New England Fishery Management Council
50 WATER STREET | NEWBURYPORT, MASSACHUSETTS 01950 | PHONE 978 465 0492 | FAX 978 465 3116
John Pappalardo, *Chairman* | Paul J. Howard, *Executive Director*

MEMORANDUM

DATE: September 14, 2009
TO: Council Members
FROM: David Goethel, Chairman, Research Steering Committee
SUBJECT: Journal Publications Derived from Cooperative Research Projects

The attached five papers were prepared by partners on five of the cooperative research projects evaluated by the Research Steering Committee in August and listed on the RSC status sheet.

1. The first two publications, authored by St. Martin and Hall-Arber, were derived from the project “An atlas-based audit of fishing territories, local knowledge, and community participation in fisheries science and management,” (NEC).
2. The second paper by Grizzle et al. was derived from information collected by the authors while conducting the project “Intensive study of the Western GOM Closure Area,” (NEC).
3. Dr. Tallack’s paper was the result of work done through the project “An assessment of escape vent selectivity, bycatch and discard survivability in the New England fishery for deep water red crab,” (NMFS).
4. The shrimp trawl paper, which includes Council member David Goethel as a co-author, was written by He and Smith and developed using data from the project “Design and test of a topless shrimp trawl and a size sorting grid system to reduce finfish bycatch and small shrimps in the pink shrimp fishery” (NMFS).
5. The last attachment is not a publication, but background information on Dr. Teresa Johnson who assisted the RSC with its evaluations of the social science projects reviewed at the committee meeting.

Creating a Place for "Community" in New England Fisheries

Kevin St. Martin

Department of Geography
Rutgers, The State University of New Jersey
Piscataway, NJ[1]

Madeleine Hall-Arber

Center for Marine Social Sciences
MIT Sea Grant College Program
Cambridge, MA[2]

Abstract

Although the Sustainable Fisheries Act that amended the Magnuson-Stevens Fishery Conservation and Management Act in 1996 defined fishing communities to be places with significant harvesting and/or processing activities, a collaborative mapping project in the Northeast has made clear the limits of such a port-based definition by documenting the presence and nature of communities "at sea." Using vessel trip report data, unique maps depicting community territories were created for a variety of communities dependent upon Gulf of Maine fisheries. Community-based researchers interviewed fishermen from the region and asked them to engage with the maps, discuss the nature of community within those "at sea" locations, and document the type of local environmental knowledge they maintained.

The participatory interviews made clear the varied ways that communities respond to and are changed by the recent history of regulatory and environmental change. While the dominant port-based vision of fishing communities sees communities as sites of impact and decline, a focus on relationships between fishermen and between fishermen and their environments reveals communities as ongoing and emerging processes. While the former produces doubt relative to the development of any community-based initiatives for fisheries management, the latter points to the resilience of "community" and the always-emerging potential for community-based approaches.

Keywords: *GIS, participatory research, commercial fishing, communities*

Introduction

Fisheries management regimes in the global north are typically silent relative to fishing communities (Jentoft 2000; McCay and Jentoft 1998). While fishing communities have always been actors and/or referents within public dialogues and debates concerning fisheries' resources and their utilization, they have not traditionally been objects of analysis, data collection, description, or documentation within the dominant discourse of fisheries science and management itself. Indeed, insofar as fishermen are present, they are seen as individually motivated bearers of an aggregate fishing effort originating from nowhere. Communities have no place within the equilibrium equations that balance aggregate fishing effort and fish populations on a species by species basis. As a result they are invisible within the space of stock calculation, the space of fishing itself (St. Martin 2001).

Despite decades of erasure and (dis)placement, "community" is, however, emerging within fisheries management as it is across a broad spectrum of resource management regimes (Berkes 2003; McCarthy 2006; Western and Wright 1994). Once the hallmark of pre-modern, traditional, and archaic forms of resource use and/or management, community-based initiatives are not only commonplace but hegemonic within participatory international development and conservation practice (Cooke and Kothari 2001; Kellert et al. 2000). Within the fisheries regime of the U.S. Northeast, however, communities are positioned primarily as sites for "impact analysis" rather than central to the dynamic of development or as agents of conservation; to the degree they are considered, they are locations subject to environmental change, economic decline, and, of course, management measures (Olson 2005). In addition, community is relegated to and seen in land based locations and activities but is absent at sea; the very sites of fisheries management are devoid of community (St. Martin 2006).

Therefore, to be effective themselves and to be participants in the management of fisheries' resources, an alternative (counter) mapping of community and commons is needed, particularly in the global north where the absence of community has been most convincingly produced (McCarthy 2003; St. Martin 2005). The Atlas Project[3] works by creating locations/spaces at sea into which can be projected community processes, community identities and histories, and a community becoming (cf. Gibson-Graham 2006; Ratner and Rivera Gutierrez 2004). In so doing it creates the conditions for community-level participation, creative place-based initiatives, and a community resiliency (cf. Berkes et al. 2003). If communities are to be more than just sites of impact, if they are to be actors within the institutions that govern access and utilization of fisheries' resources, they and the resource areas upon which they depend must be made visible such that they can become sites of negotiation and experimentation.

This paper proceeds by first briefly reviewing the current U.S. federal mandate to incorporate "community" into fisheries science and management as well as its limitations relative to community participation. It then outlines the method of the Atlas Project, a participatory action research project where "community researchers" from several Northeast ports interviewed fishermen in an effort to solicit the nature of community processes as embedded within and constitutive of shared spaces at sea.[4] Participants' responses are then discussed and interpreted. They clearly confirm the prevalence of community/commons processes. A host of such processes (e.g. sharing information, local ecological knowledge, de facto territorialization) have been documented and inscribed into particular places at sea. The conclusion points to the resiliency of community processes and commons spaces within the fisheries of the U.S. Northeast.

Containing "Community" and Limiting its Potential

In the U.S. Northeast, the category of "community" is emerging within the dominant discourse of fisheries science and management as a result of the federal mandate to consider the impacts of fisheries management plans (FMPs) upon fishing communities. FMPs for the major species targeted by commercial fishing fleets are written by the regional fishery management councils (government appointed industry, environmental, and scientific representatives) and approved or rejected by the National Marine Fisheries Service (NMFS). While the definition of community within natural resource management regimes varies (cf. Jakes and Anderson 2000), the federal government has provided a specific framework for its consideration. According to the federal Sustainable Fisheries Act (SFA) that amended the Magnuson-Stevens Fishery Conservation and Management Act in 1996,

> *Conservation and management measures shall, consistent with the conservation requirements of this Act (including the prevention of overfishing and rebuilding of overfished stocks), take into account the importance of fishery resources to fishing communities in order to (A) provide for the sustained participation of such communities, and (B) to the extent practicable, minimize adverse economic impacts on such communities* (16 U.S.C. §1851 (1996), Pub.L.94-265, Sec.301, (a) (8)).

Consideration of communities is meant to *both* sustain the participation of fishing communities in management and minimize adverse economic impacts. The Act went on to define the term "fishing community" as a

> . . . *community which is substantially dependent on or substantially engaged in the harvest or processing of fishery resources to meet social and economic needs, and includes fishing vessel owners, operators, and crew and United States fish processors that are based in such a community* (16 U.S.C. §1802, Sec.3, 104-297 (16)).

The need to identify fishing-dependent communities in order to measure and mitigate impacts led to the development of federal guidelines for defining fishing communities and for assessing the impacts of fisheries management upon them. In addition, several projects were implemented that attempted to profile fishing communities in virtually all of the seven U.S. fisheries management regions.[5] Both the federal guidelines and subsequent community assessments constituted fishing communities as primarily geographical entities (e.g. deduced from employment and other fisheries business statistics within standard municipal and census boundaries). These studies also utilized understandings of community as homogenous groupings and agreed upon norms (cf. Agrawal and Gibson 1999).

The containment and delimitation of fishing communities is, however, difficult; fishing communities are leaky containers at best. In the Northeast, recent research has pointed to the variable and flexible nature of fishing communities' boundaries. For example, Hall-Arber et al.'s (2001, 415) attempt to define community based upon the extent of capital flows (amongst other variables) soon faltered when it became apparent that "capital flows must be charted over time at local, sub-regional, regional, national and international levels to trace effects and predict change." While this work retained the definition of community as a geographic place, it considered the identified fishing communities as nodes within a network of multi-scalar capital flows. In addition, it pointed to a variety of other leaky boundaries and flows such as vessels migrating from one port to another, a movement typically associated with target species movement, marketing, and access to fishing grounds; the multi-ethnic and multi-national character of many fishing ports; and the diversity of attitudes relative to perceptions of resource change, benefits of management, etc. (Hall-Arber et al. 2001; see also St. Martin et al. 2007).

Leaky and Disintegrating Containers

The federal mandate to assess management impacts upon "fishing communities" has unleashed a search for such communities where none had been previously documented. Social science methods (e.g. ethnographic, demographic, and geographic) were suddenly needed and deployed to categorize places and activities as (or as not) "substantially dependent on or substantially engaged in" fisheries (Olson 2005). The great diversity of fishermen and related industry participants might then find themselves classified by residence or occupation within a particular municipality or census tract as being members or not of "fishing communities." Where found, communities would, presumably, be sheltered from adverse or overly harsh impacts of management or would be sites where the effects of management might be somehow mitigated.

This search and delimitation of fishing communities is clearly useful for analyses of impacts, for example, to assess the multiplier effects of decreased landings. It has, however, the unwelcome effect of also constituting communities as fundamentally sites that are threatened, in decline, or vestigial. The focus on boundaries and communities as containers of indicators and thresholds of fishing activities will, by definition, make such communities difficult to find in the largely urban and industrially mixed U.S. Northeast. Also, insofar as they are leaky containers, they are further dissipated and distanced from the ideal of a discrete, cohesive, homogenous, and geographically defined fishing community. While the difficulty to produce fishing communities in the image of the latter only confirms the extent of negative "impacts," it simultaneously undermines communities as sites of potential for community-level participation or community self-management of resources.

Containers Tied to Shore

Community as a geographically defined container of socio-economic indicators, designed to gauge impacts, works to not only position communities as threatened and in retreat, it also positions them within the terrestrial geographies of socio-economic data collection (St. Martin 2006). That is, to the degree such communities can be found, they are tied to land, albeit port, locations. Fishing economies and cultural practices certainly take place in/on docks, processing plants, neighborhoods, homes, cultural institutions, and other sites but these are not the spaces of fisheries management per se. Fishing communities are effectively outside of the marine realm of fisheries science, management, and fishing itself. While well-positioned to be sites of impact or, more accurately, impact analysis, communities are hopelessly disconnected from the very practices, processes, and relationships that are the focus of fisheries science and management.

If we look to the paradigms that are currently central to fisheries science and management, it is clear that they focus on particular processes that can be mapped and powerfully represented as integral to the marine environment. Bioeconomic and ecosystemic processes are vital to current management regimes and are subjects of extensive data collections, theorizations, implementations, and, increasingly, geocodings. These practices serve to make bioeconomic processes (e.g. aggregate fishing effort and its relationship to fish population dynamics) and ecosystemic processes (e.g. essential fish habitats, assemblages of species, or bottom morphology) visible within the marine environment, they literally map them into the space of fisheries' resources such that their relevance cannot be denied (Kostylev et al. 2001; Greene et al. 2003; Iampietro et al. 2005).[6] There is simply no corresponding data collection effort, theorization, or embedding of community/commons processes within the marine environment.

The search for fishing communities, based upon a particular image of community as a spatial unit, homogenous, and cohesive, has yielded a variety of sites where fishermen's "way of life" is threatened, economies are failing, and cultures are dissipating. These sites, severed from the commons upon which they depend, are infiltrated and dissected by other more powerful economic and cultural trends (e.g. waterfront gentrification). While these processes are certainly essential to document and to address in terms of impact analyses and, hopefully, amelioration, their conflation with "community" serves to undermine the latter as a site of potential. When community is reduced to collections of terrestrial indicators, it is difficult to see it as a determinant of fishing practices or even a force that can mitigate the drive to individual utility maximization.

(Re)Constituting Community and Commons: The "Atlas Project"

While the advent of "community" within U.S. fisheries science and management is problematic, especially relative to participation in the latter, it nevertheless provides an opening into which competing definitions and documentations of "community" might be deployed. Wishing to increase the potential of "community," the Atlas Project was designed to document community processes, rather than boundaries, and to embed them within the marine environment, rather than relegate them to ports. It raised questions about whether or not a more explicitly spatial management might be feasible, more amenable to participation, and more effective than the current regime at sustaining both local economies and environments.

Using a participatory action research approach (Cameron and Gibson 2005; Pain 2003, 2004), the project engaged fishermen in an examination of their community and territorial practices and explored their own sense of community, its utility, and its potential relative to fisheries management. Specifically, the project revolved around a series of maps that gave participants an explicit spatial framework within which to discuss the above issues. Using federally collected vessel trip report (VTR) data aggregated by gear type and port (see below), the maps depicted the fishing territories or frequently visited locations of peer groups of fishermen from several ports in Maine, New Hampshire and Massachusetts. The maps were central to the project's main goal of visualizing a space for communities within the marine environment.

Beginning from the assumption that community is commons, that they are homologous constructs, suggests alternative ways to know both community and the marine environment. Impact analyses, participatory approaches to management, and other initiatives that presume a community presence could be more directly relevant to the management of fish stock and marine habitats if community were always and necessarily co-produced by fishing grounds, environmental histories, territories, and environmental knowledge. Similarly, understanding the marine environment, the processes and dynamics of fish, fish harvesting, and environmental change, would be altered by the assumed presence and practices of communities within that marine environment. In both cases, an altered starting point would imply new forms of data collection, particularly geocoded data that would literally allow for the overlay and analysis (via Geographic Information Systems) of communities and biophysical data.

Producing an Alternative Ontology of Fisheries

Previous research amongst the trawl gear fishermen of Gloucester, MA has revealed the existence of community processes such as the sharing of information amongst fishermen, the nature of local ecological knowledge (e.g. species composition, bottom morphology), and how and why fishermen are territorial (St. Martin 2001). The Atlas Project confirms the existence of similar processes across several New England fishing communities that vary in size, dominant gear type, target species, boat size, capitalization, etc. In addition, it documents such processes relative to explicit locations at sea (see below). By superimposing the areas frequented by vessels from each port on standard nautical charts and by making the composite maps central to each Atlas Project interview, project participants were able to directly relate the processes that bind them together as a community to processes of harvesting within and knowledge about particular locations at sea. In this sense, the project worked to (re)unite community and commons.

The Atlas Project presents a forum in which community and commons can be co-constituted (cf. Gudeman and Rivera 2002). It suggests an alternative ontological frame within which communities are assumed to affect and be affected by the specific ocean spaces they inhabit. This understanding works as a way of knowing, a starting point for investigating the relationship between fishermen and the marine environment that displaces the currently institutionalized starting point of bioeconomics where fishermen are individuals competing on an open access resource. The latter attempts to control the behavior and practices of individuals and/or individual vessels in order to maximize harvest while the former suggests the possibility of community-based mechanisms or innovations aligned with place-based ecosystem approaches.

Motivating Community

As a collaborative project, the Atlas Project sought to enroll "community researchers" who would contribute to the project design and who would then recruit and interview commercial fishermen from the ports where they lived and/or worked (cf. Community Economies Collective 2001). Community researchers were, ideally, either fishermen themselves or other members of fishing communities with close ties to fishermen and their experiences. While there was considerable interest in the project insofar as it advocated for fishing communities generally, most prospective community researchers were skeptical once they understood that the project would revolve around the mapping of commercial fishing locations. They perceived the project as one of revealing the secret fishing spots, the "hot spots," of fishermen. Concern about the outcome of the project was expressed very simply, "If we give them [meaning fisheries regulators] that information, it will be used against us."

The premise of the project was to engage participants (both community researchers and eventual interviewees) as representatives of their community (albeit only vaguely defined); yet actually doing so was initially very difficult. Prospective participants were much more likely to relate to the project (and us) as individuals, with individual fishing histories, and individual "hot spots" or experiences at sea. They could not see that the project was not interested in mapping locations at the scale of individual boats and their "hot spots" but broad areas important to communities. The identity of fishermen as individuals competing on an open access commons, the very positionality that we were hoping to challenge/redefine with this project, was a barrier to participation insofar as individuals did not want to divulge their individual fishing areas either to each other or to the government. While espousing their allegiance to "the fishing community" in a variety of ways, prospective participants had difficulty imagining themselves as community members (or able to map community domains) within the marine environment.

The resultant hesitancy of prospective participants to engage with the project, to position themselves as community members/representatives within the space of fisheries management itself, eventually dissipated for at least two reasons. First, the management of groundfish, the primary fishery in the region, radically changed with the implementation of Amendment 13 to the Multispecies Fishery Management Plan in 2004. In addition to reducing access to fish via gear and days-at-sea regulations, the amended plan opened up the possibility of "sector allocations" (50 CFR 648.87). Under this amendment, the Cape Cod Commercial Hook Fishermen's Association (CCCHFA) gained an allocation of 12.587% of the total allowable catch for Atlantic cod. Suddenly, the fishing industry became acutely aware of the potential benefit of acting as a community and documenting their "traditional" fishing grounds. A new institution had emerged that could accommodate community interests and direct involvement in management.

The CCCHFA's allocation must be harvested by association members, using specific gear (hooks), and within a particular area (i.e. Georges Bank). It is clearly representative of the trend toward more localized and area-based fisheries management strategies and, more generally, of an emerging marine spatial planning (Norse and Crowder 2005; Pauly 1997). In the Northeast there are now a variety of competing claims that would parcelize and zone the marine environment in ways reminiscent of terrestrial enclosures and their resultant exclusions. For example, recent proposals to establish a large wind farm on fishing grounds in Nantucket Shoals and to restrict access to the Stellwagen Bank Marine Sanctuary, an historically important fishing area. The rapid emergence of area-based initiatives within the marine environment is convincing fishermen that they too need to make area-based claims to resources. While doing so as an individual is difficult, the example of the CCCHFA's allocation suggests a place for community both within the politics of marine planning and, importantly, within the marine environment itself.

The second process that worked to recruit participants was considerably more micropolitical. At several workshops with prospective community researchers, we presented maps that already depicted broad areas frequently visited by peer groups of fishermen from ports of interest to those at the workshop. Using fishing trip locations from VTRs (which must be reported to NMFS) and a GIS-based density mapping methodology, we created a series of unique maps that showed neither individual "hot spots" nor the distribution of an aggregate fishing effort but areas upon which particular ports and/or gear groupings clearly depended. These maps were both alarming and intriguing to our workshop attendees. While most were very familiar with the nautical charts upon which we superimposed the data and, indeed, charting their individual presence within the marine environment, they had not seen a map of any collective/peer group experience. The maps made clear that the government (and academic researchers) already knew where fishermen fished.

The VTR maps as well as the general trend toward staking claims on locations within the marine environment worked together to shift fishermen's desire for secrecy to a desire to be seen as inhabiting and depending upon particular locations at sea. Within this shift we see a nascent community subject replacing that of the competing individual on the commons.

Creating a Graphic Language of Community

Working with community researchers from a variety of fishing ports, we developed an interview protocol that integrated and revolved around maps similar to those used in the recruitment workshops. The immediate goal of each interview was to assess the accuracy of the maps depicting "community territories" (made from NMFS collected VTR data) and amend them accordingly. While doing so, it was hoped that the maps would also become a forum for documenting extant community processes as well as a space within which fishermen might project themselves as community members. To counter the potential for the initial interview maps to fix community boundaries rather than solicit community processes, we repeatedly asked questions about the nature of the boundaries depicted, overlaps amongst communities, and movements between communities. We thought of the maps as entry-points into processes of community and territoriality rather than containers within which to place interviewees.

For each interview, three maps were created that moved from the scale of the Gulf of Maine as a whole to areas of specific concern to each peer group (defined by port and gear type) of the fisherman being interviewed (Figure 1). During the interviews each map was presented to the participant with a series of questions guiding the interviewee to react to the accuracy of the areas outlined, offering them the opportunity to physically amend the maps to show current and previous patterns. How the areas are inhabited, by whom, how they are important, and how they have changed were all asked. Explanations for change over time were also requested, as was local ecological information. The community researchers recorded each of the interviews and took extensive notes.

By the end of the data-gathering portion of the project, seven community researchers had interviewed 59 commercial fishermen from Gloucester, New Bedford, and Cape Cod, Massachusetts; New Hampshire; and Portland and Port

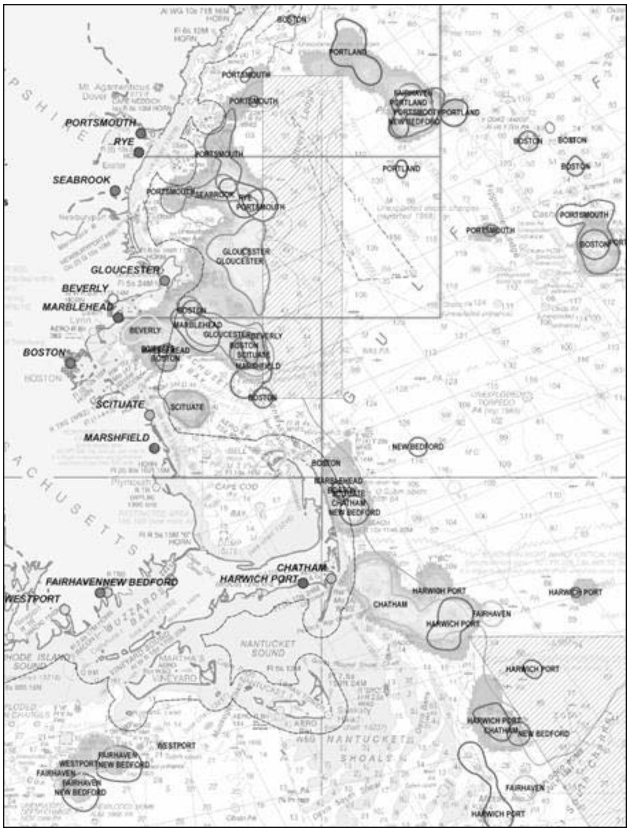

Figure 1. An extract from one of the Gulf of Maine maps used in the project. The outlined areas (color-coded in the original) correspond to individual ports from which, in this case, vessels with gilnet or longline gear originate. The outlines represent primary fishing grounds by principal port. The shaded acreas represent locations important to the aggregate of all vessels across all ports.

Clyde, Maine.[7] All but four of those interviewed were captains and 46 (78%) were owners (though two no longer own boats). All were experienced fishermen with from 15 to 46 years on fishing vessels (averaging 29 years). Gear types included trawl gear on vessels both over and under 65 feet, lobster pots, gillnets, scallop dredge, handlines, longlines, harpoon and jigs. About two-thirds of the interviewees fish for multispecies (groundfish) primarily using otter trawls, gillnets or hooks. Eight lobsterers and nine scallop fishermen were also interviewed. A few interviewees fished for a combination of finfish, lobster and/or scallops.

The diversity of the interviewees effectively reflects the breadth of experience within and between the fishing communities of the Northeast. This diversity, while limiting any quantitative analysis, provided a rich set of recorded narratives and hand amended maps illustrating the pervasiveness of community processes, their variability from one site to the next, and the degree to which they are part of the spatial experiences and domains of fishing communities.

Preliminary Results

The three maps used in each Atlas Project interview offered participants the opportunity to analyze and amend the patterns of fishing depicted. The first two maps were at the scale of the entire Gulf of Maine, one showing overall fishing patterns by gear type and the other outlining areas important to particular ports (also by gear type) (see Figure 1). While these first two maps were used by the interviewees to point to a variety of processes, they most often used them to discuss and illustrate the effects of recent area-based regulations (permanent closures and "rolling closures") that have altered the spatial patterns of communities and have created new concentrations, overlaps, and intermingling of fishermen. The third map was much more focused upon the experiences and knowledge of the interviewees. It was at the scale of their port/peer group and depicted only those areas of importance to the interviewee's peer group.[8] The results from this section of the interviews point to the wealth of local knowledge about specific fishing grounds. Their environmental history, utilization and fishing practices, and importance to community were clearly possible to capture through the interview/mapping method.

While project participants, both the community researchers and the interviewees, used the maps to often focus on the impacts of regulations, they did so in terms of the spatial displacements and replacements of their peer group and other groups/communities of fishermen rather than in terms of port-side effects due to decreases in landings, which is typical of official impact analyses. Their descriptions of and dismay relative to spatial change pointed not only to a desire for spatial stability (rather than infinite mobility) but also to a variety of community processes that were disrupted and transformed. In addition, they hinted at the formation of new alliances and communities as a result of displacement. Indeed, if community and commons are co-constitutive, then the re-formation of one suggests the re-formation of the other.

Several interviews were done in the port towns of New Hampshire and the north coast of Massachusetts. These interviews describe the struggles of inshore fishermen who work on relatively small vessels, deploy trawl gear, and take single day trips to familiar fishing grounds to catch ground fish such as cod and flounder. They, invariably, used the interview maps to illustrate the effects of specific regulatory closures of prime fishing grounds and to, thereby, explain the current pattern of fishing depicted on the maps. For example, they spoke of the closure of areas on Georges Bank (offshore) in the mid-1990s that had pushed larger trawl vessels into the inshore areas of the smaller vessels. They described in detail just which areas they had traditionally fished within the now closed Western Gulf of Maine. And they reported just where they go when their remaining fishing grounds are closed in

June due to the "rolling closures" instituted in 2002.

> *Before 2002, you would see more concentration [in] area[s] closer to home, more to the west. People would wait for the fish to come to them [. . .] They made enough money fishing there [. . .] They didn't have this need to go 25 miles offshore, or to drive down to [the] Boston area in June like we do now. A lot of things have changed [. . .] We spend a lot more time riding than before all of these restrictions* (interviewee).

The quote above is a brief excerpt from one interview with a small boat fisherman from Hampton, NH. The longer passage from which it is taken describes the nature of fishing practices in each location, who fishes in each location, and the degree to which the interviewee considers these to be sites of community (e.g. degree of cooperation, sharing of local knowledge, mutual dependence). The locations discussed were drawn in detail on a corresponding map (Figure 2).

Interviewees who corroborated the stories of inshore displacements and movements due to rolling closures not only suggested increased crowding amongst fishermen and between communities, they also pointed to increases in communication, information sharing, and a sense of camaraderie between fishermen and across communities affected by regulations and forced to work in closer proximity.

> *Because of the rolling closures, everyone from different ports works together* (interviewee).

> *Yes, we communicate about regulations [and] safety. For example, if it is bad weather and we tell them to come to Gloucester, it is closer than going home to their ports* (interviewee).

> *Plenty of gossip, reg[ulation]s, everything. So few people, everyone knows each other* (interviewee).

> *Yes, more social information and opinion because of the escalation of management, regulation has focused a lot of discussion, broadened people's discussion on social issues* (interviewee).

> *Yes, during fishing. Some new people do not know the bottom and I warn them about it and give suggestions about where to fish* (interviewee).

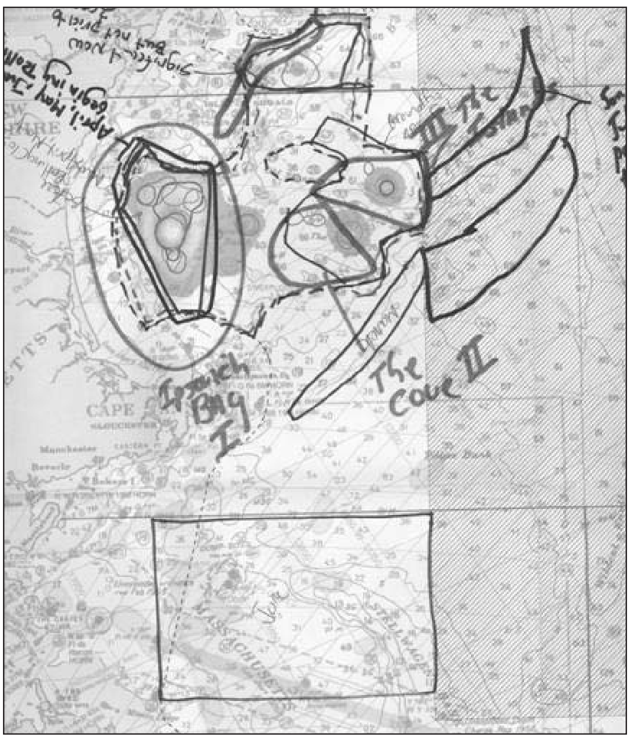

Figure 2. An extract from a map that focuses on the fishing locations of small trawl vessels from Hampton, NH. The interviewee has extensively amended this chart to illustrate the story of displacement due to regulations. The square box in Massachusetts Bay (lower part of image) represents the fishing grounds to which this NH fleet moves in June.

Rather than pointing to increased competition and the demise of community processes, the above quotes suggest, to some degree, increased cooperation and emergent processes of community. It is clear that community processes are not so much erased by regulations as they are (re)shaped and (re)placed.

While the issues of displacement and overcrowding have been voiced before in a variety of public fora and are widely known, the local and distinctly spatial dynamics of displacement on a community by community basis remain largely undocumented. Project participants, however, were eager to graphically illustrate and describe precisely these dynamics, not at the scale of management (the scale of regional stock assessments) but at the scale of community and the resource areas upon which they depend; they spoke not as individuals but as representatives of such communities tied to particular locations. Furthermore, the suggestion that new community processes and potentials might be emerging as a result of regulations is nowhere discussed; yet, interviewed fishermen repeatedly pointed to just such processes amidst their stories of, very real, community hardship and decline.

While the solicitation of similarly rich map-based descriptions of community resource use and change are commonplace within participatory development and conservation projects in the global south (Harris and Hazen 2006; Fox 2002), they are unexpected and uncommon in the industrialized fisheries of the U.S. Northeast where their invisibility has served to constitute the current absence of community-based development and conservation schemes. The repositioning of fishermen as community representatives, of community as coexistent with a commons, and the marine environment as a social landscape, however, suggests a role for community as an active agent in development and conservation even in the industrial Northeast.

Conclusion

Despite the institutionalization in the U.S. and elsewhere of a fisheries science and management built upon what might be characterized as "anti-community" foundations, there is a growing trend in fisheries toward the incorporation of "community" that parallels a global shift within resource management and development practices toward community-level initiatives (See for example, Locally-Managed Marine Area (LMMA) Network in the Pacific and Asia[9]). The call to community-level participation and implementation, even by such macro-level actors as the World Bank and the FAO, is designed to facilitate projects that build upon local skills and resources, and to enroll local people as active participants in conservation and sustainable development (Chuenpagdee et al. 2004). While "community" may be increasingly central, if only rhetorically, to development and conservation across many sites, its position within fisheries science/management, particularly in the global north, remains peripheral. This is true despite recent government mandates that it be incorporated and considered relative to fisheries management plans.

Defined and measured primarily in terms of the potential social and economic impact of fisheries management, communities remain external to the essential(ized) bioeconomic dynamic of fish harvesting. Indeed, as a function of percentages of fisheries related activities (e.g. numbers of vessels, employment, vessel services, or sea food processing), fishing communities are reduced to terrestrial locations, entities bound by the spatial units within which socio-economic indicators of community can be calculated. This understanding of community as a geographic container of indicators severed from the dynamics of fisheries themselves impedes community-level participation in both fisheries science and management; understood in these terms, community cannot be harnessed for conservation or sustainable development. Yet, the case of the CCCHFA (see above) suggests the power of placing community—community fishing practices and community knowledge—within the marine environment.

The Atlas Project was designed to address this problematic by documenting the existence of community processes and their corresponding commons within the fisheries of the U.S. Northeast. The project utilizes a map-centered action research methodology to produce a series of maps for a variety of ports in the Northeast that depict areas frequented by fishermen grouped by gear types and port. The maps are interpreted and given meaning in terms of community by fishermen and community researchers working together in an interview setting. The resultant stories offer information that is distinctly different than that found in standard impact analyses insofar as they describe processes associated with harvesting practices directly (e.g. where harvesting occurs and by whom) rather than port-side effects of changes in harvesting practices (e.g. landings decline or economic multiplier effects). In addition, these stories make clear the spatially uneven effects of regulations, which are obscured by impact analyses that are solely port based.

The project, however, works in other ways that also foster a community and commons becoming. In particular, as an action research project its goal is not only to produce data but a transformation of participants' understanding of and relationship to community and commons (St. Martin and Hall-Arber 2007). Also, the project has the potential to work as an intervention into the emerging ecosystems based approach to fisheries that is distinctly spatial and potentially accommodating of community as the "human dimension" of marine ecosystems. The vetted maps and narratives of the Atlas Project constitute a new ontological foundation and starting point for fisheries science and management as well as community advocacy. Such foundations are essential for the formation of new institutions that would foster community and expand commons.

Endnotes

1. Author to whom correspondence should be directed:
   E-mail: kstmarti@rci.rutgers.edu
2. E-mail: arber@mit.edu
3. "An Atlas-based Audit of Fishing Territories, Local Knowledge, and Community Participation in Fisheries Science and Management" was funded by NOAA via the Northeast Consortium (#01-840). Principal investigators were Kevin St. Martin, Rutgers University and Madeleine Hall-Arber, MIT Sea Grant.
4. By "community processes" we mean those actions, practices, knowledges, forms of inhabitation, etc. that constitute community not as a closed and bounded entity but as a set of relations, itself an ongoing process of becoming.
5. Examples of community profiles and descriptions of methodology can be found in McCay and Cieri 2000; McCay, Oles et al. 2002; McCay, Wilson et al. 2002; and St. Martin et al. 2005 concerning the Mid-Atlantic region. For the New England region see Hall-Arber et al. 2001. For examples beyond the U.S. Northeast see Jacob et al. 2002; Langdon-Pollock 2004, 2006; Sepez and Package 2004.
6. See, for example, the website for the Gulf of Maine Ocean Observing System (GoMOOS) http://www.gomoos.org/.
7. Fourteen interviewees listed their homeport as Gloucester; 13 were from New Bedford/Fairhaven; five from Portland, ME; one from Boston; five from four different ports in New Hampshire; five from

three ports in ME outside of Portland; six were from Chatham/Harwich and one from New York.

8. These maps also included spatial pattern by season. This was done by creating percent volume contours for trips by season. The depiction of seasonal pattern was variably successful depending upon the numbers of data records available and the nature of the peer group/gear type in question (e.g. communities that fish with lobster pots show virtually no seasonal variation in spatial pattern).
9. http://www.lmmanetwork.org/

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The missing layer: Geo-technologies, communities, and implications for marine spatial planning

Kevin St. Martin [a,*], Madeleine Hall-Arber [b,1]

[a] Department of Geography, Rutgers University, 54 Joyce Kilmer Drive, Piscataway, NJ 08854-8045, USA
[b] Massachusetts Institute of Technology, Sea Grant Program, 292 Main Street, Bldg. E38-300, Cambridge, MA 02139, USA

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ABSTRACT

The assessment and management of marine resources is an increasingly spatial affair dependent upon emerging geo-technologies, such as geographic information systems, and the subsequent production of diverse layers of spatial information. These rapid developments are, however, focused on biophysical processes and data collection initiatives; the social landscape of the marine environment is undocumented and remains a "missing layer" in decision-making. As a result, the resource areas upon which stakeholders and communities are dependent are neither mapped nor integrated into planning processes. We report on a participatory method to map the presence of fishing communities at-sea. The lessons learned concerning the spatial representation of communities informs not only fisheries, but other sectors struggling to incorporate similarly the human dimensions of the marine environment in assessment and planning.

1. Introduction

The assessment and management of marine resources is an increasingly spatial affair [1,2]. For example, fisheries management practices are increasingly relying upon area-based methods [3–5]; impact analyses of energy and industrial offshore development primarily focus on spatial displacement and access to place-based resources [6]; and marine protected areas (MPAs) are widely viewed as a key resource management tool [7]. As a result, the marine environment is rapidly becoming a collection of habitats, natural processes, multi-stakeholder practices, and use rights that are tied to places.

This "spatial turn" is reflected in recent increased efforts to collect geo-coded environmental information [8]. Remote sensing, tracking technologies, and global positioning systems are rapidly making visible what had previously been hidden or inaccessible. Living and mineral resources, marine habitats, environmental conditions, sea bottom morphology, and species ranges and interactions are all increasingly documented and mapped. Indeed, geo-technologies are revolutionizing marine resource management and are suggesting the technical possibility of comprehensive marine spatial planning (MSP).

Geographic information systems (GIS) and other digital technologies are allowing these new data streams to be merged and analyzed in ways that not only facilitate MSP but increasingly align with emerging ecosystem-based approaches that place greater emphasis on the character of local habitats and species interactions in places and across scales [9]. Yet, while the call to integrate a diversity of ecosystem processes over a variety of scales for marine management is being met by a host of data collection initiatives, the scope of the information being collected falls short relative to the "human dimensions" of the marine environment [10]. Neither the complexity of human communities nor their relationship to locations and resources at-sea are represented in current data collection initiatives despite the insistence that marine ecosystems (and ecosystem-based science and management) include human processes, impacts, knowledge, and needs.

Below we briefly examine how the human dimensions of the marine environment are being incorporated into marine environmental management. We focus on the question of spatial data as an entry into understanding the barriers to representing the human dimensions of the marine environment. We rely upon the case of fisheries where science and management are increasingly spatial and ecosystems-based, and key issues relative to the consideration of human dimensions have emerged. We then present a methodology for addressing the human dimensions of fisheries that attempts, like biophysical processes, to represent human processes and practices as complex, integrated, and multi-scalar. We conclude that such methods will be needed if we are to

* Corresponding author. Tel.: +1 732 445 7394.
E-mail addresses: kstmarti@rci.rutgers.edu (K. St. Martin), arber@mit.edu (M. Hall-Arber).
[1] Tel.: +1 617 253 9308.

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document and map, beyond fisheries, the human dimensions of the marine environment for MSP purposes.

2. What's missing from the geo-coded marine environment?

Many of the key issues found in the call for MSP are mirrored in fisheries science and management. In fisheries, single-species stock models, largely devoid of environmental parameters, are giving way to more complex ecosystem-based approaches that foreground not only environmental diversity but also species interactions (including non-commercial fish species, marine mammals, turtles, etc.), tradeoffs between sectors (including commercial fishing, recreational fishing, tourism, conservation, etc.), as well as the multiple uses of fisheries habitats by a variety of stakeholders. In addition, fisheries management, once essentially numeric and a-spatial [11], is experimenting with a variety of spatial management tools such as "rolling closures", zoning, and marine protected areas. Finally, participatory science and management models that solicit the environmental knowledge of fishers and engage them more directly in decision-making processes are slowly emerging. This shift in fisheries from single-species/single-sector models to more comprehensive spatial and ecosystems-based approaches [12,13], while not equivalent to MSP, is an essential element in the general movement toward MSP.

Such a shift toward spatial understandings and spatial management/planning will also require a shift in technical methods, in particular, an increased reliance upon GIS [14,15]. For example, ecosystems-based approaches for either fisheries management or MSP are invariably paired with GIS methodologies within articles, workshops, and management initiatives that promote the former (e.g., [16–18]). GIS is quickly becoming the forum where marine spatial data is aggregated, planning options are visualized, impact analyses are performed, and regulatory zones are established and mapped.

GIS, however, models the environment as layers of data to be queried, combined, and analyzed in various ways (e.g., bathymetry, sea surface temperature, bottom substrate, habitats, commercial operations, sea lanes, and distance from coast). This logic structures analyses and decision-making as the consideration of layers of data and, primarily, their overlap. For example, in multi-criteria and multi-objective decision-making, criteria are represented as layers, given weights, and aggregated using a variety of algorithms that can account for tradeoff and risk relative to the objectives at hand [19]. While such methods hold much promise for area-based fisheries management and MSP, they are useless without the many layers of information needed for comprehensive analysis and decision-making. While this might be obvious, the degree to which a GIS-based system for environmental decision-making is limited by the layers of data that are available to it is rarely acknowledged.

In the case of fisheries, the challenge of producing new streams of geo-encoded data is already being met by a wide range of initiatives that include the deployment of remote-sensing technologies (e.g., [20]), finer scale and more localized data collections (e.g., [21]), as well as the incorporation of local ecological knowledge of fishers into existing systems of assessment and management (e.g., [22,23]). The advent of new layers of data is opening fisheries science and management to new assessment and management possibilities that range from the "discovery" of local fish populations and their revival [24] to the use of rotational area closures [25].

While the biophysical environment is being mapped in ever greater detail and incorporated into systems of spatial analysis, the "social landscape" of fisheries and fishing communities remains largely undocumented. Detailed information concerning which fishing communities utilize, rely upon, and maintain local knowledge concerning which areas of the marine environment is only vaguely known. This is symptomatic of representations of the human dimensions of the marine environment generally. Mining, shipping, energy development, recreational fishing, tourism, etc., to the degree they are mapped, are represented as occurring in locations at-sea but those locations and activities are only rarely linked to onshore locations or dependent communities. There is, then, a "cartographic silence" present within current mappings of the marine environment that threatens to structure decision-making such that communities dependent upon particular marine resources or uses of marine space will be difficult to see and include in terms of either participatory science/management of place-based resources or analyses of the differential impacts of any spatial management (in terms of fisheries (see [26])). In this contemporary moment, we might wish to think of this silence not as a blank space on a paper map, but as a "missing layer" within the GIS.

Yet, in fisheries as in ecosystems-based management generally, the success of the spatial turn and its acknowledgement of heterogeneous habitats, place-specific flora and fauna, and species interactions across space (see Crowder and Norse in this issue) will require a parallel acknowledgement of a heterogeneous "social landscape" of communities, fishing and other resource-dependent practices, and local knowledge that similarly varies across space [10]. Within a variety of initiatives it is increasingly clear that documentation of and engagement with local communities and resource users is vital if local and area specific schemes are to work (see also Pomeroy and Douvere in this issue). For example, advocates of ecosystems-based approaches in fisheries have suggested that such approaches will require "local participation" [27,28], obtaining local ecological knowledge from fishers directly will only work in the long-term if fishers are partners in the scientific and management process [22], and MPAs appear most sustainable when the variety of local stakeholders are included in their design and administration [29]. Even broad calls for co-management or cooperative research suggest engagements with fishers and other resource users in particular places and from particular communities [30,31].

In the case of fisheries, where fishing communities are integrated into fisheries management, typically as sites for regulatory impact analysis, they are relegated to terrestrial/port locations [32] and do not appear within the space of natural resource management itself [26]. As a result, the territories, local practices, assemblages, and communities to which fishers might be connected remain largely unmapped and unavailable to increasingly GIS dominated fisheries science and management.[2] Again, this is also an issue beyond fisheries. For example, the impacts and economic multiplier effects of some individual offshore development (e.g., a wind farm) may be calculated for terrestrial locations, but specifically who is displaced by the same offshore development will be difficult to assess because of the absence of any data or map depicting existing or traditional use of offshore locations. Finally, linking port-based communities to the locations at-sea that they utilize, know, and depend upon is fundamental to community-level participation and cooperation relative to ecosystem and area-based approaches to marine resource management.

Increasingly "community" is being considered in fisheries and other marine sector impact analyses to document the possible

[2] This is clearly not the case in developing nations and peripheral locations of the first world where local territories are tied to communities, fishing villages are assumed to have traditional resource areas upon which they depend, and co-management is more easily imagined [43].

effects on and transformations of local economies and communities relative to some offshore development or management initiative. Impact analyses, however, are a response to individual developments or management plans and do not represent a comprehensive integration of the social landscape of the marine environment into a planning process. They may, importantly, demonstrate community linkages to offshore areas (e.g., [33,34]) but they do so only relative to the development or management plan in question. MSP will require a comprehensive mapping of the social landscape comparable to that being developed for the biophysical landscape. While both are important tools for impact analyses, they are essential layers of information for MSP.

Incorporating the ''missing layer'', the diverse, dynamic, and multi-scalar social landscape of the ocean into MSP will require new methodologies and data collection efforts that document the ''at-sea'' locations, interests, and dependencies of specific communities and groups of stakeholders. If communities are relegated to terrestrial locations and if they are only considered as sites of impact, their ability to engage in cooperative science, management, restoration of environments, and stewardship of marine resources will be severely limited. In addition, the displacements and dispossessions that will inevitably occur as a result of ecosystem and area-based management of the marine environment (e.g., area closures that overwrite the traditional territories of particular fishing communities) will be difficult to trace or avoid.

3. A method for producing the ''missing layer''

Below we report on a method developed to address the problem of the ''missing layer'' in fisheries. While developed within the context of fisheries in the US Northeast, the method as well as the lessons learned concerning its implementation, should prove useful to those interested in a more comprehensive and multi-sectoral mapping of the social landscape of the marine environment for MSP. The method was developed for the ''Atlas Project'' that was funded by a US federal program designed to promote ''cooperative research'' between fishermen and scientists.[3] The program was a response to the industrial/environmental crisis in fisheries in the 1990s and, among other things, it served to indirectly funnel funds to struggling fishing communities [35]. While most projects funded by this program were concerned with designing and testing new forms of fishing gear or testing scientific hypotheses based on the knowledge of fishermen of local fish stocks, the Atlas Project utilized both spatial analytical techniques and a participatory research approach to develop GIS data layers depicting the territories of fishing communities that were then interpreted and given meaning by fishers themselves.

Combining spatial analyses with community-based workshops and interviews within a single research design, what is often referred to as a ''mixed method'' approach (cf. [36,37]), was important given the limitations of GIS relative to the representation of social processes and meanings [38]. The first phase of the project used existing datasets from the National Marine Fisheries Service (NMFS) and spatial analytical techniques to produce a series of provocative maps depicting community utilization of fishing grounds, overlap between community territories, and displacements due to area closures. The second phase was a community-based participatory project involving ''community researchers'' and fishers that resulted in a collection of rich narratives that complemented, explained, and added meaning to the map series. The results from the project, then, include not only a series of vetted maps showing the locations of resource areas important to particular communities, but a rich qualitative database detailing the boundaries (social and geographic) of fishing communities, their relationship to specific resource areas over time, and the effects of recent legislation on their spatial patterns and practices.

3.1. GIS methods to map community resource areas

Initial maps of the patterns and territories of fishing communities were produced using vessel trip report (VTR or ''logbook'') data collected by NMFS since 1994. On a trip-by-trip basis, all fishing vessels engaged in federally regulated fisheries (that include virtually all commercial species in the Gulf of Maine) must submit VTRs that detail, amongst other things, catch and bycatch (by species and weight), numbers of crewmembers, data and time of departure and landing, type and size of gear, latitude and longitude coordinates of the trip,[4] and vessel permit number. This dataset is unique insofar as it contains geo-coded trip data that can be linked (via vessel permit number) to vessel attributes. For this project, the essential link was between trip location and the declared ''principal port'' of the vessel. This link allowed us to filter the VTR data by what we considered to be tentative ''communities''—combinations of declared principal port and gear type.[5] Similar logbook data in digital form is increasingly required by national and international fisheries management bodies worldwide.

From the VTR and vessel permit datasets for the available years (1994–2004), we built annual tables that could be queried using GIS to map commercial fishing trips by gear type, principal port, crew size, vessel size, etc. The resultant dataset excluded VTR records that did not have valid coordinate information.[6] As a result, our dataset, for any query, could be considered only a sample of trips that limited our analysis to relative comparisons. As a rough measure of locational accuracy, we observed that the data tended to be strongly auto-correlated when filtered by principal port and/or gear type (our initial measures of ''community'') suggesting only minimal misreporting (or a well-coordinated conspiracy of misreporting) by individual fishers.[7]

An obvious spatial clustering emerged from the data when filtered by principal port and gear type, and this became the basis for assuming that community territories might exist (Fig. 1).

While different communities exhibited different spatial patterns at-sea, we were encouraged by the degree to which discrete clusters were identifiable and, in many cases, consistent from year to year. Principal component analysis by gear type suggested a high degree of consistency for the period 2002–2004; data from these 3 years were then aggregated and were considered to

[3] ''An Atlas-based Audit of Fishing Territories, Local Knowledge, and Community Participation in Fisheries Science and Management'' was funded by NOAA via the Northeast Consortium (#01-840). Principal investigators were Kevin St. Martin, Rutgers University and Madeleine Hall-Arber, MIT Sea Grant.

[4] Coordinates are actually required for each gear deployment rather than trip. In practice, however, the vast majority of VTRs specify only one gear deployment and, therefore, one set of ''trip'' coordinates. Where multiple sets of coordinates were available for a given trip, we used only the first pair and considered the data to represent ''trip locations'' rather than gear deployment locations.

[5] We based our tentative ''community'' definitions upon many years of research and participant observation within fishing communities of the Northeast. Combinations of principal port and gear type are the main axes along which fishers self-identify and relate to one another.

[6] VTRs were discarded when latitude/longitude coordinates were not included, when coordinates were nonsensical due to data entry mistakes or misreporting, when coordinates did not match official statistical areas (that are also reported), or when coordinates were technically correct but outside of the Northeast region (e.g., in Oklahoma or the Arctic Ocean).

[7] This point is important to note given the constant disparagement of VTR data because it is self-reported by fishers.

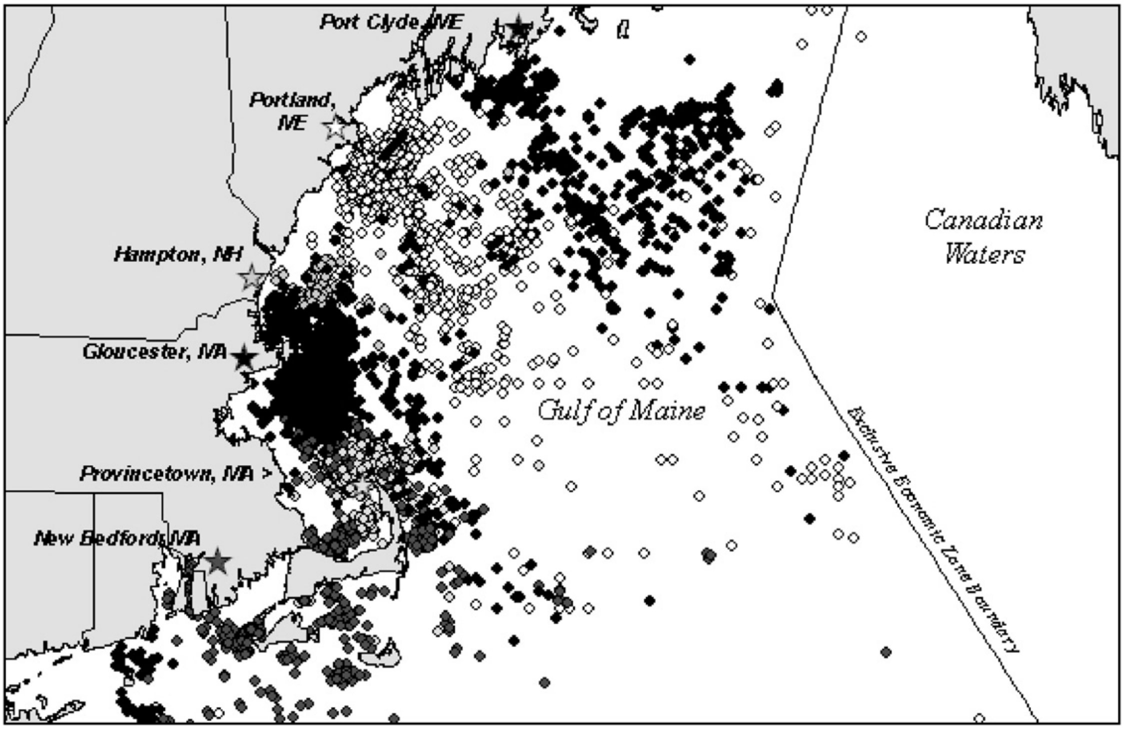

Fig. 1. Trip locations for vessels deploying trawl gear 2002–2004 from six representative ports in the GOM. Trip location colors correspond to port symbol colors. Note that many of the clusters and community overlap is difficult to visualize with point symbols.

represent the most recent spatial pattern of commercial fishing in the Gulf of Maine. Combining years also provided sufficient data such that we could identify clusters for even relatively small ports with few vessels.[8]

We employed two basic methods for visualizing the clusters of trip locations as "community resource areas." The first was by density mapping that transformed the point data, which we grouped by gear type and/or community, into a continuous variable surface. The second, akin to "home range" mapping of wildlife, utilized percent volume contours (PVC) to outline areas of primary and secondary importance to specific gear types and/or communities (Fig. 2).[9]

Both the density maps and PVCs were produced using trip locations weighted by crew size and trip length. The resultant variable, "fisherman days," is essentially a measure of labor time and serves here as a measure of "community presence" in the marine environment that is independent of amount caught or catch value (measures that highlight large vessel locations rather than small vessel, labor intensive, and, typically, inshore locations) (cf. [33]).

3.2. *Integrating maps into a qualitative protocol*

The density surfaces and PVCs for specific gear types and communities were then superimposed onto familiar nautical charts. Other basic summary information (e.g., numbers of vessels per port, percent trips by season) was also placed on the charts in the form of pie charts and tables. The final charts where then integrated into a qualitative and participatory research design [39,40]. In a variety of Gulf of Maine ports community-based researchers, themselves fishers or closely affiliated with the fishing industry, were recruited to interview local fishers who were asked questions about the practices and interests of their respective communities [41,42].

Each semi-structured interview incorporated a series of three charts depicting fishing patterns by gear type from the level of the Gulf of Maine to the more local level of the fishing community of the interviewee. Interviewees were invited to correct and amend each chart and, relative to each, were asked questions concerning community composition, spatial pattern, change over time, and local environmental knowledge. To our surprise, we found that most interviewees found the charts to be reasonably accurate despite the reputation, even amongst fishers, of VTR data, which is self-reported, to be inaccurate.

Throughout the interviews, interviewees were repeatedly reminded that they should provide information about their community or peer group rather than their personal fishing locations or experiences. This last strategy, along with recent area-based management initiatives (e.g., seasonal closures) that clearly affected some fishing communities more than others, was key to circumventing the reticence of fishers to reveal fishing locations.

4. Implementing the method and initial outcomes

Below we report upon our experiences implementing the method outlined above as well as some initial outcomes based upon the responses of fishers. Our goal is to reflect upon the feasibility of producing a data layer representing fishing communities and the areas at-sea that they inhabit. Given the participatory nature of the project, we necessarily include the goals and objectives of the participants themselves that clearly emerged during project workshops and interviews. In addition, we briefly report upon the general responses of project participants to each of the three charts (representing different scales of experience) used in each interview setting.

[8] Ports/communities with less than four vessels were not mapped for reasons of confidentiality.

[9] Both density surfaces and PVCs were calculated using: Beyer, H.L., 2004. Hawth's Analysis Tools for ArcGIS. Available at http://www.spatialecology.com/htools.

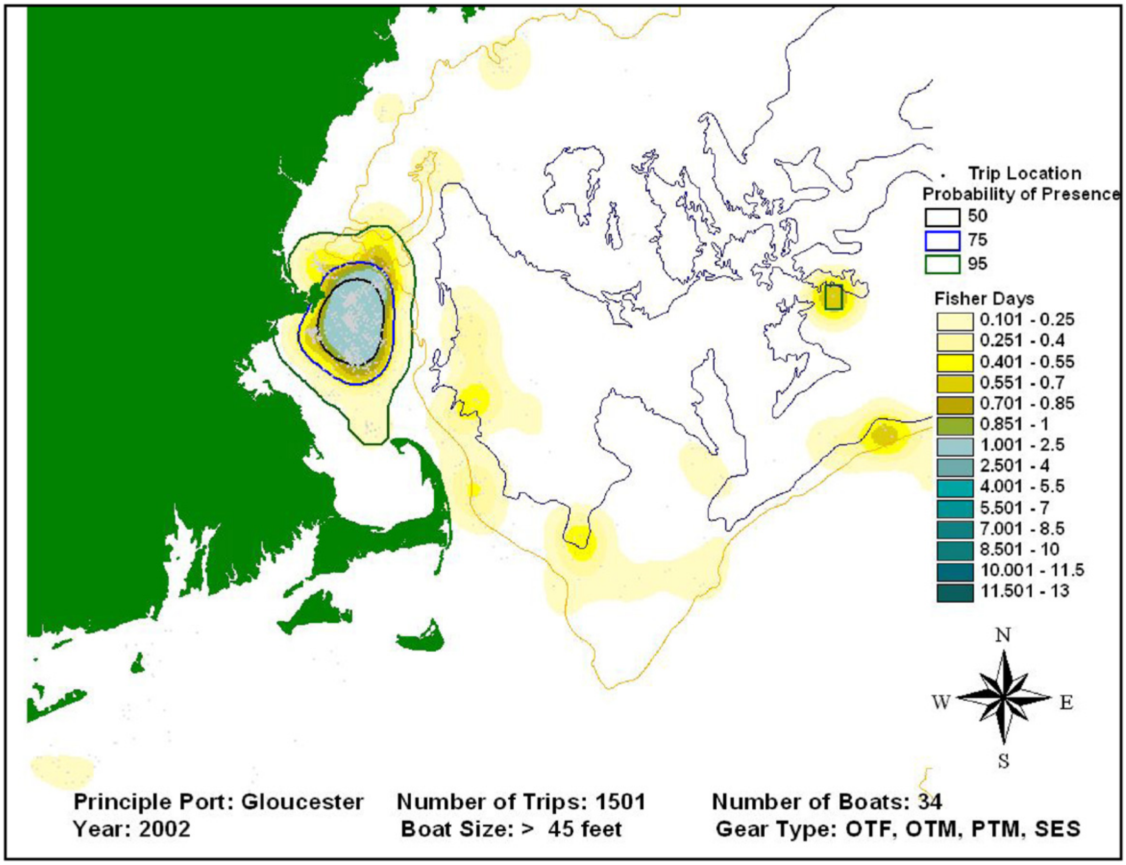

Fig. 2. Raster density surface and PVCs based on ''fisherman days'' variable for small trawler vessels from Gloucester, MA.

In total, seven community researchers interviewed 59 commercial fishers representing a range of gear types, vessel types, and port sizes.[10] All but four of those interviewed were captains and 46 were vessel owners. All were experienced fishers, with from 15 to 46 years on fishing vessels (averaging 29 years). Gear types included trawl gear on vessels both over and under 65 feet; pots and traps; gillnets and longline; and dredges. Approximately two-thirds of the interviewees fished for multispecies (groundfish) using otter trawls, gillnets or hooks. Eight lobstermen and nine scallop fishermen were also interviewed. All interviews were recorded and transcribed. The resultant database reflects a range of stories at different scales and from a variety of perspectives concerning fishing communities, the places to which they are intimately linked, and the knowledge of those places that they maintain.

From these interviews, there is clear evidence of social–spatial groupings/territories based on gear type and port. Our findings to date suggest that the nature of these territories and the reasons for their formation vary considerably from one community to the next. Some stretch across the entire management region while others are only a few miles from port of origin, some are intensively fished while others only occasionally visited, and some are isolated while others overlap with several other communities. In addition, vessel size and range, knowledge of the environment, species sought, community traditions, season, and market location all contributed to the determination of territories/resource areas.

[10] Fourteen interviewees listed their homeport as Gloucester; 13 were from New Bedford/Fairhaven; five from Portland, ME; one from Boston; five from four different ports in New Hampshire; five from three ports in Maine outside of Portland; six were from Chatham/Harwich and one from New York.

The variability of the spatial experiences of the communities investigated suggests that they will experience and respond to regulations differently. Indeed, our (and fishers) documentation of community territories and their histories highlighted the uneven experiences of fishing communities relative to recent fishing regulations (e.g., ''rolling closures'' and permanent closures in the Gulf of Maine). Furthermore, many of the interviewees saw their participation in the project as an opportunity to document experiences of, for example, spatial displacement or forced community overlap/competition resulting from area-based regulations. They hoped to legitimate their claims of injustice that they felt were previously dismissed as anecdotal. It would seem that the ''missing layer'' was already working as a way to document the impacts of area-based fisheries management.

While the variability of community territories may not be surprising, we were surprised to find the degree to which interviewees acknowledged and related to them, agreed with their boundaries, pointed to their relative stability, and filled them with stories and knowledge reflecting years of community dependence on specific resource areas.

4.1. *The reactions of fishers to the charts*

While our focus on the spatial experiences of fishing communities allowed the issue of spatial displacement to clearly emerge, there were many other specific reactions and insights relative to each of the charts and their corresponding sets of questions. The first chart (titled: ''Where in the Gulf of Maine do We Fish?'') depicted the presence of fishers using the same gear type as the interviewee (Fig. 3).

Questions concerning the accuracy of the chart and change over time prompted most interviewees to discuss their fishery (e.g., those utilizing trawl gear were primarily associated with the groundfish fishery, pots and traps were primarily lobsters, etc.), in broad terms. They explained the current pattern of fishing, how it was (or was not) different in the past, and why the pattern changed over time. Changes in pattern were, invariably, linked to specific area-based regulations such as the Western Gulf of Maine Closure in 1998, Area 1 and Area 2 closures on Georges Bank in 1995, and the seasonal "rolling closures." While fishing community representatives have voiced similar stories in other fora (e.g., fisheries management council meetings), the maps of community territories worked to concretize their claims. Few of the communities engaged in the project were unaffected by these area-based regulations.

Fig. 3. Here a fisherman amends a chart showing the locations of vessels with dredge gear in the Gulf of Maine.

The second chart (titled: "Who Fishes in Which Locations?") included PVCs by individual port/gear type combinations (Fig. 4).

Interviewees were asked to again correct or amend these charts and were asked questions concerning community overlap, conflict, cooperation, and communication. Again, stories emerged relative to the closures mentioned above and many interviewees suggested that regulations forced fishers into smaller areas with increased community overlap. Curiously, while this produced competition due to crowding, in some instances it also produced new networks of communication and cooperation engendered by a sense of "all being in the same boat."

The final chart (titled: "Where Does My Peer Group Fish?") included a density surface for the individual community and gear type of the interviewee (e.g., small trawl vessels from Gloucester)

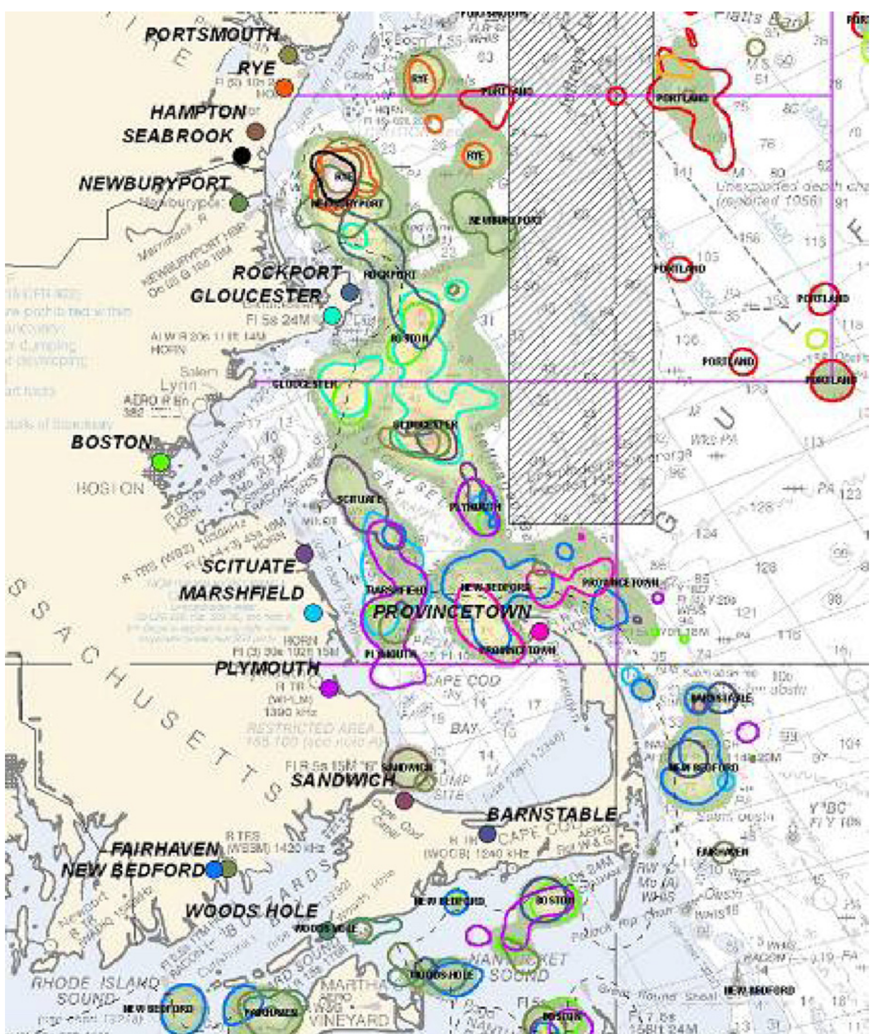

Fig. 4. An extract from a "Chart 2" with color coded PVCs (here in grayscale) superimposed upon a NOAA nautical chart. The PVCs correspond to Gulf of Maine ports from which, in this case, small trawl vessels originate. Areas outlined represent primary fishing grounds by principal port. The chart also contains a raster density surface based on the aggregate of all vessels.

as well as PVCs for each of four seasons (i.e., areas of primary importance in the winter, spring, summer, and fall). Interviewees were asked to reflect on their own community, changes in fishing locations by season, and detailed environmental information for particular locations important to their community. Interviewees pointed to heightened awareness of local environments as demands for precision and efficiency emerge with fewer fishing days and other regulations that limit effort and location. In addition, they demonstrated considerable local ecological knowledge relative to the specific locations frequented by their community. That knowledge was, however, different for different communities. For example, fishers working with lobster pots had different knowledge than those working with ground trawling gear.

Overall, the depiction of community resource areas on nautical charts provided fishers with a graphic medium and graphic "language" that was very familiar to them. They were generally impressed by and agreed with these cartographic representations of their community resource areas and were eager to engage with them. The common language of the charts and acceptance of the project by fishers allowed them to clearly articulate (in reference to or literally on the charts) the effects of fisheries regulations on their communities. The positive reactions to the charts and the general desire expressed by interviewees to see them integrated into management, suggests that the missing layer of fishing communities can be successfully developed via the method described above.

The Atlas Project has resulted in a concrete set of maps (vetted by fishing community representatives) that are already proving useful. These maps, while not comprehensive for the entire Gulf of Maine, will be of interest to scientists wanting to work cooperatively with "local communities", managers interested to link port-based communities to locations at-sea for impact analyses, and fishing communities hoping to maintain sustainable access to "their" fishing grounds and livelihoods.

5. Conclusion

The marine environment is increasingly understood, analyzed, and managed via layers of digital information representing a wide range of spatial phenomena across a variety of scales, and GIS and other geo-technologies are rapidly becoming essential fora for assessment, planning, and decision-making relative to a host of competing uses of the marine environment. In addition, emerging spatial forms of representation and analysis are closely aligned with ecosystems-based resource management as well as MSP generally. Overlooked in this "spatial turn" both in terms of data collection and integrated analyses are the human dimensions of the marine environment. While "communities" and "stakeholders" are present in terrestrial locations subject to the impacts of individual development projects or management initiatives, they are absent from the integrated layers of information useful for more comprehensive marine resource assessment and planning.

The Atlas Project suggests that this "missing layer" can be developed via a participatory methodology and will be well received by communities subject to ever-more spatial approaches to management. The initial results of the project suggest that participants will be eager to use maps depicting resource utilization and change over time as evidence of unfair displacements and overcrowding due to area closures or other place-based resource management initiatives. Participants' eagerness to document and thereby legitimize their histories of use and stories of displacement suggests that such information has been absent from resource assessments as well as the planning stages of management. Without its inclusion, and without detailed knowledge of the human dimensions of the marine environment, decision-makers are likely to face continued resistance to forms of management that spatially restrict use of the marine environment.

While fisheries are central to both ecological and social/cultural understandings of the marine environment, the social landscape is composed of more than fishing communities and their territories. Nevertheless, the Atlas Project's method can work as a model for community-level involvement in marine resource assessment and planning beyond fisheries. Its techniques—the inclusion of community researchers, in-depth map-based interviews, and community workshops—are widely used for participatory conservation and development, particularly in developing countries, and, as we have shown, can be adapted to the maritime sectors of industrialized countries.

Coastal communities with economic and cultural ties to the marine environment are beginning to recognize that they need to make themselves (and their diverse practices, histories, and local knowledges) visible within the environment itself; they need to put themselves on the map if they are to play an active role in emerging ecosystem-based and MSP approaches to marine resources. Conversely, if institutions and authorities continue to overlook and "silence" the intimate connections and long histories that exist relative to communities and the resource areas upon which they depend, opportunities for local participation in resource management as well as the facilitation of community stewardship will be lost.

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Escape ring selectivity, bycatch, and discard survivability in the New England fishery for deep-water red crab, *Chaceon quinquedens*

S. M. L. Tallack

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The trap fishery for red crab, *Chaceon quinquedens*, occurs at depths of 600–800 m along the continental slope of New England. The target product is a male crab with a carapace width of ~105 mm or greater. Selectivity was tested at two discrete depths (600 and 800 m), for four different escape ring scenarios: control trap with no escape rings, and escape rings with internal diameters of 9, 10, and 11 cm. Proportions of non-marketable *C. quinquedens* were large (71–100%) at both depths for all traps, but were smallest in traps with escape rings. Discard mortality was estimated at ~5% through caging experiments across three haul frequency conditions (every 24 h, every 4 d, and after 8 d), which represented the likely reality of multiple recaptures during a commercial trip. The impact of discarding techniques (low and high impact) was also assessed. If discard proportion estimates of >71% are realistic, and if an estimated ~5% of these discards die, the recommendation must be made for fishery participants to improve gear selectivity, and thereby to minimize discard mortality rates. On the management side, stock assessments will be more accurate if estimates of discard mortality are incorporated.

Keywords: *Chaceon quinquedens*, deep-sea red crab, discard mortality, escape rings, gear selectivity, trap fishery.

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S. M. L. Tallack: Gulf of Maine Research Institute, 350 Commercial Street, Portland, ME 04101, USA; tel: +1 207 228 1639; fax: +1 207 772 6855; e-mail: stallack@gmri.org

Introduction

The commercial trap fishery for deep-water red crab, *Chaceon quinquedens*, takes place at depths of ~600–800 m along the continental shelf from Georges Bank south to waters off Virginia (NEFSC, 2006). Landings have risen steadily since 1995, peaking at ~4000 t in 2001; as such, this species is increasingly valuable for the diversified New England fisheries. The market for red crab originally required a carapace width (CW) of ~115 mm, which encouraged a male-only fishery because few females reach this size; more recently this market size has been reduced to ~105 mm CW in response to decreased catches of large male crabs. In 2002, legislation was enacted prohibiting red crab vessels from landing more than "one standard US fish tote" of females from any directed red crab trip (CFR, 2002). No legal size limit is currently in place.

The deep-water nature of this fishery poses a challenge for fishers and researchers alike. Research on *C. quinquedens* in the Northwest Atlantic began during the 1970s (Wigley *et al.*, 1975; Haefner, 1978) and progressed into the 1980s focusing on shell disease (Feeley, 1993), reproduction (Haefner, 1977; Elner *et al.*, 1987; Hines, 1988; Hinsch, 1988), and growth (Perkins, 1973; Lux *et al.*, 1982; Van Heukelem *et al.*, 1983), but soon waned in the face of reduced fishing effort and research difficulties. Since the establishment of a target fishery in more recent years, the need for contemporary research on *C. quinquedens* is topical again. Data have been collected to furnish stock assessments and abundance estimates, in addition to estimates of movement and growth (Keith, 2003, 2005; Weinberg *et al.*, 2003; Wahle *et al.*, 2006).

Currently, the fishery for *C. quinquedens* is not subject to gear restrictions other than a trap capacity limit (18 cubic feet or 0.51 m^3), gear line and marking requirements, and a 600 pot trap limit (CFR, 2002). Operators can choose trap designs according to desired performance in terms of catchability, durability, and space efficiency on deck, all of which are important considerations for the safe and economical operation of any fishery. In recent years, many of the traps have been fitted with 9 cm diameter escape rings, though no evaluation was undertaken to assess the most efficient escape ring size. The current study assesses the relative selectivity of different sized escape rings incorporated into the industry's standard nylon mesh traps. This is important because maximizing the selectivity of gear often translates into minimizing the capture of non-target animals, and in turn, reduces the impact of discard mortality.

Discard mortality is a component of fishing mortality (F) which, combined with natural mortality (M), gives an estimate of total mortality (Z); all three are vital parameters for stock assessments. Traditionally, the mortality of discarded crustacean species has been assumed to be low, but more recent assessments on various crustaceans discarded from both mobile (Stevens, 1990; Wileman *et al.*, 1999; Lancaster and Frid, 2002) and fixed (Grant *et al.*, 2002; Grant, 2003; Harris and Ulmestrand, 2004) gears suggest that crustacean discard mortality can be high. A summary of mortality estimates for major commercial crab species makes clear that findings vary greatly (0–100%) between gear types, species, and intermoult conditions (Alverson *et al.*, 1994). Recent research on the snow crab, *Chionoecetes opilio*, documented high rates of discard mortality (up to 51%; Winger and Walsh, 2005) for a trap fishery, which takes place in 170–380 m; that stock is now considered to be in decline (DFO, 2003). However, the discard mortality component of fishing effort is often under-researched (Alverson *et al.*, 1994), a fact recognized by the New England Fisheries Management Council in its recent documentation of prioritized research needs (NEFMC, 2004). Currently, there is no information regarding the survival rate of *C. quinquedens*, which are hauled to the surface from considerable depth and exposed to air and sunlight, before being discarded.

Multiple factors are likely to affect discard mortality in *C. quinquedens*, including the physiological capacity of the species to survive the significant change in environment experienced during the haul and discard process. In the red crab fishery, traps are typically emptied, re-baited, and reset immediately in nearby grounds (pers. obs.), so it is probable that surviving discarded crabs will be recaptured (possibly multiple times) during the course of a single commercial trip. The potential cumulative impact of fishing procedures is rarely investigated in discard mortality studies, but it was identified as key to this fishery and, as such, is investigated by undertaking caging studies at different haul frequencies to represent recapture events. In addition, different components of the actual discard process will influence the mortality levels of discarded crabs; for example, the "drop" (or height) between the trap emptying and sorting locations, and the discard location and the water surface have been shown to have a considerable impact on other crab species (Grant *et al.*, 2002; Grant, 2003; Purves *et al.*, 2003). In the red crab fishery, the drop of relevance is that from the sorting location to the water surface (~2–3 m), which could prove significant if vulnerability of red crabs to injury is high, as was proposed by Gray (1970). Additional factors influencing survival in other crab fisheries relate to aerial exposure and extreme changes in temperature (Zhou and Shirley, 1995, 1996; MacIntosh *et al.*, 1996; Tracy and Byersdorfer, 2000, 2002; Zhou and Kruse, 2000a, 2000b; Suuronen, 2005; Warrenchuk and Shirley, 2002) or salinity (Harris and Ulmestrand, 2004). The current study investigates discard mortality, focusing on (i) ascent/descent survival, and (ii) the effects of handling during the discard process.

Material and methods

Fishery-independent sampling took place in May 2006 on the red crab fishing grounds near Block Canyon (39°50′N 71°20′W). The 10-d research trip was aboard the FV "Hannah Boden" (26 m), one of the primary commercial red crab vessels. A variety of experiments was conducted to estimate trap selectivity and discard mortality.

Trap selectivity and escape ring trials

The standard industry trap was used; this is a conical crab trap (120 cm diameter × 60 cm height), rigged with ~7.6 cm nylon mesh and a top bucket-entry (25 cm). Two depths were targeted: ~600 m (typically associated with smaller and female red crab) and ~800 m (typically associated with larger male crabs). At both target depths, three strings were set, each consisting of 15 sequentially attached traps, three traps for each of the four escape ring conditions: (C) control, with no escape rings, and escape rings with internal diameters of 9 cm (S), 10 cm (M), and 11 cm (L).

The entire catch of every trap was sampled, including non-target species. *C. quinquedens* were sexed and their CW measured. These data were used to calculate estimates of catch per unit effort (cpue) and were also used to generate selectivity curves for each escape ring scenario. Selectivity curves were calculated using logistic curve analysis:

$$P = \frac{1}{(1 + \exp^{-r(\mathrm{CW}-\mathrm{CW}_{50})})}, \qquad (1)$$

where P is the proportion of the total catch of the size CW caught in the trap, r a constant, and CW_{50} the mean length at which 50% of the crabs are retained (King, 1995; Jennings *et al.*, 2001).

A VEMCO temperature-depth recorder (rated to 1000 m) was attached inside a trap on the 800 m string and sampled at a rate of 30 readings per hour; this yielded temperature–depth data throughout the trip, and the live well was chilled according to this *in situ* information.

Bycatch data collection

The bycatch component of the red crab fishery was determined through frequency analysis of target and non-target species data collected during the escape ring trials.

Survival of ascent and descent: crab "hotels"

The physiological capacity of red crab to survive the variable environment associated with the haul and return to the seabed was assessed through a caging experiment. Crabs were captured using commercial traps and, from the sorting table, were placed directly into compartmentalized cages (hotels) for return to the sea floor. Each hotel took ~5 min to fill and, because hotels could not be deployed individually (owing to the operating depth of ~600 m), hotels were submerged in the vessel's chilled (5°C) and aerated live well to minimize non-typical aeration on board the vessel. The total hotel loading/deployment duration was ~50 min. Data on crab size and sex were collected at the end of the experiment to avoid burdening the findings with additional, non-typical handling procedures gathered during the course of the experiment.

The hotels were made from 2.5 cm Aquamesh and measured 90 cm × 120 cm × 45 cm; each hotel provided a total of 36 individual compartments, each measuring 30 cm × 30 cm × 15 cm. The hotels were hauled at different frequencies to simulate three different recapture scenarios: (i) every day after initial capture, (ii) every 4 d, and (iii) 8 d after initial capture. During the course of the experiment, the survival of each crab was monitored using a stamina index (SI) where:

- 0 = dead;
- 1 = weak, slow movement of mouthparts, limp legs, little sign of life, but alive;
- 2 = slow movement of mouthparts, slight tension in legs;
- 3 = fast movement of mouthparts, tension in legs, fast reaction to touch stimuli on abdomen;
- 4 = fast movement of mouthparts, tension in legs, fast reaction to touch stimuli on abdomen, aggressive display.

Drop effects

The vessel's aerated live well was filled with seawater and chilled to the *in situ* temperature (5°C), as indicated by the temperature data collected during gear selectivity trials. The impact of the discard drop was assessed by creating two discard conditions:

(i) Control—dropped: 100 crabs discarded using the typical fishery practice, i.e. sorted on a table and dropped into the live well from the same height as would happen if a crab entered the sea via the vessel's discard shoot (~2 m);

(ii) Treatment—slid: 100 crabs sorted on the sorting table and slid down a plastic slide that delivered the crab into the live well with minimal impact.

This experiment was repeated for five consecutive days using separate, non-compartmentalized cages (90 cm × 120 cm × 45 cm) for each day and each discard condition. At the end of 5 d, cages were retrieved from the live well and the following data were collected: sex, size, injury, shell condition, SI, and holding duration.

Results

Trap selectivity and escape ring trials

Cpue data indicate a significantly higher mean catch rate at 600 m ($\mu = 35.06$) than at 800 m ($\mu = 16.24$; $\chi^2 = 6.927$, d.f. = 1, $p < 0.01$). Sex ratio differences in crab distribution between 600 m and 800 m were dramatic and significant. By the end of the gear trial experiment, 225 traps had been hauled at each depth. The total catch of females was significantly higher at 600 m ($n = 4369$) than at 800 m ($n = 94$), whereas males were caught in almost equal numbers at 600 m ($n = 3374$) and 800 m ($n = 3420$; $\chi^2 = 2918.371$, d.f. = 1, $p < 0.001$).

Table 1 shows that, at both 600 and 800 m, there is also a significant difference in cpue between trap conditions. All three traps with escape rings retained considerably fewer crabs than the control trap (Figure 1), with the smallest number of crabs being caught by the traps with 11 cm (L) escape rings (Table 1).

The size range of crabs captured by each trap condition is presented in Figure 2. Size-frequency analysis of the catch for each trap condition indicates that undersized crabs represent between 71.7% and 98.4% of the catch at the 10 mm CW market size (and 93.6–100% at the original market size of 115 mm CW). Two-sample Kolmogorov–Smirnov analysis (Table 2) on size-frequency distributions by trap treatment indicated that the catch compositions differed significantly at both depths; the only exception was at 800 m between the 10 cm (M) and 11 cm (L) escape rings. Gear selectivity curves (Figure 3) reveal that, for all gear conditions, the size at which the probability of capture is 50% (CW_{50}) is well below both the current market size (105 mm CW) and the previous market size (115 mm CW).

Table 1. Cpue data (average number of crabs trap^{-1}) by trap treatment across two depths (600 and 800 m).

Depth	Control cpue	Small cpue	Medium cpue	Large cpue	χ^2 statistic	*p*-value
600 m	85.99	40.31	24.67	18.11	66.471	<0.001
800 m	36.62	19.44	12.32	9.62	22.734	<0.001
% empty	1.1%	1.1%	0.0%	1.1%	–	–

Chi-squared analysis (χ^2) revealed significant differences both between depth and between trap treatments. The total proportion of empty trap hauls by trap treatment is also presented.

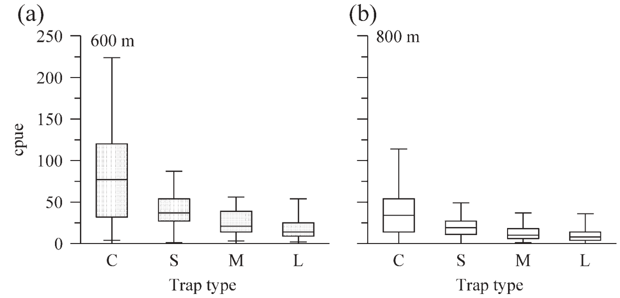

Figure 1. Mean cpue of *C. quinquedens* by trap treatment at target depths of (a) 600 m, and (b) 800 m. C = no escape rings, S = 9 cm escape rings, M = 10 cm escape rings, and L = 11 cm escape rings. Whiskers depict the minimum and maximum; upper and lower quartiles are represented by the box; and the line through the box represents the median.

Although the incorporation of escape rings did increase the size composition of the catch overall, particularly at 800 m, no significant differences in CW_{50} were found between gear treatments at either depth (Table 3).

The proportions of marketable vs. non-marketable catch by trap condition are presented in Table 4; at the current 105 mm CW market size, the smallest mean proportion of undersized crabs (72.4% at 600 m and 81.3% at 800 m) and the greatest number of marketable crabs (57 at 600 m and 36 at 800 m) are observed for the 9 cm (S) escape ring. If the 115 mm CW market size were imposed again, the combination of smallest mean proportion of discards and greatest number of marketable crabs would be achieved by the 10 cm ring (M). If the number of marketable (>105 mm CW) crabs and discard crabs are considered as a ratio, the 9 cm (S) escape ring is favoured relative to other escape ring options; 22:57 at 600 m, and 8:36 at 800 m (Table 4). Box plot visualizations (Figure 2) also demonstrate that the 9 and 10 cm escape rings retain a more restricted and larger size range of crabs.

Bycatch data collection

From 450 gear trial trap hauls, a total of 16 non-target organisms were recorded; this equates to 0.001% of the total catch of target species ($n = 11\,257$). The organisms captured included golden crab (*C. fenneri*, $n = 2$), Jonah crab (*Cancer borealis*, $n = 8$), unidentified whelk spp. ($n = 3$), ocean pout (*Macrozoarces americanus*, $n = 1$), and wrymouth (*Cryptacanthodes maculatus*, $n = 1$). Too few non-target organisms were recorded to discover any relationship with escape rings. All other bycatch consisted of undersized and/or female *C. quinquedens* and represented 85.7% of the total catch ($n = 9650$).

Physiological survival of ascent and descent: crab hotels

A total of seven hotels ($n = 252$ crabs) were filled and set for each condition. The total proportion of red crab that survived the descent/ascent hotel experiments was 93.8% (Table 5). Comparisons of the three hauling conditions (i.e. crabs hauled every 24 h, after 4 d intervals, or after 8 d) revealed that crabs that undergo the ascent/aeration/descent procedure regularly (i.e. every 24 h) demonstrate significantly greater mortality than crabs retrieved after either 4 d or 8 d ($\chi^2 = 18.092$, d.f. = 2, $p < 0.001$; data pooled when observations were <5). There was no evidence of effects related to crab sex (Table 5) or crab size.

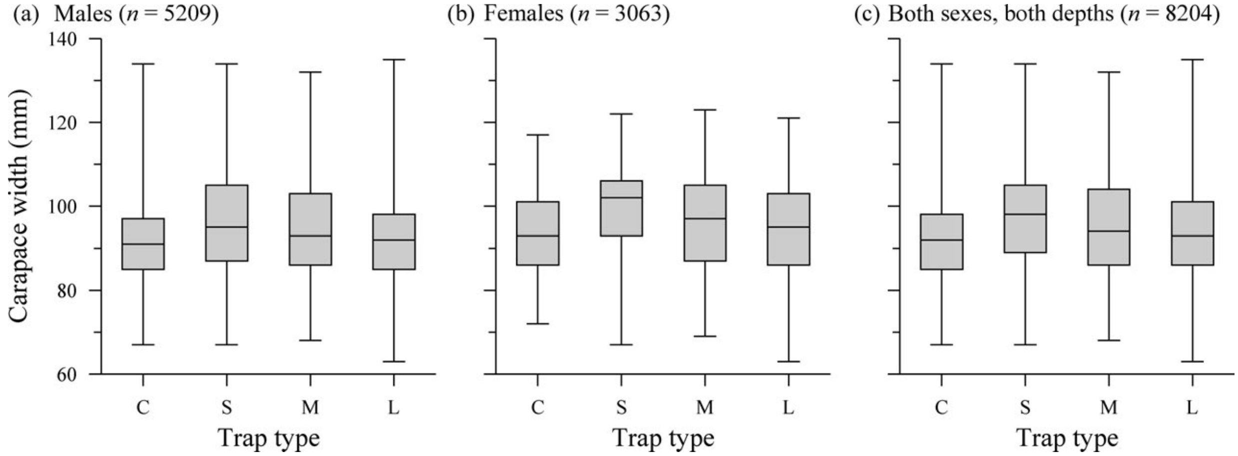

Figure 2. The total size composition (depths combined) of *C. quinquedens* for each trap treatment. C = no escape rings, S = 9 cm escape rings, M = 10 cm escape rings, and L = 11 cm escape rings. Whiskers depict the minimum and maximum; upper and lower quartiles are represented by the box; and the line through the box represents the median.

Drop effects

The discard handling technique had a strong impact on SI and the overall survival of crabs. Chi-squared analysis (categories pooled when observations were <5) indicated that crabs that had been slid into the water (i.e. no surface impact) were significantly more likely to be recorded as strong (SI3 or SI4), and crabs that had been dropped into the water were significantly more likely to be categorized as dead (SI0) or weak (SI1 or SI2; $\chi^2 = 12.738$, d.f. = 2, $p < 0.01$). Table 6 shows the relative frequencies for each SI for males and females exposed to the two conditions. Overall, mortality was greater (4.3%) for dropped crabs than for slid crabs (0.8%). No sex differences were observed.

Fresh limb loss was considered a possible impact of fishing/handling and was observed in 25 females (4.3%) and 13 males

Table 2. Two-sample Kolmogorov–Smirnov analysis on the size-frequency distributions of catch compositions across different escape ring treatments.

Trap comparisons	600 m			800 m		
	Z statistic	*n*	*p*-value	Z statistic	*n*	*p*-value
C: S (9 cm)	8.457	3 110	<0.0001	9.501	1 529	<0.0001
C: M (10 cm)	3.697	2 761	<0.0001	7.885	1 319	<0.0001
C: L (11 cm)	1.829	2 398	<0.01	6.901	1 183	<0.0001
S (9 cm): M (10 cm)	4.048	2 545	<0.0001	1.841	1 328	<0.01
S (9 cm): L (11 cm)	5.264	2 272	<0.0001	1.752	1 192	<0.01
M (10 cm): L (11 cm)	1.795	1 833	<0.05	1.197	982	NS

NS, not significant.

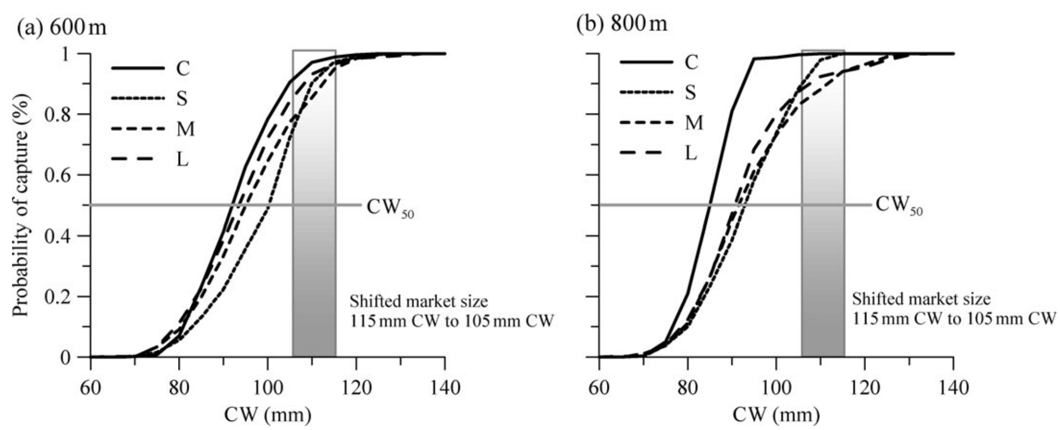

Figure 3. *Chaceon quinquedens* selectivity curves for different escape ring treatments at (a) 600 m and (b) 800 m. C = no escape rings, S = 9 cm escape rings, M = 10 cm escape rings, and L = 11 cm escape rings. The size at which the probability of capture is 50% (CW_{50}) is indicated by the grey horizontal line. The vertical bar represents the shift in market size from ~115 mm CW to ~105 mm CW.

Table 3. The CW_{50} values obtained for each trap treatment across two depths (600 and 800 m).

Depth	Control CW_{50}	Small CW_{50}	Medium CW_{50}	Large CW_{50}	χ^2 statistic	*p*-value
600 m	92	101	96	94	0.478	N. S.
800 m	86	93	92	92	0.350	N. S.

Chi-square analysis (χ^2) revealed no significant differences in the size at which the probability of capture is 50% (CW_{50}) between trap treatments at either depth. N. S. = not significant.

(2.8%), although this difference was not significant ($\chi^2 = 3.789$, d.f. = 1, $p > 0.05$). For males, fresh limb loss was equally frequent between dropped crabs ($n = 6$, 2.8%) and slid crabs ($n = 7$, 2.9%). However, females that had been dropped into the live well were significantly more likely to exhibit fresh limb loss ($n = 18$, 6.6%) than those that had been slid ($n = 7$, 2.8%; $\chi^2 = 4.840$, d.f. = 1, $p < 0.05$).

Discussion

Although traditional fisheries have diversified to include deep-water fisheries, there is a paucity of information available regarding the impact that changing fishing practices is having on these deep-water communities. From the current study, it would

Table 4. The relative selectivity (at both current and original market sizes) of each trap condition at 600 and 800 m depth for *C. quinquedens*; because females are not legally marketable, they are considered as 100% discards, so marketable numbers for females is always 0, even if females of market size were caught in the trap.

Depth, ring size, and sex	Average number in trap	At market size 105 mm CW			At market size 115 mm CW		
		Undersized (%)	Marketable[a] (n)	Discards[a] (n)	Undersized(%)	Marketable[a] (n)	Discards[a] (n)
600 m							
Control							
Males	84	91.7	7	77	96.6	3	81
Females	93	89.6	0	93	97.5	0	93
Total	177	90.6	17	160	97.1	5	172
Small (9 cm)							
Males	39	73.1	10	29	87.9	5	35
Females	40	71.8	0	40	100.0	0	40
Total	79	72.4	22	57	90.3	8	71
Medium (10 cm)							
Males	24	77.7	5	19	82.5	4	20
Females	27	77.2	0	27	100.0	0	27
Total	51	77.4	12	39	85.5	7	44
Large (11 cm)							
Males	18	86.0	3	15	90.5	2	17
Females	18	82.9	0	18	95.3	0	18
Total	37	84.4	6	30	93.2	3	34
800 m							
Control							
Males	37	92.4	3	34	95.6	2	35
Females	0	87.5	0	0	100.0	0	0
Total	37	90.0	4	33	96.4	1	36
Small (9 cm)							
Males	20	80.8	4	16	89.2	2	17
Females	24	81.8	0	24	100.0	0	24
Total	43	81.3	8	36	90.6	4	38
Medium (10 cm)							
Males	12	82.8	2	10	87.9	1	11
Females	0	92.9	0	0	100.0	0	0
Total	12	87.8	1	11	87.7	2	10
Large (11 cm)							
Males	10	87.2	1	9	92.1	1	9
Females	11	93.8	0	11	100.0	0	11
Total	20	90.5	2	19	93.8	1	19

[a]Of key interest is the ratio of marketable:discard crabs.
[a]To the nearest whole crab.

Table 5. The overall proportions of *C. quinquedens* that survived, died, or escaped during the course of the hotel experiment.

Haul frequency	Female			Male			Totals		
	n	Alive (%)	Dead (%)	*n*	Alive (%)	Dead (%)	*n*	Alive (%)	Dead (%)
Every 24 h	138	85.5	13.2	114	83.3	12.3	252	84.5	11.5
Every 4 d	136	99.3	0.9	116	97.4	1.7	252	98.4	1.2
After 8 d	113	100.0	0.0	139	97.1	2.2	252	98.4	1.2
Totals	387	94.6	4.3	369	93.0	5.1	756	93.8	4.6

In all, 12 crabs were lost as a result of cage damage. Thus, when proportions sum to less than 100%, the difference represents "missing" crabs.

appear that the deep-water red crab fishery's impact on non-target species (as evidenced by capture frequencies) is low; the most abundant bycatch for this fishery is undersized and female *C. quinquedens*. Very few non-target species were observed in the current study, consistent with observations during commercial sampling trips (pers. obs.; R.A. Wahle, pers. comm.).

Gear trial experiments demonstrated significant differences in both the cpue and the size structure of the crabs retained in each of the trap conditions. The control traps (without escape rings) had the highest mean cpue (~86 and ~36 crabs trap^{-1} at 600 and 800 m, respectively), with undersized (<105 mm CW) crabs averaging >90% of the catch. The mean cpues for traps with escape rings were considerably lower (18–40 crabs trap^{-1} at 600 m and 9–20 crabs trap^{-1} at 800 m), and the proportions of discards were also smaller. This suggests that vessels using the 9 cm escape ring have probably reduced their catch rates of undersized crabs considerably. Although no escape ring was found that completely eliminates undersized animals, if minimizing capture of non-marketable (<105 mm CW) crabs is the aim, then the industry's current 9 cm escape ring appears most effective in achieving this goal, and also retaining a good catch of marketable crabs. If, however, a larger market size (e.g. 115 mm CW) were required, the 10 cm (M) ring would be recommended. Although the size range of retained crabs differs little from the 9 cm ring, the cpue of the 10 cm ring is lower, so the number of non-marketable crabs impacted is also lower. The relative benefit of either size escape ring is best seen by comparing the ratio of marketable:discard crabs, with the goal of maximizing the mean number of marketable (large male) crabs relative to the numbers of discards. If industry also increased the soak time (20–24 h is currently typical), crabs that are small enough to escape may also leave the trap once the bait supply has been exhausted.

Table 6. The proportion of *C. quinquedens* recorded at different stamina indices after being dropped vs. slid into the holding facility; stamina index 0 = dead.

Discard method by sex	*n*	Stamina index (per cent)				
		0	1	2	3	4
Drop						
Female	275	4.4	0.4	0.4	5.8	89.1
Male	216	4.2	0.9	0.0	1.4	93.5
Total	491	4.3	0.6	0.2	3.9	91.0
Slide						
Female	255	0.4	0.0	0.0	3.9	95.7
Male	254	1.2	0.0	0.8	1.2	96.9
Total	509	0.8	0.0	0.4	2.6	96.3

The findings in this study are not necessarily representative of the catch composition during all commercial operations, because fishers will target an area where larger, male crabs are anticipated. Setting traps at 600 m ensured that the gear was tested in a zone where females and smaller crabs were likely to be abundant. Even when sampling at depths most typically associated with marketable males (i.e. ~800 m), the catch was heavily skewed towards undersized crabs (>71%). Because the fishery tends not to operate during May, it is possible that this effect is less typical during the peak fishing season. However, fishery-dependent sampling during commercial trips in 2002 (pers. obs.; R.A. Wahle, pers. comm.) revealed that catches of non-marketable crabs can be very large, particularly at the start of the season when fishers are prospecting for the crabs.

The mortality rates estimated from the caging (hotel) experiment suggest that discard mortality may be ~5% in deep-sea red crab. No significant differences were found between mortality rates associated with sex or size. Mortality was greatest in crabs that experienced multiple ascents and descents (11.5%), suggesting that if crabs are recaptured multiple times in a short period of time, their susceptibility to mortality is increased. Key influences on discard mortality are thought to be thermal shock (Suuronen, 2005) associated with extreme air and surface water temperatures (Tracy and Byersdorfer, 2000; Warrenchuk and Shirley, 2002), and changes in salinity (Harris and Ulmestrand, 2004). The variations in air and water temperatures are less extreme during May (the sampling period) than during summer and fall (primary fishing months), when air and surface water temperatures are at a maximum, and the water column is most stratified. Because the fishery operates at a time when discarded crabs will experience the greatest difference between *in situ* and surface environments, it is recommended that future work investigates how discard mortality varies over the course of the fishing season.

This study demonstrated that the impact associated with discard methods can result in higher levels of crab damage, particularly for females. Mortality was also ~5× higher for dropped vs. slid crabs, suggesting that the impact associated with discard procedures can cause discard mortality, and this finding is in line with other observations on drop effects during handling (Grant *et al.*, 2002; Grant, 2003). The distance from the discard chute to the water's surface is ~2–3 m for most red crab vessels, and modifications to the chute so that crabs are dropped closer to the water's surface would reduce the potential for discard-associated damage.

Additional factors likely to affect the survival rate of discarded crabs are predation *en route* to the sea floor and displacement from their preferred habitat (Brown and Caputi, 1983). A discarded crab must fall through the water column to return to the sea floor. At a hypothetical fast sinking speed estimate of 0.5 m s^{-1}, and a water depth of 600–800 m, this journey may take 20–26 min. Crabs may be exposed to a variety of predators during this period, although assessment of predation rates throughout the 800 m water column presents a considerable logistical research challenge. Sinking rate is another component of the discard process that is likewise difficult to observe, but that also might prove crucial to the survival of crabs returning to the seafloor. Because *C. quinquedens* is a species that demonstrates strong, sex-specific depth preferences, if sinking rates are slow or currents are strong, discarded crabs may be displaced outside their narrow band of preferred habitat along the continental slope, and thus, survival may be impeded.

In summary, these findings represent the first attempt to quantify discard mortality for *C. quinquedens*, and the accuracy of future stock assessments for *C. quinquedens* might be improved if these estimates of discard mortality were incorporated into the estimates of fishing-related and total mortality. If the estimates calculated are truly representative of this species' resilience to fishing procedures, then discard mortality may be a minor issue for this resource, but further investigations into the effects of season, predation, and displacement are recommended. The fact that discard mortality occurs means that the large proportions of undersized and non-marketable catch observed are far from ideal. Both the industry and the crab resource would benefit from further gear research to improve the selectivity of the traps. Recommended gear research foci for the future include gear design (e.g. entry disincentives for smaller crabs) and soak time studies.

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Design and Test of a Topless Shrimp Trawl to Reduce Pelagic Fish Bycatch in the Gulf of Maine Pink Shrimp Fishery

Pingguo He
Ocean Process Analysis Laboratory of Institute for the Study of Earth,
Oceans and Space and New Hampshire Sea Grant,
University of New Hampshire, 142 Morse Hall, Durham, NH, USA 03824
E-mail: phe@ceunh.unh.edu

David Goethel
F/V "Ellen Diane", 23 Ridgeview Terrace, Hampton, NH, USA 03842

and

Tracey Smith
Ocean Process Analysis Laboratory of Institute for the Study of Earth,
Oceans and Space, University of New Hampshire,
142 Morse Hall, Durham, NH, USA 03824

He, P., D. Goethel, and T. Smith. 2007. Design and test of a topless shrimp trawl to reduce pelagic fish bycatch in the Gulf of Maine pink shrimp fishery. *J. Northw. Atl. Fish. Sci.*, **38**: 13–21. doi:10.2960/J.v38.m591

Abstract

A new innovative topless shrimp trawl was designed and tested in the flume tank, and at sea to evaluate its potential of reducing finfish bycatch in the pink shrimp fishery in the Gulf of Maine. The trawl design removed the square and the top part of the section after the square (first belly section), to become "topless". A five-day sea trial was carried out using the alternating tow method to compare the topless trawl and a commercial (control) trawl. The target species was the pink shrimp (*Pandalus borealis*) and the major bycatch species was Atlantic herring (*Clupea harengus*) that formed 90.6% of all bycatch by weight. Comparative fishing indicated that the topless trawl reduced bycatch of Atlantic herring by an average of 86.6%, and at the same time produced a modest increase of 13.5% in the catch of the pink shrimp. There was some increase in the bycatch of flounders, particularly American plaice and winter flounder, though overall amount of flounder bycatch was less than 3% of the total catch. The reduction of Atlantic herring was most likely due to the fish escaping over the headline where the top panel was removed. The increased bycatch of flounders (and increased catch of shrimp) might have resulted from a wider wingend spread and subtle differences in the footgear between the topless and commercial trawls. The substantial reduction of Atlantic herring, the major bycatch species, without a reduction of the target shrimp species proved the concept of the topless trawl and may have a profound impact on other shrimp trawl fisheries around the world.

Keywords: bycatch reduction, *Clupea harengus,* herring, *Pandalus borealis*, shrimp, trawl

Introduction

Before 1992, large quantities of juvenile groundfish were discarded by small mesh shrimp trawlers in the Gulf of Maine (Howell and Langan, 1992). The use of the Nordmore grid became mandatory in 1992 in the fishery and has reduced finfish bycatch tremendously (Kenny *et al.*, 1992; Clark *et al.*, 2000). However, a Nordmore grid cannot reduce small fish that can pass through the 25 mm (1") spacing between the grid bars (Clark *et al.*, 2000). Small fish such as Atlantic herring, silver hake, juvenile cod, haddock, red hake and flounders are often caught as bycatch in various quantities. In a separate shrimp trawl project carried out during the 2002 and 2003 shrimp seasons, an average of 13 kg of bycatch was caught for every 100 kg of shrimp (He and Littlefield, MS 2006), though the majority of bycatch were less valuable species such as silver hake and red hake. In another project carried out in April 2004, the bycatch of silver hake was as much as 400 kg per hour tow, which was three times more than the shrimp catch (He *et al.*, MS 2005). Thus there is potential for reducing finfish bycatch, which will conserve finfish stocks, as well as reduce sorting time on deck and improve shrimp quality.

Existing *Pandalus* shrimp trawls follow traditional groundfish trawl designs with an overhung panel, called the square or roof, whose purpose is to prevent finfish from escaping over the headline. In shrimp trawls, the opposite is desired, *i.e.* the majority of fish should be allowed to escape before entering the trawl. A trawl without a square, targeting Norway lobster (*Nephrops norveigicus*), was tested in the English Channel and proved successful in reducing the bycatch of haddock, whiting and other finfish species (Arkley and Dunlin, MS 2003; Revill *et al.*, 2006).

Recent findings by Valdemarsen (MS 2005) indicated that shrimp roll along bottom belly netting of a trawl when passing towards the codend. He found that the majority of shrimp were not more than 10 cm from the netting. This finding suggests that most of the top netting of a shrimp trawl may be removed without losing much shrimp. A shrimp trawl without top netting would thus be able to retain the majority of shrimp entering into the mouth of a trawl while releasing finfish species. The new trawl may be called the "topless" shrimp trawl, similar to the topless flounder trawl tested by Pol and his colleagues (Pol *et al*., MS 2003). Fish escapement during the early stages of the fishing process will help reduce stress, injury and associated unaccounted fishing mortality, and contribute to a healthier status of these fish stocks.

Materials and Methods

Gear Design and Flume Tank Tests

The topless trawl has no square and no top netting immediately behind the square. The wings of the trawl are longer than a traditional trawl to increase horizontal spread and to compensate for possible loss of shrimp due to reduced headline height. The lower belly of the trawl rises sharply so that the fishing circle at the middle of the headline is small in order to facilitate easy escape of finfish over the headline. The net plan of the topless trawl is shown in Fig. 1, and a 1:5 scale model built from the net plan and as seen in the Newfoundland flume tank is shown in Fig. 2. The topless trawl has a headline length of 31.91 m and fishing line 24.02 m (Table 1). The groundgear length for the trawl is 27.68 m.

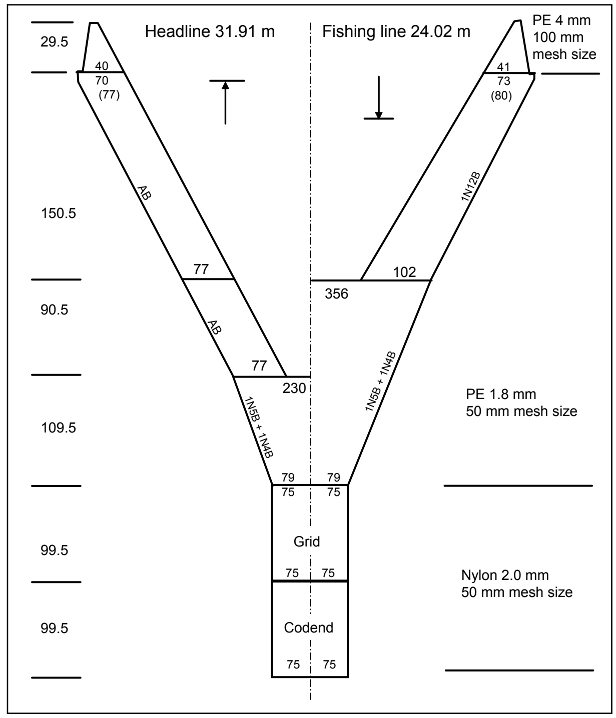

Fig. 1. Net plan of the topless trawl tested in the Gulf of Maine pink shrimp fishery in 2006. The numbers on the left hand side are number of meshes in length for each section. The numbers inside the plan indicate number of mesh in width.

Flume tank tests were carried out at the Center for Sustainable Aquatic Resource of the Memorial University of Newfoundland in St. John's, Canada. The measurements made at the flume tank of the model topless trawl and scaled to full size terms are shown in Table 2. During comparative fishing two additional floats were added at the quarter.

Sea Trials

F/V "Ellen Diane", a 13.7 m (45') inshore shrimp trawler based in Hampton Harbor, New Hampshire, was used for comparative fishing trials. Experimental fishing started in early February 2006 on shrimp fishing grounds off New Hampshire. The tow duration was half an hour and the towing speed was 2.4 knots. Commercial tow durations range from one to four hours depending on catch rates. The choice of shorter tow duration during the experiment was due to the relative high catch rates. Water depth was 70–81 m with a warp length of 229 m during all tows.

A 5-day comparative fishing trial was carried out using the alternating tow method with the experimental

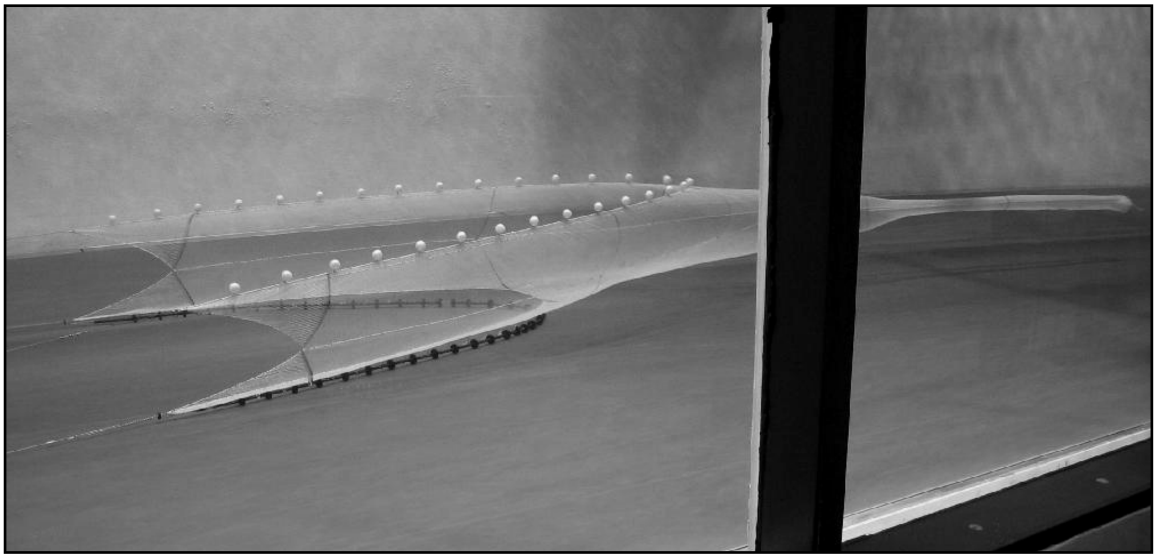

Fig. 2. A 1:5 scale-model of the topless trawl as seen in the flume tank at the Memorial University of Newfoundland in Canada.

TABLE 1. Comparison of geometry of the experimental topless trawl and the control commercial trawl based on measurements made at sea[1] and estimated using tank and at-sea measurements[2].

Parameters	Topless trawl	Commercial trawl
Headline length[1] (m)	31.91	15.88
Fishing line length[1] (m)	24.02	21.22
Door spread[1] (m)	29.74	29.74
Headline height[1] (m)	2.50	2.46
Upper wingend spread[1] (m)	16.62	10.68
Lower wingend spread[2] (m)	14.09	12.28
Mean wingend spread[2] (m)	15.35	11.48
Lower bridle angle[2] (°)	16.7	18.7

topless trawl and a control commercial trawl. We were testing the null hypothesis: there is no difference in catch amount and catch composition between the topless trawl and the commercial trawl. The control net was a commercial shrimp trawl used by the vessel during commercial fishing with headline length of 15.88 m and footgear length of 21.22 m (Fig. 3). Both nets used 8" rockhopper footgear with a drop chain made of 7 links of 5/16" long link chain. The alternating tows followed a CEEC and ECCE sequence, where E denotes the experimental topless trawl and C denotes the control commercial trawl. Four tows per day were completed at similar fishing locations, constituting two pairs of data. During ten pairs of tows, the exact same specifications of the Nordmore grid and the codend were used for both topless and commercial trawls. The difference between the topless trawl and the commercial trawl are in the net itself, not the codend or grid. The Nordmore grid was made of stainless steel, and measured 91 cm (36") long by 74 cm (29") wide. The grid spacing was 25.4 mm (1"), the maximum legal spacing in the fishery. The grid was installed at a 50° angle. The codend was made of 50 mm mesh size nylon material, 99.5 meshes long and 150 meshes on the round.

Headline height and upper wingend spread were monitored by the NetMind acoustic gear monitoring sys-

TABLE 2. Geometry and force measure of the topless trawl from flume tanks tests. Bridle length 27.45 m. All in full scale terms. UW - upper wing, LW - lower wing, WE - wingend, HL 1 - headline opening, HL 2 - headline height (from seabed), Stbd - starboard.

Towing speed (knots)	Horizontal spread (m)			Vertical height (m)			Forces (N)			Bridle angle (°)
	Door	UW	LW	WE	HL 1	HL 2	Port	Stbd	Total	
2.0	26.2	12.9	11.0	2.4	2.4	3.2	0.453	0.476	0.929	14
2.2	26.5	12.9	11.2	2.3	2.2	3.0	0.510	0.538	1.048	14
2.4	27.2	13.3	11.3	2.2	2.1	2.8	0.587	0.624	1.211	15
2.6	27.8	13.3	11.5	2.2	2.0	2.7	0.661	0.688	1.349	15
2.8	28.4	13.5	11.4	2.1	1.9	2.5	0.756	0.791	1.547	16

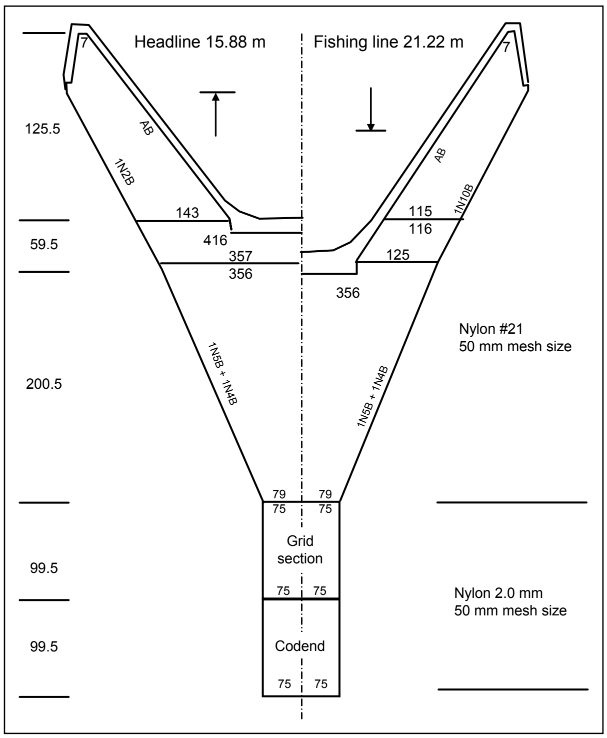

Fig. 3. Net plan of the commercial trawl used as control during the comparative fishing trial in the Gulf of Maine pink shrimp fishery in 2006. The numbers on the left hand side are number of meshes in length for each section. The numbers inside the plan indicate number of mesh in width.

tem (Northstar Technical Inc., St. John's, Newfoundland, Canada). Tow tracks were recorded by the Nobeltec mapping and plotting system to insure that comparative tows were conducted adjacent to one another and over similar bottom conditions.

Data Collection and Analysis

The catch of shrimp and finfish species was sorted and measured after each tow. Bycatch species are listed in Table 3. The shrimp catch was weighed to the nearest kg. Controlled groundfish bycatch species (including cod, haddock, American plaice, winter flounder, witch flounder, and yellowtail flounder), other groundfish (silver hake, red hake, redfish, and butterfish) and pelagic species (mainly Atlantic herring and blueback herring), were individually measured to the nearest centimeter, and the total amount for each species was weighed to the nearest 0.05 kg. Weighed sub-samples of about 1 kg were taken when a large amount of a bycatch species was caught. Other bycatch of 'trash' species were weighed and counted. A 1 kg shrimp sample from each tow was kept for carapace length measurement at the laboratory. Carapace lengths were measured to the nearest mm. A portion of the shrimp sampled was individually weighed to determine the length-weight relationship.

Comparative fishing data were analyzed using paired *t*-tests to determine differences in catch rates of shrimp and bycatch species (kg/tow). Difference in the size distribution of shrimp and bycatch species from the two nets was analyzed using the two-sample Kolmogrov-Smirnov (K-S) test. The bycatch of cod, haddock, yellowtail flounder, witch flounder, red hake and redfish was negligible at the time of sea trials and was not analyzed. Bycatch of Atlantic herring, blueback herring, silver hake, American plaice and winter flounder are reported.

Results

Gear Performance, Handling and Operation

There was no problem in handling the topless trawl with the existing deck machinery onboard F/V "Ellen

TABLE 3. Bycatch species caught during the shrimp trawl experiment.

Atlantic cod	*Gadus morhua*
haddock	*Melanogrammus aeglefinus*
yellowtail flounder	*Limanda ferruginea*
American plaice	*Hippoglossoides platessoides*
witch flounder	*Glyptocephalus cynoglossus*
winter flounder	*Pseudopleuronectes americanus*
Atlantic herring	*Clupea harengus*
blueback herring	*Alosa aestivalis*
silver hake	*Merluccius bilinearis*
red hake	*Urophycis chuss*
redfish	*Sebastes fasciatus*
butterfish	*Peprilus triacanthus*
fourspot flounder	*Paralichthys oblongus*
longhorn scuplin	*Myoxocephalus octodecempinosus*
wrymouth	*Cryptacanthpdes maculatus*

Diane". The power needed to tow the topless trawl was similar to that required for the commercial trawl as indicated by engine revolution per minute (RPM). The average RPM was 1 178 for the topless net and was 1 155 for the control net. The topless trawl came up clean, indicating that it was not digging into the seabed too hard. The topless trawl seemed practical in terms of operation and handling.

For both nets, the door spread was about 29.7 m when fishing at a depth of around 75 m with a bridle length of 27.5 m (Table 1). At this door spread, the upper wingend and lower wingend spread of the new topless net was about 16.62 m and 14.09 m, with its headline height at 2.5 m when towed at 2.4 knots. The upper wingend and lower wingend spread for the commercial net was about 10.68 m and 12.28 m, and headline height was 2.46 m (Table 1).

Shrimp Catch

There was an increase in the shrimp catch using the topless trawl when compared with the commercial trawl. The catch rate ranged from 55–136 kg per half hour tow. The average catch for 10 tows using the topless trawl in the comparative fishing period was 92 kg per tow with a standard error (SE) of 2.14 kg compared with 81 kg per tow (SE = 2.18 kg) for the commercial trawl, giving an average increase of 13.6% in the shrimp catch. The topless trawl outfished the commercial trawl in nine out of ten pairs (Fig. 4). The difference is statistically significant (paired *t*-test, $t = 4.00$, d.f . = 9, $p<0.01$) and the null hypothesis was thus rejected.

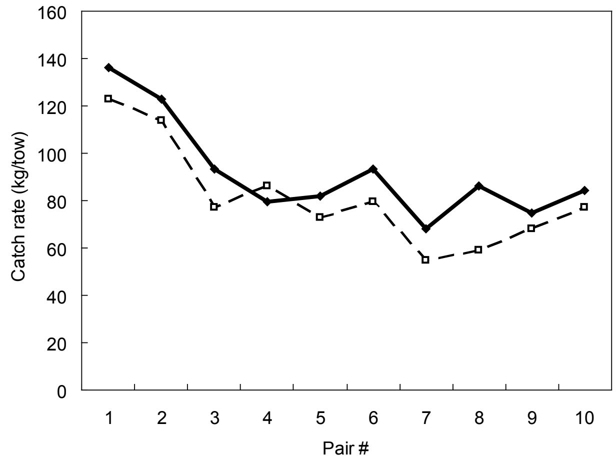

Fig. 4. Catch rates (kg/tow) of pink shrimp caught by the topless (—♦—) and commercial (- -□- -) trawls during the 10 pairs of tows.

Shrimps caught in the topless trawl were slightly larger. On average, the count per kg was 133.6 for the topless trawl and 141.3 for the commercial trawl. Comparisons of length distribution also indicate relatively more large shrimp in the topless trawl. The two-sample Kolmogrov-Smirnov test indicates that the difference is statistically different ($Z = 1.734$, $P = 0.005$).

Finfish Bycatch

The major finfish bycatch species was Atlantic herring. Other bycatch species include blueback herring, silver hake, American plaice, and winter flounder. Very few cod, haddock, witch flounder and yellowtail founder were caught as bycatch during the fishing period.

For the commercial trawl, shrimp accounted for 69.5% of the total catch (shrimp and bycatch combined), while bycatch accounted for 30.5%, with Atlantic herring accounting for 26.3% of the total catch (Fig. 5A). For the topless trawl, shrimp represented 90.6% of the catch while Atlantic herring only accounted for 4.1% of the total catch (Fig. 5B). The topless trawl was much "cleaner" and required less labor to sort the catch.

The amount of Atlantic herring bycatch during the 10 pairs of tows is plotted in Fig. 6. Average Atlantic herring bycatch was 4.1 kg per tow (SE = 0.45 kg) while the control net caught an average of 30.7 kg of Atlantic herring per tow (SE = 1.85 kg). Paired analysis indicated that the experimental topless net caught significantly less

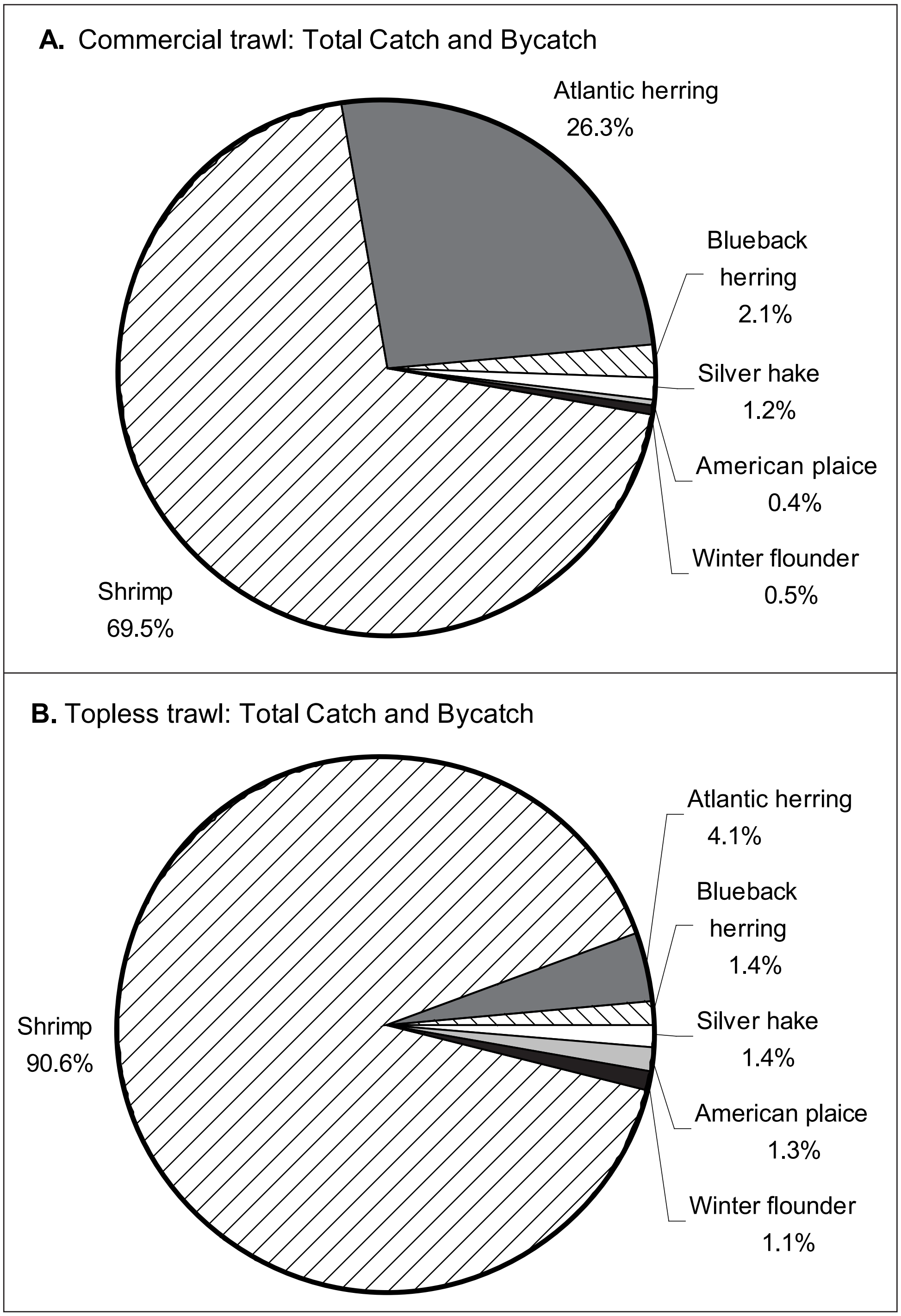

Fig. 5. Total shrimp target species catch and major species of finfish bycatch over 10 tows as percentage of total catch by (**A**) the topless trawl, and by (**B**) the commercial trawl.

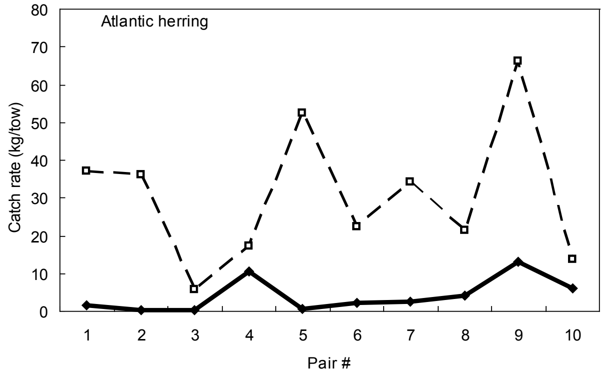

Fig. 6. Bycatch rates (kg/tow) of Atlantic herring caught by the topless (—♦—) and commercial (- -□- -) trawls during the 10 pairs of tows.

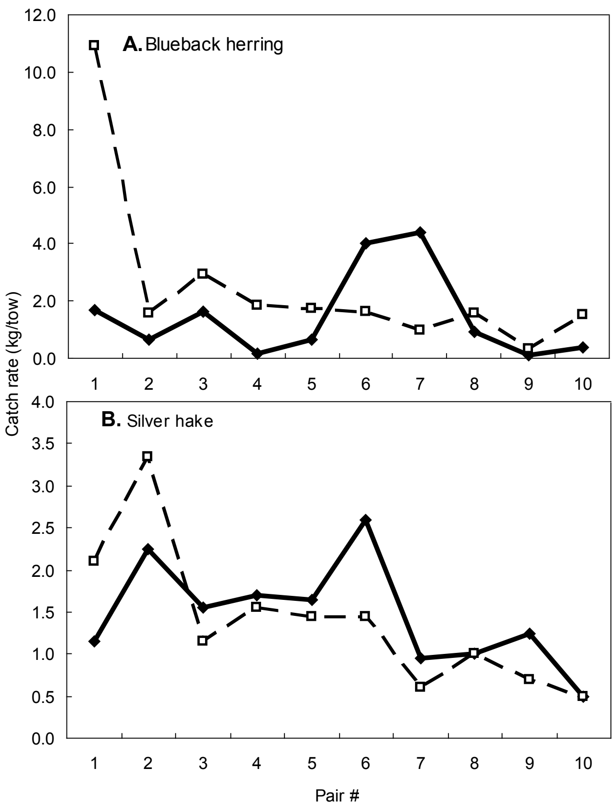

Fig. 7. Bycatch rates (kg/tow) of (**A**) silver hake and (**B**) blueback herring caught by the topless (—♦—) and commercial (- -□- -) trawls during the 10 pairs of tows.

herring than the control gear (t = 2.89, d.f. = 9, P<0.01). The size of Atlantic herring caught was slightly larger in the commercial trawl when analyzed using the two-sample K-S test.

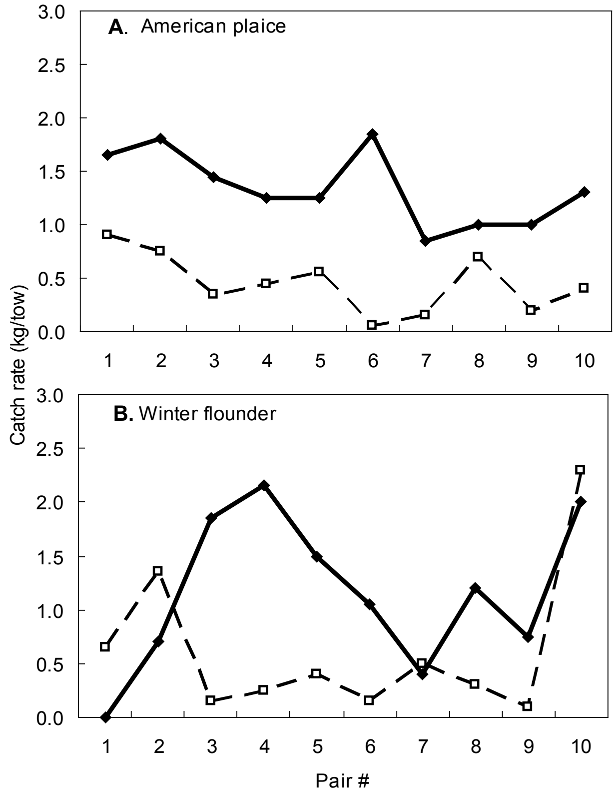

Fig. 8. Bycatch rates (kg/tow) of (**A**) American plaice, and (**B**) winter flounder caught by the topless (—♦—) and commercial (- -□- -) trawls, during the 10 pairs off tows.

There were no statistical differences between the control and experimental gears for both blueback herring and silver hake as seen in Fig. 7 (P>0.05). Though the amount of catch was small for both American plaice and winter flounder, the topless trawl caught statistically more of the two species than the commercial trawl (American plaice: t = 7.26, d.f. = 9, P<0.001; winter flounder: t = 1.86, d.f. = 9, P<0.05) (Fig. 8).

Discussion

The topless trawl performed very well in reducing the amount of bycatch in the Gulf of Maine shrimp fishery. Even though the Nordmore grid was able to exclude the majority of finfish bycatch, small fish and juveniles of large species can still pass through the gap between the bars spaced at 25 mm. In the 10 pairs of comparative tows, the overall bycatch was reduced from 30.5% to 9.4% and with a moderate increase in shrimp catch. The primary species reduced was Atlantic herring. The topless feature of the topless trawl provided the opportunity for Atlantic herring to swim over the headline and escape capture, virtually eliminating Atlantic herring from shrimp catches. Atlantic herring that escape over the headline may suffer less damage and have higher survival than those that pass through the funnel in front of the grid and bounce off the grid bars before escaping the net.

The increase in shrimp catch may be related to the slightly wider mouth in the topless trawl. In the topless trawl, the upper wingend spread was about 18% more than the lower wingend spread; in contrast to most commercial shrimp trawls for which upper wingend spread is usually 15% less than the lower wingend spread (Harold Delouche, Fisheries and Marine Institute, Canada, pers. comm.). Based on measurements of the model at the flume tank and of the full scale net at sea, the mean wingend spread is estimated at 15.35 m for the topless trawl and 11.48 m for the commercial trawl respectively. The mean wingend spread was therefore about 33.5% more in the topless trawl.

There was a slight increase in flounder bycatch in the topless trawl compared to the commercial trawl catches. Though the overall amount of flounder bycatch was small (<3% of total catch), the higher catches were consistent and statistically significant. The increase in flounder bycatch may be partially due to a wider spread of the lower wings, which was about 14.09 m in the topless trawl compared with 12.28 m for the commercial trawl. The smaller angle of the lower bridle in the topless trawl (16.7^{o}) may herd flounders more effectively than the larger bridle angle (18.7^{o}) in the commercial trawl. In addition, while the groundgear of both the commercial and topless trawls have the same specifications there could be small differences that may have affected the catch of small flounders and the differences in size distributions of the shrimps. With successful development of the topless concept for reducing pelagic species, it can be reasoned that existing commercial trawls may be modified to become "topless" without changing the rest of the trawl. In this way, bycatch of pelagic species may be reduced without increasing the amount of flounders caught.

Bycatch of pelagic species in shrimp trawls is quite common. In the Gulf of St. Lawrence shrimp fishery, capelin (*Mollotus villosus)* are caught as bycatch in large quantities (Brothers, MS 2002). There is a potential for use of the topless trawl in this fishery when capelin bycatch is high. Mortality of pelagic species escaping from a trawl codend is quite high (Suuronen *et al*., 1996). Facilitation of an earlier escape from the net, as is possible in the topless trawl, would improve the survival of escapees (Suuronen, 2005).

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