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REVIEW

First records of unusual marine fish distributions—can they predict climate changes?

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Global climate change is impacting the ecology and biogeography of marine fish populations and will continue to do so in the future. Here, I review recent records of unusual marine fish distributions from different regions of the world, and discuss the relevance of such observations to climate changes. In conclusion, I suggest that first records of fish in unusual habitats may aid as an indicator of climate changes, provided each record is critically assessed and combined with recent records of fish population parameters, population dynamics, marine habitat assessments and abiotic data such as sea bottom, middle and surface temperatures.

Keywords: first records, unusual marine fish distributions, prediction, climate change

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The current change in the global climate is impacting us all by unusual floods, heavy rains and warm weather just to mention a few examples. In the oceans the impact of global climate change is perhaps especially a result of elevated temperature. This shift will continue to impact us and the majority of animal and plant populations. Data trends reveal global climate change effects ranging from increased oxygen consumption rates in fish, to changes in foraging and migrational patterns to fish community changes (Henderson, 2007). Future CO_2-induced climate change scenarios from global circulation models point to increasing air temperatures, with the greatest warming in the Arctic and Subarctic. Changes to the wind fields and precipitation patterns are also likely to happen. These will lead to changes in the hydrographical properties of the ocean, and the vertical stratification and circulation patterns (Drinkwater, 2005). Thus, we can expect fish populations in new habitats on a global scale to decline as well as a collapse of many fisheries species. As an example, stocks of Atlantic cod (*Gadus morhua*) in the Celtic and Irish Seas are likely to disappear under predicted temperature changes by the year 2100, while those in the southern North Sea and Georges Bank will decline (Drinkwater, 2005).

The shift in ecology and biogeography of marine fish species in the beginning of the 21st Century may hypothetically be a useful indicator for climate changes. However, first sightings of fish in highly unusual habitats and, or, new geographical areas may differ in relevance from case to case. Here, I have selected some recent cases which I discuss the pertinent use of as climate change indicators.

Settlement of the tropical lessepsian blue-barred parrotfish *Scarus ghobban* (Teleostei: Scaridae) in the eastern Mediterranean was recently observed by Bariche & Saad (2005). The blue-barred parrotfish, *Scarus ghobban* Forsskål, 1775, is a wide-ranging Scaridae found from the eastern Pacific to the Red Sea and south to Algoa Bay in South Africa. This first observation in the Mediterranean is probably due to the migrational possibility via the Suez Canal. However, settling is highly dependent on optimum conditions, and such circumstances in a subtropical region for a tropical fish species may be due to climate change (Bariche & Saad, 2005).

Another lessepsian fish species, the migrant dusky spinefoot (*Siganus luridus*), was caught for the first time in March 2004 in the southern Tyrrhenian Sea (a part of the Mediterranean Sea off the western coast of Italy). This species migrated from the Red Sea through the Suez Canal into the Mediterranean where it was first recorded in 1956 (Castriota & Andaloro, 2005 and references therein). It then became common in Lebanon, Cyprus, the southern coast of Turkey, Rhodes, and was also recorded in Cretan waters and in the Gulf of Patras, Ionian Sea. Along the southern coast, *S. luridus* reached the Nile Delta, the Libyan coasts

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and Tunisia, where it first appeared in 1969 in the Gulf of Tunis, and later in the Gulf of Gabès in 1974, where it is now found frequently. Since the 1990s it has been observed by SCUBA divers in Maltese waters. A settled population was recently also recorded in the Pelagie Islands, Strait of Sicily, south Italy (Castriota & Andaloro, 2005).

A bit further north in the Mediterranian region, there was a recent first record of the Mediterranean parrotfish (*Sparisoma cretense*) in Ria Formosa, south Portugal. The Mediterranean parrotfish is a common species in the Macaronesian archipelagos (Azores, Madeira, Canaries and Cape Verde Islands), north-western coast of Africa and on the southern and eastern coasts of the Mediterranean, but it is the only species from the family Scaridae to be found in Mediterranean waters (Abecasis *et al.*, 2006). The possibility that warming water occurring in the Mediterranean basin may be involved in the spreading of *S. cretense* outside its typical distribution range was recently also noticed in south-eastern Italy (Guidetti & Boero, 2001).

The unusual sightings of *Scarus ghobban*, *Siganus luridus* and *Sparisoma cretense* makes them potential candidates as indicators of climate changes, but the speculative reasonings for the unusual abundances make the observations too weak presently to be used as signs of climate changes. However, in combination with other parameters such as recent population biography assessments of the distribution of the populations as a whole the sightings may, or may not, be useful indicators.

The first record of the African lockdown (*Selene dorsalis*; of the tropical pelagic family Carangidae) in the Spanish waters of the Gulf of Cádiz, was made recently by Juárez *et al.* (2006). *Selene dorsalis* is a schooling species, which inhabits inshore waters at depths of at least 100 m from the Cape Verde Islands and Senegal to South Africa. The presence of this species in the Gulf of Cádiz is unexpected according to Juárez *et al.* (2006). They conclude that their record, together with other appearance records in waters off Portugal and Madeira, may indicate a displacement of the northern limit of the species distribution, which may be related to episodes of local warming-up of the water masses that converts the area into an optimal habitat for *S. dorsalis*. The appearance of this species in the Canary Islands and in Moroccan waters may support this hypothesis (Juárez *et al.*, 2006).

In California, USA, another family member of the Carangidae, the fortune jack, *Seriola peruana*, a pelagic and demersal marine fish found in coastal areas of the tropical eastern Pacific Ocean, was recently reported in the southern Gulf of California for the first time, further north than its usual area of occurrence in the tropical eastern Pacific (Tavera *et al.*, 2005). According to local fishermen, the fortune jack is now quite common and can be found as far north as the middle of the Gulf of California. Tavera *et al.* (2005) suggest that the present record of *S. peruana* might signal the hypothesized pattern of oceanic warming (tropicalization phenomenon) or an indicator that they can adapt to the temperate or subtropical regime of the Gulf of California. The hypothesis that these sightings are indicators of climate changes is promising but it must, as for the first sightings, be tested before any conclusions can be made, by including several biotic and abiotic parameters related to the population of this species, before it is possible to conclude that the unusual distribution may be caused by climate changes.

In Argentinean waters Venerus *et al.* (2007) recently made the first record of the namorado sandperch, *Pseudopercis numida*, in a shallow rocky reef located near Pardelas Beach (42°38′S 64°16′W), Nuevo Gulf, Argentina, about 1600 km southwards of the previously reported limit. Venerus *et al.* (2007) point out that this new record represents an addition to a list of recently reported range expansions of warm-temperate reef fish species into higher latitudes within the northern Patagonian gulfs of Argentina of the dusky grouper *Epinephelus marginatus* (Irigoyen *et al.*, 2005) and the silver porgy, *Diplodus argenteus* (Galván *et al.*, 2005). Venerus *et al.* (2007) emphasizes that the mechanisms by which these species appeared in the North Patagonian Gulfs Ecoregion (*sensu* Sullivan Sealey & Bustamante, 1999) are unknown. Venerus *et al.* (2007) continue with the consideration that if the new records just reflected increased sampling effort, one would expect to find both warm-temperate and temperate species incrementing their distributional ranges. Another possibility is that the new records indicate true southward expansions of warm-temperate species favoured by a possible increase in water temperature. Though no time data series of temperature exist for northern Patagonia, a statistically significant increase of 1.2°C (surface) and 0.5°C (bottom) in the mean summer water temperature was detected in San Jorge Gulf and adjacent waters (43°S–47°S) between 1995 and 2000 (Venerus *et al.*, 2007 and references therein).

This is the kind of analysis each case of unusual first sighting must go through before it can be considered a reliable support to other observations of climate changes.

Moving from Argentina across the Pacific, to the north-western Pacific, there is at least one recent case which is likely to be caused by climate change. This is an interesting case because it is a report of change in habitat use by a coral reef fish, but not a change in the geographical distribution pattern of this species (as most examples in this review are). In the Ryukyus Archipelago, southern Japan, at the southernmost local eastern reef of Akajima Island (26.640′N 127.867′E) Arvedlund & Takemura (2005) observed one adult anemonefish (SL = 9 cm) of the species *Amphiprion clarkii* (*sensu* Fautin & Allen, 1997) residing in the same soft coral of the genus *Lobophytum* sp. (*sensu* Fabricius & Alderslade, 2001) at 1-m depth, over 20 months from May 2003 to December 2004 (Figure 1). Anemonefish comprise a well known guild of 28 damselfish (family Pomacentridae) that are obligate symbionts of 10 host sea anemones (families Actiniidae, Stichodactylidae and Thalassianthidae) in the tropical and suitable subtropical Indo-Pacific region (Allen, 1975; Dunn, 1981; Fautin & Allen, 1997). This case can be traced back to a result of climate change. The 1998 global coral bleaching event (Wilkinson, 1998) had a serious impact on the local coral reefs of Sesoko Island (Loya *et al.*, 2001). In addition, several host sea anemone species disappeared and the abundance of the surviving species declined seriously (Hattori, 2002). In February 2005 the host sea anemones had not recovered yet (Arvedlund, personal observation).

Of cases which are most likely not indicators of climate changes, there is for example the anterior portion of a smooth hammerhead shark (*Sphyrna zygaena*), a large marine top predator, that was found near the high tide mark in Portreath Harbour, north Cornwall, the United Kingdom, by Mr Kevin Melton of Portreath (Southall & Sims, 2006). This large hammerhead shark species has a

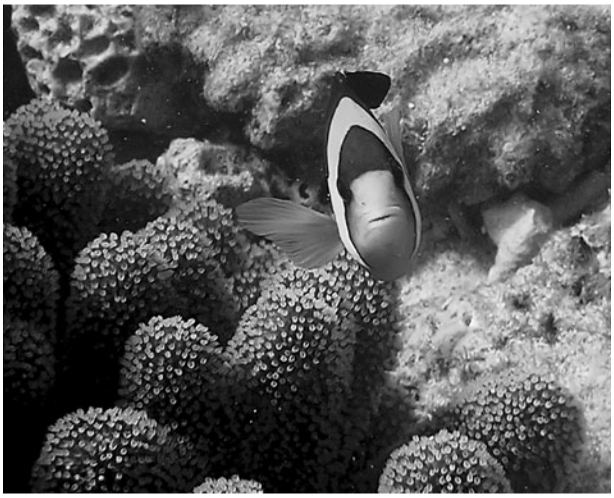

Fig. 1. First records of marine species of fish in highly unusual habitats are on the increase. The image shows the first long term record of the anemonefish *Amphiprion clarkii* in association with a soft coral of the genus *Lobophytum* at a shallow coral reef in the Ryukyu Archipelago, Japan, during 20 months in 2003 and 2004 (Arvedlund & Takemura, 2005). This unusual anemonefish microhabitat pattern is thought to be the result of all host sea anemones dying out on local reefs. The 1998 global coral bleaching event (Wilkinson, 1998) had a serious impact on Japanese coral reefs (Loya *et al.*, 2001). Image by M. Arvedlund.

broad geographical distribution, occupying coastal–pelagic and semi-oceanic habitats of the continental and insular shelves in tropical and warm-temperate zones of the Pacific, Atlantic and Indian Oceans. In the eastern North Atlantic it is present in the Mediterranean, extending south to Senegal, and northwards to the British Isles. It is considered exceptionally rare in British waters. Only five records of single individuals occurring in British waters exist, made between 1829 and 1865 (Southall & Sims, 2006). However, because of these five records in the 19th Century, the recent record shows that the range pattern for this shark sometimes includes the United Kingdom, not because of climate change but for other reasons.

Two individuals of the longfin mako shark (*Isurus paucus*), a large marine top predator, were caught in September 2005, north-west of the Azores (42°50′N 36°16′W) on swordfish long lines, with baits set at a depth between 50 and 100 m over an average water depth of 4000 m (Queiroz *et al.*, 2006). The longfin mako is a pelagic, oceanic, probably circumtropical shark, apparently common in the western Atlantic (Queiroz *et al.*, 2006). Querioz *et al.*'s result confirms the presence of *I. paucus* in mid-North Atlantic waters, expanding their known distribution. The ragged-tooth shark (*Odontaspis ferox*) was recently spotted at Fernando de Noronha Archipelago, western equatorial Atlantic for the first time (Garla & Júnior, 2006). The ragged-tooth shark is a poorly known species with cosmopolitan and disjunct distribution throughout most of the tropical and subtropical oceans of the world (Garla & Júnior, 2006). These shark cases are most likely not indicators of climate changes because these fish are pelagic, and often cosmopolitan in range.

Another type of first records, which is of little or no use as an indicator of climate changes, is when marine fish with a prolonged pelagic larval phase are involved in first records of unusual distributions. Palacios-Salgado *et al.* (2007) published a first record of *Acanthurus nigricans* (Perciformes: Acanthuridae) and *Cantherhines dumerilii* (Tetraodontiformes: Monacanthidae) from the Guerrero coast, México. Both species are categorized as wandering residents of the tropical eastern Pacific (Robertson *et al.*, 2004). Species of the genus *Acanthurus* are characterized by a prolonged larval stage, lasting several months (McCormick, 1999). The duration of the pelagic larval stage of species of the genus *Cantherhines* is unknown, but juveniles of *Cantherhines dumerilii* are often associated with floating objects (Castro *et al.*, 2002), which enables them to disperse widely (Palacios-Salgado *et al.*, 2007 and references therein).

Finally, some species cannot be used as indicators because they have been transported directly by human activity into a new area and/or habitat. For example, the first record of the muzzled blenny, *Omobranchus punctatus*, was recently recorded for the first time in the Mediterranean Sea, collected among fouling organisms covering the frame of aquaculture cages at the entrance to the port of Ashdod, Israel (Golani, 2004). Golani suggests that its presence there is most likely due to accidental introduction attributed to ship-mediated transfer. Such cases are numerous.

Summing up, *some* first records may be useful for marine ecologists, and fisheries and conservation management, in order to improve our understanding of declining and migrating commercially important populations of fish, provided each record is critically assessed and combined with recent records of fish population parameters, population dynamics, marine habitat assessments and abiotic data such as sea bottom, middle and surface temperatures.

More research and monitoring of climate change impacts on marine fish species and their populations are essential. The distribution and occurrence of populations should be surveyed and the migratory and reproductive behaviour of individuals has to be observed and recorded. I suggest that the establishment of easily accessible Internet online databases, containing first records of species of fish and GIS maps indicating where the first records were made, should be considered in the near future in order to help marine ecologist fisheries and conservation management track recent changes in fish populations quickly. Internet discussion fora covering first records and related issues may also be of help. DNA barcodes on as many species as possible are also a good technique to show whether fish populations are closed or open, i.e. the connectivity of populations. This may help to show if a first record of a fish species in an unusual habitat or a new geographical area is an indicator of climate changes or just a natural part of this species dispersal pattern. For example, tropical demersal coral reef fish populations were until recently considered open. The pelagic nature of the early larval stages of marine fish should point to a passive dispersal model where ocean currents cause panmixis over great spatial scales and prevent isolation of populations, a precondition for speciation (Gerlach *et al.*, 2007). Even though ocean currents are a major force in larval dispersal, recent studies show far greater retention than predicted by advection models (Gerlach *et al.*, 2007).

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