). Cambridge, UK: Cambridge University Press.

IPCC (2013). Summary for Policymakers. In T. F. Stocker, D. Qin, G.-K. Plattner, M. Tignor, S. K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, & P. M. Midgley (Eds.), *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, UK and New York, NY: Cambridge University Press.

Jenkins, G., Murphy, J., Sexton, D., Lowe, J., Jones, P., & Kilsby, C. (2010). *UK Climate Projections: Briefing report* Version 2, December 2010. Retrieved from http://ukclimateprojections.metoffice.gov.uk/media.jsp?mediaxml:id=87867&filetype=pdf

Johnston, F. D., Arlinghaus, R., & Dieckmann, U. (2012). Fish life history, anger behaviour and optimal management of recreational fisheries. *Fish and Fisheries*, 14, 554–579. https://doi.org/10.1111/j.1467-2979.2012.00487.x

Jones, M. C., Dye, S. R., Fernandes, J. A., Frölicher, T. L., Pinnegar, J. K., Warren, R., & Cheung, W. W. L. (2013). Predicting the impact of climate change on threatened species in UK waters. *PLoS ONE*, 8, e54216. https://doi.org/10.1371/journal.pone.0054216

Jones, M. C., Dye, S. R., Pinnegar, J. K., Warren, R., & Cheung, W. W. L. (2012). Modelling commercial fish distributions: Prediction and assessment using different approaches. *Ecological Modelling*, 225, 133–145. https://doi.org/10.1016/j.ecolmodel.2011.11.003

Kerr, L. A., Connelly, W. J., Martino, E. J., Peer, A. C., Woodland, R. J., & Secor, D. H. (2017). Climate change in the US Atlantic affecting recreational fisheries. *Reviews in Fisheries Science*, 17, 267–289. https://doi.org/10.1080/10641260802667067

Khalfallah, M., Dimech, M., Ulman, A., Zeller, D., & Pauly, D. (2017). Reconstruction of marine fisheries catches for the Republic of Malta (1950–2010). *Mediterranean Marine Science*, 18, 241–250. https://doi.org/10.12681/mms.1683

Last, P. R., White, W. T., Gledhill, D., Hobday, A. J., Brown, R., Edgar, G. J., & Pecl, G. T. (2011). Long-term shifts in abundance and distribution of a temperate fish fauna: A response to climate change and fishing practices. *Global Ecology and Biogeography*, 20, 58–72. https://doi.org/10.1111/j.1466-8238.2010.00575.x

Lehodey, P., Senina, I., Calmettes, B., Hampton, J., & Nicol, S. (2013). Modelling the impact of climate change on Pacific skipjack tuna population and fisheries. *Climatic Change*, 119, 95–109. https://doi.org/10.1007/s10584-012-0595-1

Lejeusne, C., Chevaldonné, P., Pergent-Martini, C., Boudouresque, C. F., & Perez, T. (2010). Climate change effects on a miniature ocean: The highly diverse, highly impacted Mediterranean Sea. *Trends in Ecology and Evolution*, 25, 250–260. https://doi.org/10.1016/j.tree.2009.10.009

Lewin, W. C., Strehlow, H. V., Ferter, K., Hyder, K., Niemax, J., Herrmann, J. P., & Weltersbach, M. S. (2018). Estimating post-release mortality of European sea bass based on experimental angling. *ICES Journal of Marine Science*, 75, 1483–1495. https://doi.org/10.1093/icesjms/fsx240

Loarie, S. R., Duffy, P. B., Hamilton, H., Asner, G. P., Field, C. B., & Ackerly, D. D. (2009). The velocity of climate change. *Nature*, 462, 1052. https://doi.org/10.1038/347660a0

Lorenzen, K., & Enberg, K. (2002). Density-dependent growth as a key mechanism in the regulation of fish populations: evidence from among-population comparisons. *Proceedings of the Royal Society of London B: Biological Sciences*, 269, 49–54. https://doi.org/10.1098/rspb.2001.1853.

Lowry, M., Molony, B., Keag, M., & Penney, A. (2016). *Yellowtail kingfish Seriola lalandi*. (Fisheries Research and Development Corporation.) Retrieved from http://fish.gov.au/reports/finfish/Pages/yellowtail kingfish.

Lynch, A. J., Cooke, S. J., Deines, A. M., Bower, S. D., Bunnell, D. B., Cowx, I. G., ... Beard, D. (2016). The social, economic, and environmental importance of inland fish and fisheries. *Environmental Reviews*, 24, 115–121. https://doi.org/10.1139/er-2015-0064

Mackay, M., Jennings, S., van Putten, E. I., Sibly, H., & Yamazaki, S. (2018). When push comes to shovel in recreational fishing compliance, think 'nudge'. *Marine Policy*, 95, 256–266. https://doi.org/10.1016/j.marpol.2018.05.026

MacKenzie, B. R., Payne, M. R., Boje, J., Høyer, J. L., & Siegstad, H. (2014). A cascade of warming impacts brings bluefin tuna to Greenland waters. *Global Change Biology*, 20, 2484–2491. https://doi.org/10.1111/gcb.12597

Matić-Skoko, S., Soldo, A., Stagličić, N., Blažević, D., & Iritani, D. (2014). *Croatian marine fisheries (Adriatic Sea): 1950–2010*. Fisheries Centre Working Paper No. 26.

McClenachan, L. (2009). Documenting loss of large trophy fish from the Florida Keys with historical photographs. *Conservation Biology*, 23, 636–643. https://doi.org/10.1111/j.1523-1739.2008.01152.x

Meager, J. J., & Batty, R. S. (2007). Effects of turbidity on the spontaneous and prey-searching activity of juvenile Atlantic cod (*Gadus morhua*). *Philosophical Transactions of the Royal Society*, 362, 2123–2130. https://doi.org/10.1098/rstb.2007.2104

Miller, D. D., Ota, Y., Sumaila, U. R., Cisneros-Montemayor, A. M., & Cheung, W. W. L. (2018). Adaptation strategies to climate change in marine systems. *Global Change Biology*, 24(1), e1–e14 https://doi.org/10.1111/gcb.13829

Montero-Serra, I., Edwards, M., & Genner, M. J. (2015). Warming shelf seas drive the subtropicalization of European pelagic fish communities. *Global Change Biology*, 21, 144–153. https://doi.org/10.1111/gcb.12747

Muhling, B. A., Liu, Y., Lee, S.-K., Lamkin, J. T., Roffer, M. A., Muller-Karger, F., & Walter, J. F. (2015). Potential impact of climate change on the Intra-Americas Sea: Part 2. Implications for Atlantic bluefin tuna and skipjack tuna adult and larval habitats. *Journal of Marine Systems*, 148, 1–13. https://doi.org/10.1016/j.jmarsys.2015.01.010

Munday, P. L., Jones, G. P., Pratchett, M. S., & Williams, A. J. (2008). Climate change and the future for coral reef fishes. *Fish and Fisheries*, 9, 261–285. https://doi.org/10.1111/j.1467-2979.2008.00281.x

Ormsby, J. (2004). *Research Publication No. 78. A Review of the Social, Motivational and Experiential Characteristics of Recreational Anglers from Queensland and the Great Barrier Reef*. Great Barrier Reef Marine Park Authority. Townsville.

Peck, M. A., Buckley, L. J., Caldarone, E. M., & Bengtson, D. A. (2003). Effects of food consumption and temperature on growth rate and biochemical-based indicators of growth in early juvenile Atlantic cod *Gadus morhua* and haddock *Melanogrammus aeglefinus*. *Marine Ecology Progress Series*, 251, 233–243. https://doi.org/10.1038/347660a0

Pecl, G. T., Araújo, M. B., Bell, J. D., Blanchard, J., Bonebrake, T. C., Chen, I. C., ... Williams, S. E. (2017). Biodiversity redistribution under climate change: Impacts on ecosystems and human well-being. *Science*, 355, eaai9214 https://doi.org/10.1126/science.aai9214

Pecl, G., Ogier, E., Jennings, S., van Putten, I., Crawford, C., Fogarty, H., ... Tracey, S. (2019). Autonomous adaptation to climate-driven change in marine biodiversity in a global marine hotspot. *Ambio*, https://doi.org/10.1007/s13280-019-01186-x

Pecl, G. T., Stuart-Smith, J., Walsh, P., Bray, D., Brians, M., Burgess, M., ... Moltschaniwskyj, N. (2019). Redmap Australia: challenges and successes with a large-scale citizen science-based approach to ecological monitoring and community engagement on climate change. *Frontiers in Marine Science*. https://doi.org/10.3389/fmars.2019.00349

Pecl, G. T., Ward, T., Doubleday, Z., Clarke, S., Day, J., Dixon, C., ... Stoklosa, R. (2011). Risk Assessment of Impacts of Climate Change for Key Marine Species in South Eastern Australia. Part 1: Fisheries and Aquaculture Risk Assessment. *Fisheries Research and Development Corporation*, Project 2009/070.

Pecl, G. T., Ward, T. M., Doubleday, Z. A., Clarke, S., Day, J., Dixon, C., ... Stoklosa, R. (2014). Rapid assessment of fisheries species sensitivity to climate change. *Climatic Change*, 127(3-4), 505–520 https://doi.org/10.1007/s10584-014-1284-z

Perkins-Kirkpatrick, S. E., White, C. J., Alexander, L. V., Argüeso, D., Boschat, G., Cowan, T., ... Purich, A. (2016). Natural hazards in Australia: Heatwaves. *Climatic Change*, 139, 101–114. https://doi.org/10.1007/s10584-016-1650-0

Perry, A. L., Low, P. J., Ellis, J. R., & Reynolds, J. D. (2005). Climate change and distribution shifts in marine fishes. *Science*, 308, 1912–1915. https://doi.org/10.1126/science.1111322

Pinnegar, J. K., Garrett, A., Simpson, S. D., Engelhard, G. H., & van der Kooij, J. (2017). Fisheries. *Marine Climate Change Impacts Partnership*, 2017, 73–89. https://doi.org/10.14465/2017.arc10.007-fis

Pinsky, M. L., Worm, B., Fogarty, M. J., Sarmiento, J. L., & Levin, S. A. (2013). Marine taxa track local climate velocities. *Science*, 341, 1239–1242. https://doi.org/10.1126/science.1239352

Poloczanska, E. S., Brown, C. J., Sydeman, W. J., Kiessling, W., Schoeman, D. S., Moore, P. J., ... Richardson, A. J. (2013). Global imprint of climate change on marine life. *Nature Climate Change*, 3, 919–925. https://doi.org/10.1038/nclimate1958

Pörtner, H. O., & Farrell, A. P. (2008). Physiology and climate change. *Science*, 322, 690–692. https://doi.org/10.1126/science.1163156

Queensland Department of Primary Industries (2019). *Fishweb*. Retrieved from: http://www.dpi.qld.gov.au/fishweb/

Radford, Z., Hyder, K., Zarauz, L., Mugerza, E., Ferter, K., Prellezo, R., ... Weltersbach, M. S. (2018). The impact of marine recreational fishing on key fish stocks in European waters. *Plosone*, 13, e0201666 https://doi.org/10.1371/journal.pone.0201666

Rätz, H. J., & Lloret, J. (2003). Variation in fish condition between Atlantic cod (*Gadus morhua*) stocks, the effect on their productivity and management implications. *Fisheries Research*, 60, 369–380. https://doi.org/10.1016/S0165-7836(02)00132-7

Reguero, B. G., Losada, I. J., & Méndez, F. J. (2019). A recent increase in global wave power as a consequence of oceanic warming. *Nature Communications*, 10, 205. https://doi.org/10.1038/s41467-018-08066-0

Roberts, A., Munday, M., Roche, N., Brown, A., Armstrong, M., Hargreaves, J., ... Hyder, K. (2017). Assessing the contribution of recreational sea angling to the English economy. *Marine Policy*, 83, 146–152. https://doi.org/10.1016/j.marpol.2017.05.028

Robinson, L., Gledhill, D., Moltschaniwskyj, N., Hobday, A., Frusher, S., Barrett, N., ... Pecl, G. (2015). Rapid assessment of an ocean warming hotspot reveals 'high' confidence in potential species' range extensions. *Global Environmental Change*, 31, 28–37. https://doi.org/10.1016/j.gloenvcha.2014.12.003

Rutterford, L. A., Simpson, S. D., Jennings, S., Johnson, M. P., Blanchard, J. L., Schön, P.-J., ... Genner, M. J. (2015). Future fish distributions constrained by depth in warming seas. *Nature Climate Change*, 5, 569–573. https://doi.org/10.1038/nclimate2607

Sabatés, A. N. A., Martin, P., Lloret, J., & Raya, V. (2006). Sea warming and fish distribution: The case of the small pelagic fish, *Sardinella aurita*, in the western Mediterranean. *Global Change Biology*, 12, 2209–2219. https://doi.org/10.1111/j.1365-2486.2006.01246.x

Sainsbury, N. C., Genner, M. J., Saville, G. R., Pinnegar, J. K., O'Neill, C. K., Simpson, S. D., & Turner, R. A. (2018). Changing storminess and global capture fisheries. *Nature Climate Change*, 8, 655–659. https://doi.org/10.1038/s41558-018-0206-x

Schlegel, R. W., Oliver, E. C. J., Wernberg, T., & Smit, A. J. (2017). Nearshore and offshore co-occurrence of marine heatwaves and cold-spells. *Progress in Oceanography*, 151, 189–205. https://doi.org/10.1016/j.pocean.2017.01.004

Schultz, A. D., Zuckerman, Z. C., Stewart, H. A., & Sucki, C. D. (2014). Seasonal blood chemistry response of sub-tropical nearshore fishes to climate change. *Conservation Physiology*, 2, cou028. https://doi.org/10.1093/conphys/cou028

Schultz, A. D., Zuckerman, Z. C., & Suski, C. D. (2016). Thermal tolerance of nearshore fishes across seasons: Implications for coastal fish communities in a changing climate. *Marine Biology*, 163, 83. https://doi.org/10.1007/s00227-016-2858-2

Sguotti, C., Lynam, C. P., García-Carreras, B., Ellis, J. R., & Engelhard, G. H. (2016). Distribution of skates and sharks in the North Sea: 112 years of change. *Global Change Biology*, 22, 2729–2743. https://doi.org/10.1111/gcb.13316

Sharmila, S., & Walsh, K. J. E. (2018). Recent poleward shift of tropical cyclone formation linked to Hadley cell expansion. *Nature Climate Change*, 8, 730–736. https://doi.org/10.1038/s41558-018-0227-5

Simpson, S. D., Jennings, S., Johnson, M. J., Blanchard, J. L., Schön, O.-J., Sims, D. W., & Genner, M. J. (2011). Continental shelf-wide response of a fish assemblage to rapid warming of the sea. *Current Biology*, 21, 1565–1570. https://doi.org/10.1016/j.cub.2011.08.016

Stuart-Smith, J., Pecl, G., Pender, A., Tracey, S., Villanueva, C., & Smith-Vaniz, W. F. (2016). Southernmost records of two Seriola species in an Australian ocean-warming hotspot. *Marine Biodiversity*, 48, 1579–1582. https://doi.org/10.1007/S12526-016-0580-4

Sunday, J., Pecl, G., Frusher, S., Hobday, A., Hill, N., Holbrook, N. J., ... Bates, A. E. (2015). Species traits and climate velocity explain geographic range shifts in an ocean-warming hotspot. *Ecology Letters*, 18, 944–953. https://doi.org/10.1111/ele.12474

Sutton, S. G. (2006). *An assessment of the social characteristics of Queensland's recreational fishers*. Report prepared for the CRC Reef Research Centre, Townsville.

Szekeres, P., Eliason, E. J., Lapointe, D., Donaldson, M. R., Brownscombe, J. W., & Cooke, S. J. (2016). On the neglected cold side of climate change and what it means to fish. *Climate Research*, *69*, 239–245. https://doi.org/10.3354/cr01404

Szuwalski, C. S., & Hollowed, A. B. (2016). Climate change and non-stationary population processes in fisheries management. *ICES Journal of Marine Science*, *73*, 1297–1305. https://doi.org/10.1093/icesjms/fsv229

Tidd, A. N., Hutton, T., Kell, L. T., & Padda, G. (2011). Exit and entry of fishing vessels: An evaluation of factors affecting investment decisions in the North Sea English beam trawl fleet. *ICES Journal of Marine Science*, *68*, 961–971. https://doi.org/10.1093/icesjms/fsr015

van der Kooij, J., Engelhard, G. H., & Righton, D. A. (2016b). Climate change and squid range expansion in the North Sea. *Journal of Biogeography*, *43*, 2285–2298. https://doi.org/10.1111/jbi.12847

van der Kooij, J., Fassler, S. M. M., Stephens, D., Readdy, L., Scott, B. E., & Roel, B. A. (2016a). Opportunistically recorded acoustic data support Northeast Atlantic mackerel expansion theory. *ICES Journal of Marine Science*, *73*, 1115–1126. https://doi.org/10.1093/icesjms/fsv243

van Gennip, S. J., Popova, E. E., Yool, A., Pecl, G. T., Hobday, A. J., & Sorte, C. J. B. (2017). Going with the flow: The role of ocean circulation in global marine ecosystems under a changing climate. *Global Change Biology*, *23*, 2602–2617 https://doi.org/10.1111/gcb.13586

van Putten, I. E., Jennings, S., Hobday, A. J., Bustamante, R. H., Dutra, L. X. C., Frusher, S., … Pecl, G. (2017). Recreational fishing in a time of rapid ocean change. *Marine Policy*, *76*, 169–177. https://doi.org/10.1016/j.marpol.2016.11.034

VMO (2019). *Veals Mail Order Blog*. Retrieved from: https://www.veals.co.uk/blog/tag/weymouth-squid-fishing/

Walsh, K. J., McBride, J. L., Klotzbach, P. J., Balachandran, S., Camargo, S. J., Holland, G., … Sugi, M. (2016). Tropical cyclones and climate change. *WIRES Climate Change*, *7*, 65–89. https://doi.org/10.1002/wcc.371

Welch, D., Saunders, T., Robins, J., Harry, A., Johnson, J., Maynard, J., … A. (2014). *Implications of climate change impacts on fisheries resources of northern Australia Part 1: Vulnerability assessment and adaptation options*. Fisheries Research and Development Corporation, project No. 2010/565.

Yamashita, Y., Tanaka, M., & Miller, J. M. (2001). Ecophysiology of juvenile flatfish in nursery grounds. *Journal of Sea Research*, *45*, 205–218. https://doi.org/10.1016/S1385-1101(01)00049-1

Young, I. R., & Ribal, A. (2019). Multiplatform evaluation of global trends in wind speed and wave height. *Science*, *364*, 548–552. https://doi.org/10.1126/science.aav9527