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Review Article

Conflicts in the coastal zone: human impacts on commercially important fish species utilizing coastal habitat

Elliot J. Brown[1]*, Rita P. Vasconcelos[2,3], Håkan Wennhage[4], Ulf Bergström[5], Josianne G. Støttrup[1], Karen van de Wolfshaar[6], Giacomo Millisenda[7], Francesco Colloca[7], and Olivier Le Pape[8]

[1]National Institute of Aquatic Resources (DTU-Aqua), Technical University of Denmark, Building 205, Henrik Dams Allé, Kgs Lyngby DK 2800, Denmark
[2]MARE—Marine and Environmental Sciences Centre & FCUL - Faculdade de Ciências da, Universidade de Lisboa, Campo Grande, Lisboa 1749-016, Portugal
[3]IPMA - Instituto Português do Mar e da Atmosfera, Rua Alfredo Magalhães Ramalho 6, 1495-006 Lisboa, Portugal
[4]Department of Aquatic Resources, Swedish University of Agricultural Sciences, Turistgatan 5, Lysekil 453 30, Sweden
[5]Department of Aquatic Resources, Swedish University of Agricultural Sciences, Skolgatan 6, Öregrund 74242, Sweden
[6]Wageningen Marine Research (Ecological Dynamics Group), IJmuiden AB 1970, The Netherlands
[7]Institute for Coastal Marine Environment, National Research Council, Mazara del Vallo 91026, Italy
[8]ESE, Ecology and Ecosystem Health, Agrocampus Ouest, INRA, Rennes 35042, France

*Corresponding author: tel: +45 35 88 34 46; fax: +45 35 88 33 33; e-mail: elbr@aqua.dtu.dk

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Coastal ecosystems are ecologically, culturally, and economically important, and hence are under pressure from diverse human activities. We reviewed the literature for existing evidence of effects of human-induced habitat changes on exploited fish utilizing coastal habitats. We focused on fish species of the Northeast Atlantic for which fisheries advice is provided by International Council for the Exploration of the Sea (ICES) and which utilize coastal habitats for at least one life-history stage (LHS). We found that 92% of these species are impacted by human activity in at least one LHS while utilizing coastal habitat and 38% in multiple stages. Anthropogenic pressures most commonly shown to impact these fish species were toxicants and pollutants (75% of species). Eutrophication and anoxia, invasive species, and physical coastal development affected about half of the species (58, 54, and 42% of species, respectively), while indirect fishing impacts affected a minority (17% of species). Moreover, 71% of the ICES advice species that utilize coastal habitats face impacts from more than one pressure, implying cumulative effects. Given that three-fourths of the commercial landings come from fish species utilizing coastal habitats, there is an obvious need for a better understanding of the impacts that human activities cause in these habitats for the development of ecosystem-based fisheries management.

Keywords: anthropogenic pressure, coastal, ecosystem-based management, fisheries, habitat degradation, habitat loss, human activity

Introduction

Coastal habitats (as defined in Seitz *et al.*, 2014) are valuable for numerous fish and invertebrate species, functioning as spawning grounds, juvenile growth areas, foraging areas, and migration corridors (Beck *et al.*, 2001; Elliott and Hemingway, 2002). For example, 44% of the commercially important species for which advice is provided by the International Council for the Exploration of the Sea (ICES) in 2010 in the Northeast Atlantic have been reported to utilize coastal habitats for at least one life-history stage (LHS) for one of the above functions (Seitz *et al.*, 2014).

While coastal and estuarine areas are widely acknowledged to be of high ecological and economic value (Costanza *et al.*, 1997;

de Groot *et al.*, 2012), they are also highly vulnerable and impacted by multiple human activities (Halpern *et al.*, 2007, 2009; Crain *et al.*, 2008; Batista *et al.*, 2014; Vasconcelos *et al.*, 2017). In temperate regions, coastal habitats such as rocky intertidal and subtidal reefs, mudflats, seagrass meadows, kelp forests, and salt marshes are exposed to high levels of anthropogenic pressures (Lotze *et al.*, 2005; Airoldi and Beck, 2007; Halpern *et al.*, 2008).

Diverse activities - whether urban, industrial, agricultural, land reclamation, or direct exploitation of resources in the estuarine and coastal realm - often impose several pressures with cumulative impacts on coastal fish habitats (Vasconcelos *et al.*, 2007). With human populations continuously increasing and aggregating around coastal areas worldwide (Airoldi and Beck, 2007; Kummu *et al.*, 2016), space for human settlement and activities is often gained through land reclamation, i.e. implying the loss and fragmentation of shallow-water aquatic coastal habitats. In addition, loss, modification, and fragmentation of aquatic coastal habitats is also caused by changes to hydrological regimes, novel artificial coastal defence structures, substrate extraction (e.g. mining or dredging for maintenance of navigation canals), and disposal (e.g. coastal nourishment) (Borja *et al.*, 2010; Peterson *et al.*, 2014). In terms of physical perturbations, destructive fishing methods such as bottom trawling also disrupt important fish habitats (Hiddink *et al.*, 2006). Simultaneously, degradation of coastal fish habitats can also be brought about through eutrophication and subsequent macroalgal blooms (Rabalais, 2015; Le Luherne *et al.*, 2016) or anoxic events (Cloern, 2001) derived from nutrient input associated with urban and agricultural activities. Other terrestrial and coastal activities (e.g. industry and mining) introduce a variety of xenobiotics, which impact regular physiological processes of fish and other organisms across different trophic levels (Davis, 1999). Concurrently, the transport of people, goods, and animals often lead to the introduction of non-native species and subsequent ecological disruption (Molnar *et al.*, 2008).

Since the onset of industrialization, human activities in coastal seas and estuaries have caused successive changes in habitat quantity and quality for many key fish species (Lotze *et al.*, 2006; Vasconcelos *et al.*, 2007). Resulting ecological effects can be extended to the provisioning of ecosystem services, e.g. effects on the availability of fish for viable commercial and recreational fisheries or of food and habitat for protected species (Holmlund and Hammer, 1999; Lotze *et al.*, 2006; Worm *et al.*, 2006).

In the Northeast Atlantic, coastal ecosystems are bordered by dense human populations and thus are severely affected by cumulative anthropogenic pressures (Airoldi and Beck, 2007; Halpern *et al.*, 2009). In this region, a wide acknowledgement of the overexploitation of many commercially important species has led to the coordination of fisheries management actions at national and European levels (Lagares and Ordaz, 2014). Yet, the effects of other human-driven pressures on fish in coastal habitats of this region have been poorly collectively evaluated or insufficiently taken into consideration in species conservation or marine resource management plans (Kempf, 2010; Jennings and Rice, 2011). These effects must be estimated, according to the European Marine Strategy Framework Directive (MSFD; 2008/56/EC), so that measures can be taken to achieve “good environmental status”, by 2020.

In this study, we aim to make a critical assessment of the impacts and perturbations in coastal habitats on different life-history stages of commercially important fish. We focus on fish populations in the Northeast Atlantic for which fisheries advice is provided by ICES (henceforth referred to as ICES advice species). To achieve our aim, we build upon the seminal paper by Seitz *et al.* (2014) by reviewing existing literature to find evidence of impacts (negative or positive) on commercially important fish species from coastal habitat changes caused by human activities. We discuss our results in relation to ongoing improvements in quantifying human impacts on coastal fish. We then make suggestions for future research and propose potential avenues for incorporating fish habitat considerations into ecosystem-based fisheries management.

Methods

We searched existing primary literature to assess the extent to which ICES advice fish species are impacted by human activities in coastal habitats. The aim here was to find evidence of impacts (i) across species, (ii) by coastal LHS (i.e. juvenile, feeding, spawning, migration; Figure 1), and (iii) across different sources of anthropogenic pressures. Species investigated were those for which ICES provides advice. The coastal use of different life-history stages was taken from Seitz *et al.* (2014) and updated using their methodology (see Supplementary Material). To differentiate between anthropogenic pressures, we placed the most commonly occurring pressures into five categories (Table 1). The “Physical Coastal Development” category deals with both physical changes to the aquatic environment (e.g. human-induced changes in surface sediment properties) and loss of area (e.g. marina construction or land reclamation). The “Eutrophication and Anoxia” category deals with changes in nutrient and oxygen concentrations. The “Toxicants and Pollutants” category deals with toxic substances and xenobiotics present or entering the coastal habitat as a result of human activity. The “Invasive Species” category refers to introduced, non-native species that become abundant and alter ecosystem structures and functions. The “Indirect Fishing Impacts” category excludes direct fishing mortality but deals with effects such as physical disturbance of the seabed, destruction of reefs, or changes in community structure through the removal of key species.

We compiled relevant scientific literature linking habitat degradation to coastal life-history stages. A database search initially utilized Google Scholar on 21 July 2015 combining species’ name (both binomial and common) with keywords relevant to different categories of habitat degradation (Table 1). This list was updated, and the collection increased using searches of the same format later in 2015 and from authors’ own literature databases. We evaluated the results of this search to compile a three-dimensional inventory of evidence of impacts for each species, each LHS, and each pressure ($24 \times 4 \times 5 = 480$, respectively). Once evidence of impact was found for a given inventory position, the search moved on to the next position. The amount of research found and the magnitude of impact effects were not quantified; hence, the result was a binary table (evidence or no evidence). From this inventory of evidence, we calculated the relative proportions of impacted species and life-history stages and of the respective category of anthropogenic pressure involved.

Results

Evidence of human activities impacting ICES advice species in coastal habitats was collated by category of anthropogenic pressure and LHS (Table 2). Considering all 5 impact categories, 4 life-history stages, and 24 species utilizing coastal habitat, a total of 58 occurrences of anthropogenic impact were found (Table 2). Of these 24 fish species, 92% (22) were impacted by at least one category of human activity in one or more life-history stages in coastal habitats. The category of impacts most commonly linked to fish in coastal habitats was "Toxicants and Pollutants", with 75% (18/24) of species having evidence of being impacted in at least one LHS (Figure 2). "Eutrophication and Anoxia" and "Invasive Species" both affected over half of species with coastal habitat use with 58% (14/24) and 54% (13/24), respectively. "Physical Coastal Development" impacted 42% (11/24) of species, while least commonly documented was the "Indirect Fishing Impacts" category where 17% (4/24) of ICES advice species utilizing the coast were shown to be linked to these types of impacts. Moreover, 71% (17/24) of species face impacts from more than one pressure (Table 2).

When considering individual life-history stages (Table 3), 54% (13/24) of fish species utilizing coastal habitats were impacted in only one LHS, while 38% (9/24) had evidence of two or more life-history stages being impacted. If we consider only those species utilizing coastal habitats for two or more life-history stages (15/24), then 60% (9/15) of these had evidence of being impacted. For two species, Norway pout (*Trisopterus esmarkii*) and sandeel (*Ammodytes* spp.), no evidence of anthropogenic impacts was found in the literature.

We found that 69% (34/49, i.e. total no. crosses/total no. shaded cells in Table 3) of life-history stages utilizing coastal habitats have documented evidence of being impacted by human activity. Within each LHS utilizing coastal habitat (Figure 3), the juvenile LHS had the most evidence of being impacted both by proportion (78%) and absolute number (14/18; Table 3). The feeding LHS was impacted at a slightly lower rate of 69% (11/16), while two-thirds (6/9) of species utilizing coastal habitats for spawning had evidence of human impacts. The migration LHS had the fewest species with evidence of impacts from human activity, where 50% (3/6) of the occasions of coastal utilization were impacted.

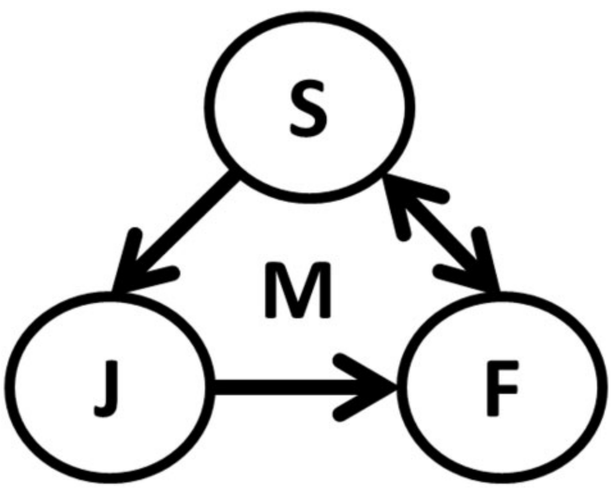

Figure 1. Conceptual diagram of common life-history stages of fish in coastal habitats: S = mature adults during spawning, J = immature juveniles, and F = feeding adults not in spawning. Arrows represent migrations (M).

Discussion

Coastal habitats experience a large variety and extent of anthropogenic pressures (Lotze *et al.*, 2006; Airoldi and Beck, 2007; Halpern *et al.*, 2008; Vasconcelos *et al.*, 2017); hence, the many fish species utilizing these habitats across different parts of their LHS may also be impacted by human activities. Based on the occurrence of reported impacts, this study highlights the current evidence of such impacts across the Northeast Atlantic.

A major conclusion of this review is that there is a large body of evidence linking a variety of human activities and habitat degradation to impacts on commercially important fishes utilizing coastal habitats. In fact, 92% of ICES fish species utilizing coastal habitats were found to be impacted by at least one pressure in these habitats. Species with certain life-history stages exhibiting a strong dependence on specific habitat types are especially at risk of habitat loss and degradation, which is usually the case for early life-history stages (i.e. juvenile LHS in the present study; Mumby *et al.*, 2004; Seitz *et al.*, 2014; Sundblad *et al.*, 2014).

While our assessment targets only the presence or absence of impacts for each species and LHS, some commonalities are to be mentioned concerning the effects and mechanisms of the different impact categories on fish utilizing coastal habitats. Eutrophication, for example, was found to impair spawning and recruitment via periodic increases in primary production from certain algal species (Isaksson *et al.*, 1994; Carl *et al.*, 2008). Although mild eutrophication was also found to increase the productivity of some systems (Parmanne *et al.*, 1994; Österblom *et al.*, 2007),

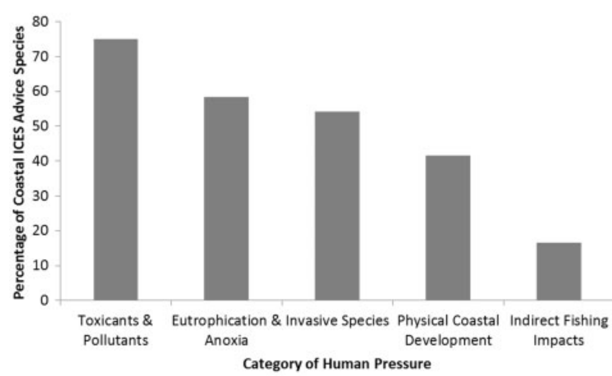

Figure 2. Percentage (by number) of ICES advice species that utilize the coastal zone and have evidence of being impacted by anthropogenic pressures separated by pressure category.

Table 1. Keywords used to define habitat degradation in review of human impacts on fish using coastal habitats in different life-history stages.

Anthropogenic pressure	Relevant keywords used in search
Toxicants and Pollutants	"xenobiotics" or "toxic* or "sewage" or "contaminant" or "pollution"
Eutrophication and Anoxia	"eutrophication" or "hypoxia"
Invasive Species	"invasi*" or "outbreak" or "proliferation"
Physical Coastal Development	"land reclamation" or "sediment" or "habitat loss" or "extraction" or "depth change"
Indirect Fishing Impacts	"fishing" or "trawling" or "dredging"

Table 2. Anthropogenic pressures impacting commercially important fish species in coastal habitats for which ICES provides advice.

		Anthropogenic pressure					
Species	**Common name**	**Toxicants and Pollutants**	**Eutrophication and Anoxia**	**Invasive Species**	**Physical Coastal Development**	**Indirect Fishing Impacts**	**References**
Engraulis encrasicolus	Anchovy		S	J F			Tsikhon-Lykanina and Reznitchenko (1991), Kideys (1994), Niermann *et al.* (1994), Shiganova *et al.* (2001), Drake *et al.* (2007), Oguz *et al.* (2008), Ruiz *et al.* (2009), Ekau *et al.* (2010)
Cetorhinus maximus	Basking shark	F					Fossi *et al.* (2014)
Scophthalmus rhombus	Brill			J			Kostecki et *al.*, (2011)
Mallotus villosus	Capelin	S					Frantzen *et al.* (2012)
Gadus morhua	Cod	F	J F	F	F	J	Isaksson *et al.* (1994), Lindholm *et al.* (1999), Hall-Spencer *et al.* (2003), Johansen *et al.* (2006, 2011), Österblom *et al.* (2007), Patel *et al.* (2007), Teschner *et al.* (2010), Thurstan *et al.* (2010), Malovic *et al.* (2010), Bratberg *et al.* (2013), Reubens *et al.* (2013), Johannessen (2014)
Limanda limanda	Dab	F	J			J	Berghahn *et al.* (1992), Houlihan *et al.* (1994), Petersen and Pihl (1995), Power *et al.* (2000)
Anguilla anguilla	Eel	M	M		M		Feunteun (2002), Palstra *et al.* (2006), Maes *et al.* (2007)
Dicentrarchus labrax	European sea bass	J			J		Laffaille *et al.* (2000), Reynolds *et al.* (2003), Kerambrun *et al.* (2012b)
Platichthys flesus	Flounder	J	J	J			Carl *et al.* (2008), Amara *et al.* (2009), Kostecki *et al.* (2011), Jokinen *et al.* (2016)
Clupea harengus	Herring	S	S	S	S		Johnston and Wildish (1981), Winters *et al.* (1986), Aneer (1987), Costello and Gamble (1992), Kornilovs (1993), Lappalainen and Pesonen (2000), Gorokhova *et al.* (2004, 2005), McIntosh *et al.* (2010), Frantzen *et al.* (2015)
Scomber scombrus	Mackerel	S		J			Longwell *et al.* (1992), Öztürk (2006)
Trisopterus esmarkii	Norway pout						
Pleuronectes platessa	Plaice	J	F J	J	J	J	Petersen and Pihl (1995), Secombes *et al.* (1995), Pihl *et al.* (2005), van de Wolfshaar *et al.* (2011)
Pollachius pollachius	Pollack		J				Johannessen (2014)
Pollachius virens	Saithe	J		J	J	J	Bordehore *et al.* (2003), Kamenos *et al.* (2004), Olsen *et al.* (2010), Falk-Petersen *et al.* (2011), Støttrup *et al.* (2014)
Salmo salar	Salmon		M		M		Alabaster *et al.* (1991), Tentelier and Piou (2011), Martignac *et al.* (2013)
Ammodytes marinus	Sandeel						

Continued

Table 2. continued

Species	Common name	Anthropogenic pressure					References
		Toxicants and Pollutants	Eutrophication and Anoxia	Invasive Species	Physical Coastal Development	Indirect Fishing Impacts	
Sardina pilchardus	Sardine	F	F				Canli and Atli (2003), Goren and Galil (2005)
Salmo trutta	Sea trout	F	M	F M			Olsson *et al.* (2001), Meland *et al.* (2010), Ilarri *et al.* (2014), Taranger *et al.* (2015)
Solea solea	Sole	J F	J	J	J		Via *et al.* (1998), Lefrançois and Claireaux (2003), Le Pape *et al.* (2004), Gilliers *et al.* (2006), Amara *et al.* (2007), Davoodi and Claireaux (2007), Jenkinson *et al.* (2007), Rochette *et al.* (2010), Kostecki *et al.* (2011), Jebali *et al.* (2013)
Sprattus sprattus	Sprat	S	J	J F S	J		Parmanne *et al.* (1994), Cameron and Von Westernhagen (1997), Shiganova and Bulgakova (2000), Peters *et al.* (2001), Österblom *et al.* (2007)
Mullus surmuletus	Striped red mullet	F		F			Levi and Francour (2004), Bianchi *et al.* (2014), Scopelliti *et al.* (2015)
Scophtalmus maximus	Turbot	J					Kerambrun *et al.* (2012a, 2012b)
Merlangius merlangus	Whiting	S	F		J		Westernhagen *et al.* (1989), Shiganova and Bulgakova (2000), Turnpenny and Taylor (2000), Ogut and Palm (2005), Pihl *et al.* (2006)
Percentage of species		75%	58%	54%	42%	17%	

Evidence of impacts at different life-history stages is indicated by J (juvenile), F (feeding), S (spawning), and M (migration).

higher nutrient loads may negatively impact fish populations by decreasing the cover of canopy forming vegetation (Cloern, 2001) and increasing the frequency of anoxic events (Rabalais, 2015), in turn causing increases in the mortality of early life-history stages and reducing growth rates in fish (Kornilovs, 1993; Petersen and Pihl, 1995; Maes *et al.*, 2007; Teschner *et al.*, 2010). In addition to the widely known direct effects of fishing on fish species, this study found that fishing often indirectly impacted fish through the destruction of biogenic structures which provide shelter (Hall-Spencer *et al.*, 2003; Kamenos *et al.*, 2004). Furthermore, trawling also causes physical damage to abiogenic bottom habitats causing changes in benthic invertebrate communities (Sciberras and Hiddink, 2014; van Denderen *et al.*, 2014; Rijnsdorp *et al.*, 2016), which can be expected to affect fish populations as they are important prey for fish (Henriques *et al.*, 2014). Invasive species were mostly noted to either directly exploit or compete for food with resident species (Öztürk, 2006; Oguz *et al.*, 2008) or otherwise alter the structure of the habitat (Pihl *et al.*, 2005). Physical development was reported to lead to reduced productivity via dams altering terrestrial water discharge regimes in nursery areas (Drake *et al.*, 2002) and the direct removal of habitat via dredging, diking, and harbour extensions (Rochette *et al.*, 2010). However, other physical developments may lead to habitat creation due to artificial hard substrates providing shelter and feeding opportunities (Reubens *et al.*, 2013). Impacts from xenobiotics ranged from egg mortality through decreased growth rates to reduced migration success (Houlihan *et al.*, 1994; Feunteun, 2002; Kerambrun *et al.*, 2012a), all of which lead to lowered fish survival (Gilliers *et al.*, 2006; Le Pape *et al.*, 2007) and density (Courrat *et al.*, 2009; Delpech *et al.*, 2010).

In reality, the impacts that fish experience in coastal habitats are not acting in isolation, but interact to form a complex combination of cumulative impacts (Lotze *et al.*, 2006; Halpern *et al.*, 2007; Vasconcelos *et al.*, 2007). In coastal habitats, fish can face cumulative impacts both in terms of different anthropogenic pressures and in terms of exposure during more than one LHS. In this study, 71% of species had evidence of exposure to multiple impact categories. A good example of this is the plaice (*Pleuronectes platessa*), where the juvenile LHS had a reported impact from all five impact categories examined in this study. Similarly, sprat (*Sprattus sprattus*) juveniles are faced with impacts from three impact categories: "Eutrophication and Anoxia", "Invasive Species", and "Physical Coastal Development". Furthermore, there is evidence of human impacts affecting sprat across three of the four life-history stages illustrating additional cumulative impacts over time. Similar cumulative impacts acting across different life-history stages are faced by

Table 3. ICES advice species showing coastal habitat use.

Common name	Binomial classification	Life history stage: Juvenile	Feeding	Spawning	Migration
Anchovy	*Engraulis encrasicolus*	X	X	X	
Basking shark	*Cetorhinus maximus*		X		
Brill	*Scophthalmus rhombus*	X			
Capelin	*Mallotus villosus*			X	
Cod	*Gadus morhua*	X	X		
Dab	*Limanda limanda*	X	X		
Eel	*Anguilla anguilla*				X
European sea bass	*Dicentrarchus labrax*	X			
Flounder	*Platichthys flesus*	X			
Herring	*Clupea harengus*			X	
Mackerel	*Scomber scombrus*	X		X	
Norway pout	*Trisopterus esmarkii*				
Plaice	*Pleuronectes platessa*	X	X		
Pollock	*Pollachius pollachius*	X			
Saithe	*Pollachius virens*	X			
Atlantic salmon	*Salmo salar*				X
Sandeel	*Hyperoplus spp./Ammodytes spp.*				
Sardine	*Sardina pilchardus*		X		
Sea trout	*Salmo trutta*		X		X
Sole	*Solea solea*	X	X		
Sprat	*Sprattus sprattus*	X	X	X	
Striped red mullet	*Mullus surmuletus*		X		
Turbot	*Scophthalmus maximus*	X			
Whiting	*Merlangus merlangus*	X	X	X	
Percentage of species with evidence of impact for life-history stages that utilize coastal habitat		**78%**	**69%**	**67%**	**50%**

Updated from Seitz *et al.*, 2014 (see Supplementary Material) in different life-history stages (shaded cells) and those life-history stages found (this study) to be impacted upon by human activities (marked by X)

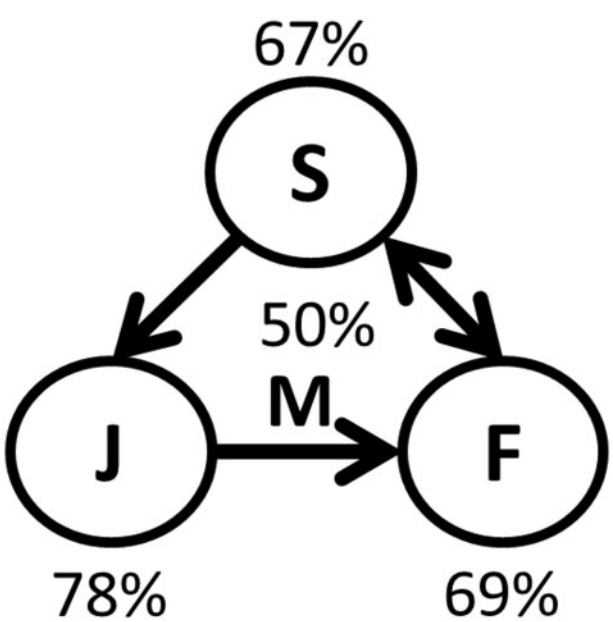

Figure 3. Conceptual diagram of common life-history stages of fish in coastal habitats displaying the percentage of impacted species at each LHS (S = mature adults during spawning, J = immature juveniles, and F = feeding adults not in spawning). Arrows represent migrations (M).

38% of the species, without considering human impacts experienced in offshore habitats. Impacts imposed at a given LHS may continue to have an effect throughout the remainder of the life cycle (Schmidt *et al.*, 2012). For example, exposure to xenobiotics at the juvenile LHS, affecting juvenile growth and survival (Gilliers *et al.*, 2006), also impacts adult fitness (Jonsson and Jonsson, 2014).

The cumulative impacts from these multiple stressors can be additive, synergistic, or antagonistic (for definitions, see Crain *et al.*, 2008; Piggott *et al.*, 2015). In marine ecosystems, cumulative impacts are often synergistic (Crain *et al.*, 2008). In coastal marine systems, more than half of combined impacts are derived from non-additive interactions, meaning simple additive approaches are often insufficient to adequately describe or predict impacts (Teichert *et al.*, 2016). A simple illustration of synergistic cumulative impacts is the multiplicative effect of habitat loss and the simultaneous degradation of habitat quality in residual habitats (Archambault *et al.*, 2015). So-called positively synergistic stressors, where multiple pressures amplify the stress on species, will have the largest impact, potentially altering entire assemblages (Tomczak *et al.*, 2013). The identification and mitigation of such combinations of anthropogenic pressures and effects along successive life-history stages will also have the largest scope for restoration benefits (Piggott *et al.*, 2015). The results of the current work provide some guidance with regard to species, different life-history stages, and the types of pressures to be considered in cumulative impact studies.

Knowledge of these impacts and their interrelated effects on fish populations needs to be quantified to be useful in management. An integrated population model (IPM) that quantifies key demographic rates across different life-history stages has proven successful in describing population changes and trends related to environmental drivers (Deegan, 1990; Fodrie *et al.*, 2009). Like all modelling approaches, IPMs can only create good approximations of reality when informed with accurate parameters, of which IPMs require many (Koons *et al.*, 2017). Because of the complexity involved in linking many submodels together, many constructions have excluded important drivers (Klanjšček and Legović, 2007), used explicit assumptions (Levin and Stunz, 2005), or failed to consider the assumptions of underlying models (Anderson, 2005), thus reducing the applicability to scenario-based predictions. This is not to say that such endeavours are not warranted; to the contrary, they can act as informed thought experiments in probing ecological questions (Levin and Stunz, 2005). However, such approaches should be iterative (Rochette *et al.*, 2013; Archambault *et al.*, 2015, 2016) and considered with an appropriate level of criticism until research in the system they aim to describe matures and provides ample and accurate parameters to inform the model (Meynecke and Richards, 2014; Archambault *et al.*, 2016). In the short term, approaches that reduce the number of parameters in a model can provide better predictions of population changes (Ruiz *et al.*, 2009). However, in complex systems with multiple pressures, the exclusion of certain drivers will neglect both their direct impact and any cumulative impacts on the population. Studies that include more and more accurately parameterized drivers in constructing IPMs can provide better insight into how cumulative impacts affect populations and hence better inform management of these stocks and resources (van de Wolfshaar *et al.*, 2011).

Taking this approach a step further involves applying IPMs from mature research areas to spatially explicit contexts (e.g. Stelzenmüller *et al.*, 2011; van de Wolfshaar *et al.*, 2011; Meynecke and Richards, 2014; Archambault *et al.*, 2015; Rahikainen *et al.*, 2017). To properly parameterize and to make these approaches more accurate and ubiquitous, research focus and investment should be made in empirical studies to link drivers to population demographic rates at specific life-history stages.

With knowledge of the population-level effects of cumulative anthropogenic pressures, trade-offs of impacts under alternative scenarios of use can be investigated. Information on the sensitivity of different habitats and fish populations across their entire life history to individual pressures may then be represented by impact scores and mapped, while cumulative effects are subsequently considered (Halpern *et al.*, 2008; Foden *et al.*, 2011; Andersen *et al.*, 2015). Such methods of estimating cumulative impacts on ecosystems are currently being developed for marine management and spatial planning purposes (Goodsir *et al.*, 2015; Knights *et al.*, 2015). Providing authorities with fish habitat maps together with quantitative information on the effects of human pressures would be an important step towards securing long-term sustainability of these coastal habitats and the ecosystem services they provide. While the development of these mapping methods continues, there is a parallel need to develop ways to integrate this new knowledge with fisheries management and maritime spatial planning (EU Directive MSP 2014/89/EU).

Our study indicates a high variety of how and where, within a species' life history, anthropogenic pressures in coastal habitats may impact commercially important fish. It also discusses the development of methods to investigate population effects of such impacts and highlights knowledge gaps in this area of research. Considering that the majority of commercial landings come from fish utilizing coastal habitats (ca. 75%) (Champbers, 1991—cited in Fodrie and Mendoza, 2006; Seitz *et al.*, 2014; Supplementary Material), it is of great importance that the impacts of human activities in coastal areas are understood and accounted for in the context of ecosystem-based fisheries management.

Supplementary data

Supplementary material is available at the *ICESJMS* online version of the manuscript.

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