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Sea Changes Ashore: The Ocean and Iceland's Herring Capital

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ABSTRACT. The story of Siglufjörður (Siglufjordur), a north Iceland village that became the "Herring Capital of the World," provides a case study of complex interactions between physical, biological, and social systems. Siglufjörður's natural capital—a good harbor and proximity to prime herring grounds—contributed to its development as a major fishing center during the first half of the 20th century. This herring fishery was initiated by Norwegians, but subsequently expanded by Icelanders to such an extent that the fishery, and Siglufjörður in particular, became engines helping to pull the whole Icelandic economy. During the golden years of this "herring adventure," Siglufjörður opened unprecedented economic and social opportunities. Unfortunately, the fishing boom reflected unsustainably high catch rates. In the years following World War II, overfishing by an international fleet eroded the once-huge herring stock. Then, in the mid-1960s, large-scale physical changes took place in the seas north of Iceland. These physical changes had ecological consequences that led to the loss of the herring's main food supply. Severe environmental stress, combined with heavy fishing pressure, drove the herring stocks toward collapse. Siglufjörður found itself first marginalized, then shut out as the herring progressively vanished. During the decades following the 1968 collapse, this former boomtown has sought alternatives for sustainable development.

Key words: Iceland, fisheries, climate change, human dimensions, Siglufjordur, herring, Great Salinity Anomaly, overfishing

RÉSUMÉ. L'histoire de Siglufjörður (Siglufjordur), un village du nord de l'Islande qui acquit le statut de «Capitale mondiale du hareng», offre une étude de cas des interactions complexes qui ont lieu entre des systèmes physiques, biologiques et sociaux. Le capital naturel de Siglufjörður – un bon port et la proximité de bancs de harengs exceptionnels – a contribué à sa mise en valeur comme grand centre de pêche durant la première moitié du XX^{e} siècle. La pêche au hareng, pratiquée tout d'abord par les Norvégiens, prit un tel essor avec les Islandais qu'elle devint, avec Siglufjörður en particulier, le moteur qui contribua à faire marcher toute l'économie de l'Islande. Durant les années fastes de cette «ère du hareng», il y eut à Siglufjörður des ouvertures économiques et sociales sans précédent. Malheureusement, le boom de la pêche représentait des taux de prises trop élevés pour être durables. Au cours des années qui suivirent la Deuxième Guerre mondiale, la surpêche pratiquée par une flottille internationale fit baisser le stock de harengs jadis abondant. Puis au milieu des années 1960, il se produisit, dans les eaux situées au nord de l'Islande, des changements à grande échelle sur le plan physique. Ces derniers eurent des conséquences écologiques qui aboutirent à la disparition de la source principale de nourriture du hareng. Un stress environnemental très fort, joint à des pressions pour augmenter encore plus les prises, mena les stocks de harengs à l'effondrement. Siglufjörður se trouva tout d'abord marginalisé, puis, à mesure que le hareng disparaissait, carrément exclu. Durant les décennies suivant l'effondrement de 1968, cette ancienne ville champignon a tenté de trouver des solutions de rechange pour se développer de façon durable.

Mots clés: Islande, pêcheries, changement climatique, dimensions humaines, Siglufjordur, hareng, grande anomalie de salinité, surpêche

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INTRODUCTION

Northern high-latitude environments have exhibited substantial change over the past three or four decades. Physical changes include shifts in the hydrography of the Arctic Mediterranean (seas north of the Greenland-Scotland ridge), sea-ice cover, patterns of atmospheric circulation, terrestrial hydrology, and the mass balance of glaciers and ice sheets (for overviews see Morison et al., 2000; Serreze et al., 2000; Vörösmarty et al., 2001). Furthermore, the Arctic Oscillation (AO) and North Atlantic Oscillation (NAO) patterns strengthened; their indexes switched from a prolonged negative state in the 1960s to more cyclical and increasingly positive behavior, reaching historically high levels in the 1990s (Hurrell, 1995). Such physical changes affect both ecosystems and human systems in the

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North. Both these types of systems are complex, however, with their own strong internal dynamics and cross-system feedbacks. We should expect that the impacts of climate change will be complex as well, rarely fitting a simple formula such as "the climate changed, so society did too."

Case studies of physical-biological-social system interactions observed during a recent period of physical changes have much to offer as guides to realistic thinking about the human dimensions of climate change. The physical changes have been well documented, and societies are nowhere more closely tied to environmental variations than in the Arctic. Climate-change effects should be easy to see. This is not necessarily the case, however. Many Arctic societies are changing rapidly and profoundly, for reasons unrelated to climate. Climate effects are just one pressure among many, perhaps far from the most important. Commercial fisheries, which comprise the main economic activity in many northern regions, well illustrate this complexity. Fishery crises have been common in recent decades, and some of the worst crises have coincided with unusual ocean conditions (e.g., Jakobsson, 1992; Vilhjálmsson, 1997; Belkin et al., 1998). In no case, however, does it appear that a fishery crisis resulted solely from environmental conditions. Overfishing alone was sometimes the culprit, but overfishing during times of adverse climatic conditions has been particularly lethal. Fishery events in turn propel social changes on land, inc-luding population shifts in coastal regions (e.g., Hamilton and Otterstad, 1998; Hamilton and Haedrich, 1999; Hamilton and Butler, 2001; Hamilton et al., 2000, 2004a, b).

One recent case study of West Greenland's cod-to-shrimp fishing transition observed that ecological dynamics (predator-prey relationships) and human resource use (overfishing) interacted with climate change to shape its ecological effects. Noting the divergent outcomes in two fishery-dependent towns along this coast, the authors conclude that natural capital (resources and geography), real capital (investments and infrastructure), human capital (education and skills), social capital (social networks and cohesion), and the institutional response all influenced the societal consequences of climate change (Hamilton et al., 2003).

The history of Siglufjörður, a north Iceland village that became the "Herring Capital of the World," well illustrates the complex interactions between physical, biological, and social systems. Siglufjörður's natural capital—a good harbor and proximity to prime herring grounds—contributed to its development not only as a fishing center, but also as an engine for the social and economic transformation of Iceland during the first half of the 20th century. Overfishing in the 1950s and 1960s eroded this resource, and in the late 1960s climate change intervened. The Herring Capital lost its livelihood and survives today in a much different form.

This Iceland case study was conducted under the North Atlantic Arc (NAArc) project, an interdisciplinary analysis of environmental and social change in fishery-dependent regions. Other NAArc case studies examined developments in Greenland (Hamilton et al., 2000, 2003; Rasmussen and Hamilton, 2001), Newfoundland (Haedrich and Hamilton, 2000; Hamilton and Butler, 2001; Hamilton et al., 2004b), Norway (Hamilton and Otterstad, 1998) and the Faroe Islands (Hamilton et al., 2004a). Although their historical, political, socioeconomic, and fishery-system details vary, these cases exhibit broadly similar patterns that can be seen in the Herring Capital's story as well.

Our approach here integrates data from oceanographers, biologists, fishery statistics, and records of population. Further information is drawn from more qualitative written records and from the Herring Era Museum in Siglufjörður. We also conducted interviews (2002–03) with local residents who remember—rather vividly, in most cases—their participation in the herring adventure. Time serves as an integrating dimension that brings these diverse strands together. Our focus on Siglufjörður leads naturally to a focus on the Herring Capital's great resource, Norwegian spring-spawning herring, and to the waters north and east of Iceland where these fish came to feed.

NORWEGIAN SPRING-SPAWNING HERRING

> Iceland in the 19th century was like a fairy-tale princess.
> It was awakened by the kiss of the Norwegian fisherman.
> (Siglufjörður scholar, reflecting on history)

The Atlanto-Scandian herring (*Clupea harengus*) complex, presently the largest in the world, consists of two main stocks known as Icelandic summer-spawning and Norwegian spring-spawning herring. A third historical stock, Icelandic spring-spawning herring, apparently no longer exists. Through the early and middle 20th century, the Norwegian spring-spawning herring, by far the largest of these stocks, followed an annual migration around the northeast Atlantic. Typically, most of the stock spawned in springtime along the coast of Norway and the Faroe Islands. Larvae drifted north into the Barents Sea, while mature fish (and eventually, the younger recruits) made a westward migration to feeding grounds north and east of Iceland (left in Fig. 1). Herring are plankton-feeders particularly attracted to the copepod *Calanus finmarchicus*, which thrives in this region. The herring stock wintered in a smaller area east of Iceland, migrating eastwards again for spring spawning (Vilhjálmsson, 1997).

Norwegian spring-spawning herring had been known and fished for centuries along Norwegian coastal waters. In the mid-19th century, Norwegian fishermen discovered that abundant herring (largely the same stock) could be caught during summer and autumn in waters around north and east Iceland. A Norwegian-dominated fishery was changing life ashore in Iceland by 1880. Norwegians provided herring-salting jobs, rented lots, and built wooden houses (an improvement over the Icelanders' mainly turf dwellings) in eastern Icelandic towns such as Seyðisfjörður. Although the main initiative came from Norway, Icelanders

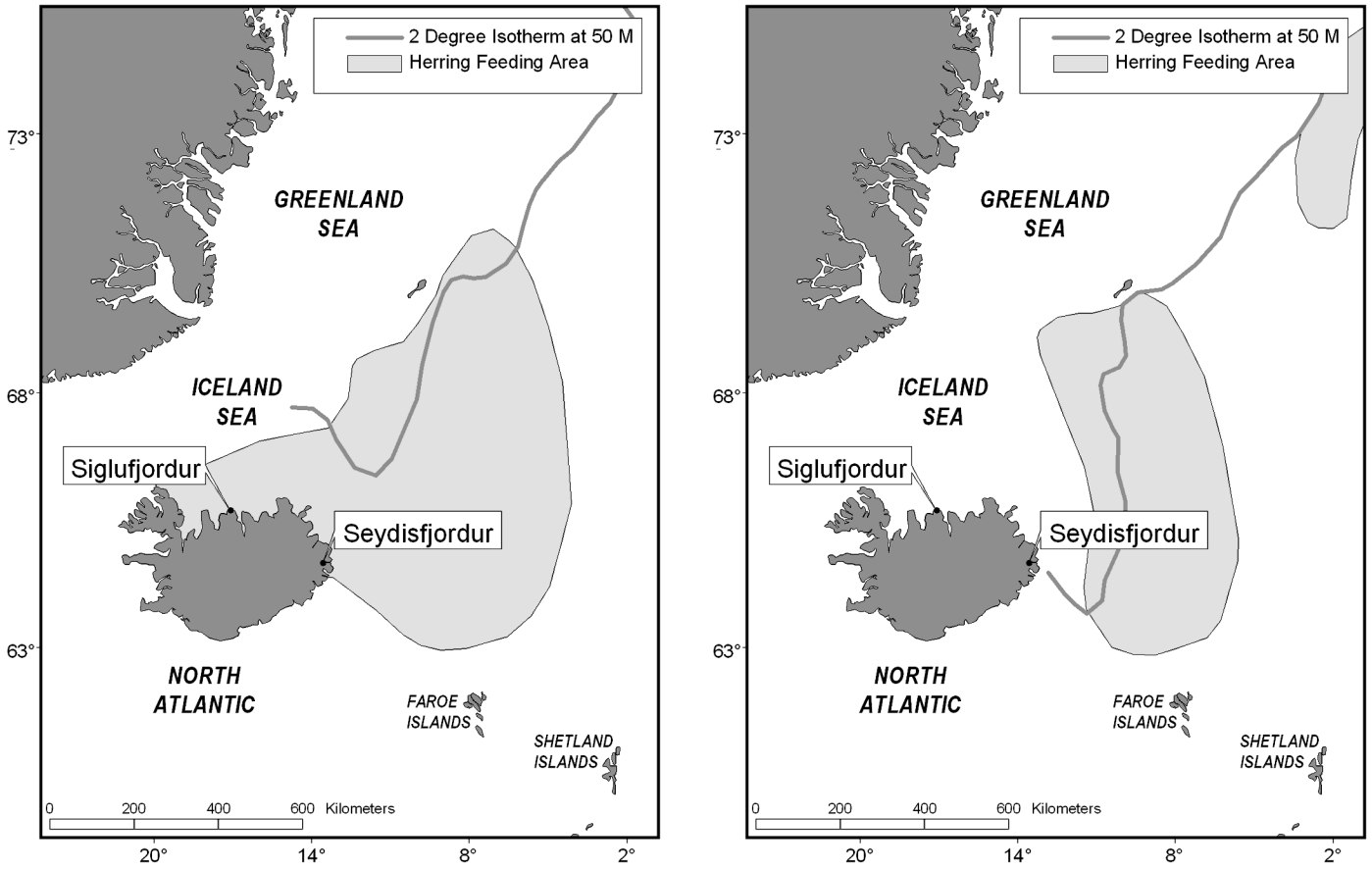

FIG. 1. Iceland and vicinity, showing the "traditional" feeding area of Norwegian spring-spawning herring (left), and their feeding area during the colder conditions of 1965–66 (right). By 1968 this stock was no longer found in Icelandic waters. Two important "herring towns" and the typical location of the 2°C isotherm at 50 m depth are marked as well. Maps by Cliff Brown, after Vilhjálmsson, 1997.

began to learn from and emulate the foreigners, starting a herring fishing company in Siglufjörður on the north coast (1880) and a Norwegian-Icelandic one in nearby Eyjafjörður. Initially, fishing efforts were concentrated within the fjords. This first bloom of the Iceland herring fishery faded in the late 1800s, however, under pressure from a worsening climate and falling prices on European markets (Sigurðsson, 1989).

Herring fishing resumed in earnest during the early part of the 20th century and became a factor in Iceland's remarkable climb from poverty to affluence. Larger vessels explored the offshore feeding grounds and, using the new purse seine technology, brought back unprecedented catches. The international herring fishery in Icelandic waters took between 10 000 and 25 000 tons per year during the first decades of the 20th century (all weights cited are in metric tons). Much of this catch was landed and processed in Iceland. Initially, Icelandic vessels accounted for only a small fraction of the herring catch from Icelandic waters, but after 1915 they became dominant. Seeing a national opportunity, the parliament (*Alþingi*) in 1922 passed a law declaring that only Icelanders could fish in Icelandic waters or process the catch. Total (mainly Icelandic) catches continued their uneven increase, reaching peaks above 200 000 tons several times in the 1930s and 1940s. These good herring seasons contributed to Iceland's achievement of economic and then political independence in the 1940s (Kristfinnsson, 2001). The first independent government (1944), recognizing fisheries as the key to Iceland's economic development, initiated a major phase of investment (1946–49) to build up catching and processing capacity (Durrenberger and Pálsson, 1989; Arnason, 1995).

Strong markets, improving technology, and increasing effort led to growing fishing pressure by Norwegian, Russian, and other fleets throughout the northeast Atlantic. Total catches fluctuated around a general upward trend, exceeding one million tons per year from the Norwegian spring-spawning stock during the 1950s. Two technological innovations—sonar to locate herring schools and power block-assisted purse seines of nylon mesh to catch them—drove a mid-1960s spike that reached almost two million tons (Fig. 2). Icelandic catches alone exceeded half a million tons. Following their government's assertion of jurisdiction over fisheries out to 12 miles in 1958 and a new phase of investment in herring purse seiners during the 1960s, Icelanders caught more herring than they had in the previous six decades (Sigurðsson, 1990; Arnason, 1995).

Catches fell precipitously on the downside of this "killer spike": by the late 1960s, the catch from the stock as a whole was less than 100 000 tons, with almost nothing from Icelandic waters. In retrospect, it became clear that

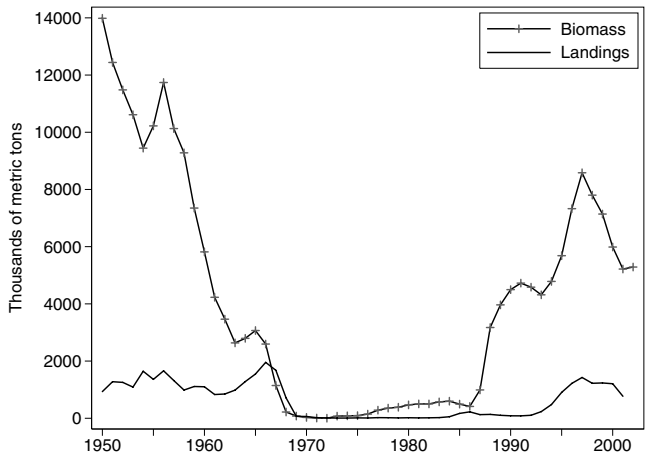

FIG. 2. Total spawning stock biomass and landings of Norwegian spring-spawning herring, 1950–2000. Data source: ICES, 2001, updated.

the fishing pattern of the boom years had been unsustainable. Estimated spawning biomass of this formerly huge stock declined from 14 million tons in 1950 to less than 2000 tons by 1972 (Fig. 2; see Toreson and Østvedt, 2000 for analysis of the biomass and its correlations with environmental conditions). The 1960s spike in catches occurred at a time when stocks had already dropped more than 80%. Rising catches combined with falling stocks produced an abrupt jump in fishing mortality, effectively killing off the resource. Only a coastal remnant of the stock survived around Norway.

From this remnant the stock recovered slowly in Norwegian waters, and remained protected through the mid-1980s. Spring-spawning herring began to reappear in Icelandic waters, at a fraction of their historical abundance, in the 1990s. The boom, collapse, and slow partial recovery have been widely recounted as a cautionary tale about overfishing. Nowhere did the human dimensions of this tale play out more dramatically than in Siglufjörður.

SIGLUFJÖRÐUR IN THE GOLDEN YEARS

> The herring years were special, indescribable, and they will never come again. Even if the fishery came back, it would now be done with cold factories and would not be the same. Why was it so special? Everybody talks about how fun (*gaman*) it was in the golden days. So exciting. Nobody recalls miserable days on docks in pouring rain. It was young people age 17 to 22 going away from home for the first time and having the time of their lives. Hormones were raging. All the girls have blond hair. (Lifetime Siglufjörður resident, looking back)

In 1890, Siglufjörður was a minor village, home to fewer than 100 people. Over the next 60 years it would become an economic center and the fifth-largest town in Iceland, then fade again back toward minor status. The golden years were largely a gift of its natural capital: one of Iceland's best harbors, at the north end of Tröllaskagi (66°10′ N) near prime herring grounds.

In 1903, Norwegians arrived in Siglufjörður to pursue this resource. New methods brought in larger quantities of fish, creating a need for more elaborate processing arrangements. The Norwegians established the first processing factory, for reducing herring to fish meal and oil; the first salting line (*síldarplan*), to produce higher-value fish for human consumption; and the first storage facility for products awaiting export. Icelanders, drawn from Siglufjörður and elsewhere, were hired to work in the new industry. Other herring towns such as Seyðisfjörður took part in this boom, but as more factories and salting-lines were built, and a growing fleet of foreign and Icelandic vessels brought in the catch, Siglufjörður remained the Herring Capital of the World (Fig. 3). Through the early 1950s, Siglufjörður was salting more herring each year than the rest of Iceland combined (Sigurðsson, 1990). In several years the herring exports from Siglufjörður comprised more than 20% of all exports from Iceland (Kristfinnsson, 2001).

The labor-intensive export fishery made substantial cash wages available to many people for the first time. Landowning farmers, Iceland's political elite, had long depended on legal restrictions controlling landless workers and shoreline access to curtail independent fishing and insure their farms' supply of cheap labor. These restrictions broke down as commercial fishing arose in the late 19th century, creating for the first time a labor market (Durrenberger and Pálsson, 1989; Pálsson and Durrenberger, 1996). Farmers now could only denounce the herring towns' "immoral" lifestyles as they watched poor farm laborers depart for the new opportunities. Young Icelandic women, the herring girls (*síldarstúlkur*), ignored warnings of sin and moved to Siglufjörður, taking arduous but well-paying jobs processing and salting the catch. The town's year-round population increased tenfold (from 144 to 1450) over 1903–24, then doubled again by the late 1930s. The seasonal workforce, arriving with the herring from May through October, added several thousand more. Thousands of foreign fishermen, when they came ashore, swelled the population even further.

This largely young, unattached workforce found in Siglufjörður a previously unimagined degree of economic and social freedom. There were opportunities for dancing, music, and entertainment—the town hosted 18 pubs in the 1920s (compared with only two today). There still exists a whole music genre, on recordings and in the older people's memories, of "herring-waltzes" (*síldarvalsar*) from the herring years, many describing the atmosphere in Siglufjörður back then.

The jobs themselves were demanding, driven by the pace of the fishery. When herring was landed, whatever the quantity, it had to be processed at once. Sigurðsson (1989:83; translated by H. Ögmundardóttir) describes the work of a herring girl on the salting line:

FIG. 3. Siglufjörður harbor in July 1946. In the center are long herring docks; at left, smoke rises from the processing factories. At peak times, the harbor might contain 400 boats. Photo by Jónas Hallgrimsson, reproduced courtesy of Magnus Hallgrimsson and the Herring Era Museum.

> She has been standing by the boxes for 14 hours without rest, 19 yesterday, 20 the day before. She has hardly had time for a meal, eaten a few pieces of bread in a hurry, a little black coffee with it. This spell has taken many days. All the storage tanks are full, and rotten heaps of herring are lying around. Some will probably be shoveled into the sea, all spoiled. The meal factories can't keep up with the speed, far from it.

The work was wet, hard, and often cold. Hands immersed all day in fish and salt suffered from cuts, blisters, and infections. Some women got so tired they collapsed. Men working around the herring line brought empty barrels and took full ones away; the women controlled the pace. To attend a dance, which almost everyone did when the opportunity came, people had to stay awake for 24 hours or more.

Although work was hard, it was also rewarding to a degree that few participants—and virtually no women—had previously known. Labor in the herring fishery provided many young people from poor backgrounds with savings they would subsequently invest elsewhere in housing, education, and new businesses: in one generation, they stepped into the middle class. Some people went to school or moved to other parts of Iceland in the winter, as there was limited work in Siglufjörður outside of the May-to-October herring season. Jobs could be found elsewhere in cod-fishing regions, where the fishery (though "boring" and "predictable" in contrast to the excitement of herring) proceeded year-round. Among those who stayed behind in Siglufjörður, recreational activities such as skiing or singing in choirs were popular winter pastimes.

People used to say that Siglufjörður was an ugly town because people were working too hard in the summertime to paint their houses or tend their gardens. The streets were mostly mud. The factories stank: children became nauseated from the odors at the school, which was located right next to a factory. But this "smell of money," however unpleasant, signaled prosperity for the town.

The freshest herring was salted and sold at good prices for human consumption. The refuse and remainder went to the factories for reduction into fish meal and oil. At its peak Siglufjörður boasted 27 salting stations and five fish-meal factories in operation. Figure 4 shows variations in the amount of salted and reduced herring from Siglufjörður over 1933–68. This chart spans the golden years of the 1930s and 1940s, leaner times in the 1950s, and the 1960s decline leading to final collapse in 1968.

In the early years there seemed to be plenty of fish in the sea. During World War II, herring was difficult to sell because the German, Norwegian, and Swedish markets were gone. Fish oil from the factories had military value to the allies, however, so that product was dominant. In 1947, great quantities of herring were caught in Hvalfjörður on the southwest coast, just north of Reykjavík. Since herring was not normally abundant in that fjord, there was no local processing capacity, so the Hvalfjörður herring catch was shipped north to Siglufjörður. It arrived there too old for salting, but instead created the 1947–48 high point in factory activity that stands out in Figure 4. The Hvalfjörður herring was unusual in several respects. Not part of the Norwegian spring-spawning stock, it was all caught in autumn, providing the welcome novelty of winter work in Siglufjörður's factories. Siglufjörður's own herring resources

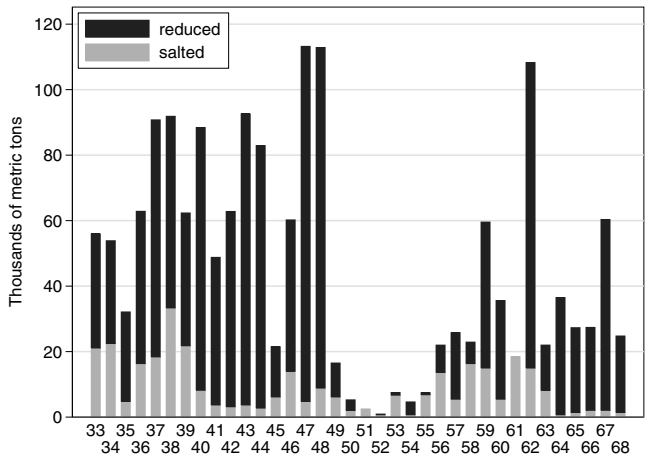

FIG. 4. Tons of herring processed by salting or reduction in Siglufjörður, 1933–68. Salting data estimated from Sigurðsson (1990). Reduction figures for 1951 and 1961 are unknown; those for other years are estimated from various sources.

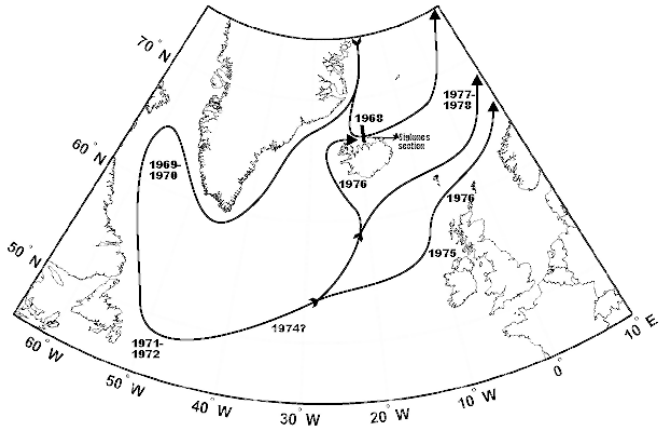

FIG. 5. Propagation of the Great Salinity Anomaly of the 1970s, GSA'70s (simplified after Dickson et al., 1988).

were declining, however. Boats traveled increasingly farther north and east to find fish, eventually towards Jan Mayen and Svalbard. Good years became infrequent after 1953. At the same time, factories became more automated, requiring fewer workers. The golden years in Siglufjörður were ending.

CLIMATE/OCEAN CHANGE

> In the winter of '67–'68 I remember watching the sea ice filling the fjord. I slept in a bed by the window in their bedroom, facing the sea, and every morning I would wake up, look out of the window and ask if the ice had not disappeared yet. No one liked the ice. Many had terrible experience of the ice years earlier in their lives with cold, isolation, and even starvation. The creaky sound of the blocks rubbing together and the icy, stale air that surrounded the seaside still remain a vague childhood memory in my head. (Eastfjords native recalling the last year of the herring adventure)

Overfishing by several nations, not just in Icelandic waters, drove the steady decline of herring biomass after 1950 (Fig. 2). Climate change contributed to its collapse in the 1960s. One aspect of recent high-latitude physical changes has been the formation and propagation of a series of decadal-scale temperature-salinity-ice cover anomalies (called Great Salinity Anomalies, or GSAs) through the North Atlantic and Arctic seas. The first to be documented was GSA'70s (ca. 1968–82), which formed in the mid-1960s in the Greenland and Iceland seas (Fig. 5; see Belkin et al., 1998; Dickson et al., 1988). Its arrival marked the end of the herring adventure.

The freshwater causing the GSA'70s originated from the rivers draining into the Arctic Ocean. When entering the sea, the freshwater mixes with seawater and lowers its salinity. This creates a low-salinity surface layer over the whole Arctic Ocean, with most of the freshwater bound in sea ice floating on the surface. The main export of water from the Arctic Ocean occurs through Fram Strait. The long-term average amount of freshwater advected through Fram Strait (mainly as sea ice) was estimated by Aagaard and Carmack (1989) to be 125 000 m^3/s relative to a salinity of 34.93, which they took as an average salinity for the Greenland, Iceland, and Norwegian seas. The freshwater is then advected with the East Greenland Current along the East Greenland coast over the shelf and slope towards Denmark Strait. Most of it exits directly through the Denmark Strait and continues its journey along the East Greenland coast. Relatively small amounts of the freshwater enter the interior parts of the Greenland and Iceland seas within the Jan Mayen Current and the East Icelandic Current, respectively. Jónsson (1992) showed that most of the freshwater in the Iceland Sea has its origin in the East Greenland Current. The great interannual variability strongly affects climate and environmental conditions in the ocean north and east of Iceland.

In the mid-1960s, northwesterly winds associated with a prolonged negative NAO/AO state drove unusual volumes of polar surface water and ice through Fram Strait into the Greenland and Iceland seas (Dickson et al., 1988; Hurrell, 1995). The result, GSA'70s, was first observed in north Icelandic waters in spring 1965 and culminated there in 1968. It circulated around the subpolar gyre of the northern North Atlantic for more than a decade, being observed off West Greenland (1969–70), near Labrador (1971–72), in the Faroe-Shetland Channel and south of Iceland (1976), in the Norwegian Sea (1977–78), south of Svalbard (1978–79) and finally back in the Greenland and Iceland seas (1981–83; see Belkin et al., 1998 and sources therein). GSA'70s affected environmental conditions in all regions it passed through. Dickson et al. (1988:103) described this as "one of the most persistent and extreme variations in global ocean climate yet observed in this century."

Figure 6 illustrates the pronounced dip in salinity, sea temperature, and air temperature that marked GSA'70s and

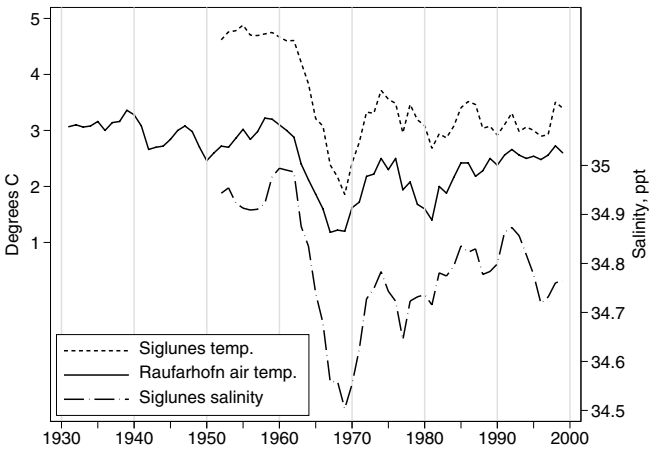

FIG. 6. Five-year running means of annual Raufarhöfn air temperature, and spring temperature and salinity at 0–200 m along the Siglunes section north of Siglufjörður. Only the five southernmost stations on the section (to 67°N) are included. Data sources: Icelandic Meteorological Office, 2002; Marine Research Institute, 2001.

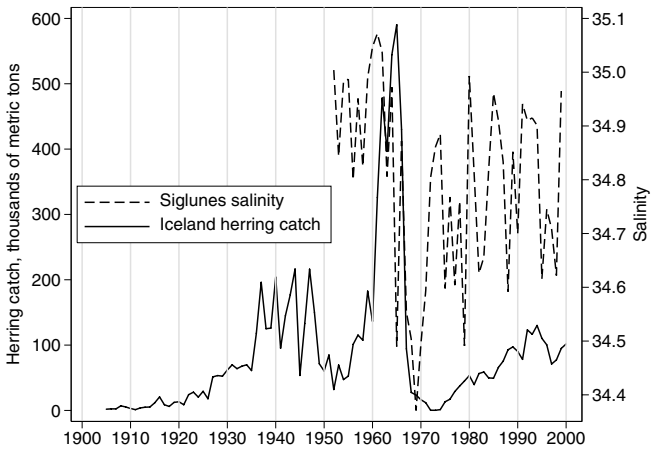

FIG. 7. Herring catch (all stocks) by Icelandic vessels in Va area, and salinity in the spring, at 0–200 m depth along the Siglunes section. Data sources: ICES, 2001; Marine Research Institute, 2001.

the general cooling of north Iceland climate in the second half of the 1960s. The Siglunes section (66°16′ N, 18°50′ W to 68°00′ N, 18°50′ W; see Fig. 5) is a standard oceanographic section north of Siglufjörður, often used to assess climate on the shelf (e.g., Malmberg and Jónsson, 1997). Also shown are annual air temperatures from the northeast Iceland village of Raufarhöfn. Among the available long-term air temperature records, those of Raufarhöfn best reflect climate over the ocean north of Iceland because of the village's exposed coastal location (66°27′ N, 15°56′ W). All three series have been smoothed for this figure.

The air and water temperature records show a similar pattern. From 1920 until 1965, relatively warm conditions prevailed over the northern North Atlantic. In 1965, a sudden change occurred; drift ice and polar water covered the north Icelandic shelf during spring. The following years until 1971 were generally cold, with sea ice and polar water frequently visiting the shores. Warmer conditions subsequently returned, but climate variability also became greater and the average salinity remained below earlier levels. Since 1997 the flow of Atlantic water to the north Icelandic shelf has increased, making salinity levels almost as high as they were prior to 1965 (Jónsson and Briem, 2003). The late-1960s episode of cold air temperatures and cold, low-salinity water, marking the passage of GSA'70s, had ecological and human consequences.

Figure 7 graphs the history of herring catches in Icelandic-waters (ICES Va region) from 1905 to 2000. (These data include Icelandic spring-spawning and summer-spawning herring, but until 1970 are dominated by the Norwegian spring-spawning herring.) The most striking feature of this graph is the great spike in catches during the early 1960s, as new technology (the power block) and intensified effort brought unprecedented catches of 400 000 to 600 000 tons. In the late 1960s this spike ended in collapse, with catches dropping below 20 000 tons. Figure 7 also graphs Siglunes section salinity (annual values, not smoothed as they were in Fig. 6) to show the striking correlation between the arrival of GSA'70s and the collapse of the herring fishery.

The advection of polar water into the area affected the availability of food for the herring (Ástthórsson et al., 1983). Polar water is less saline and therefore more stratified than the Atlantic water usually present over the north Icelandic shelf. Relatively cold fresh surface water inhibited vertical mixing, shortening the spring bloom of phytoplankton in nutrient-poor water (Thórdardóttir, 1977). *Calanus finmarchicus*, the copepod that sustained the herring, depends in turn on phytoplankton production (Ástthórsson and Gíslason, 1995, 1998). Vilhjálmsson (1997:19) observed that "with regard to the Atlantic copepod species *Calanus finmarchicus*...the north Icelandic area in fact became a veritable desert during the latter half of the 1960s."

The herring thus lost their main food source while under intense fishing pressure: removals exceeding half a million tons per year from Icelandic waters alone, and 1.5 million for the Norwegian spring-spawning stock as a whole. The result was a total collapse lasting more than two decades.

THE END OF THE HERRING ERA

> I remember well the years after 1950, the talk—mother and father talked about the families that had moved away. It was sad. Things slowed down. The people who thought they had the best opportunities—had more skills, education, connections, family in other areas—were more likely to leave. (Siglufjörður native)

After growing steeply through the boom years of 1903–39, Siglufjörður's year-round population had leveled off for a decade at around 3000 people (Fig. 8). It reached its maximum (3100) in 1949, following the great herring

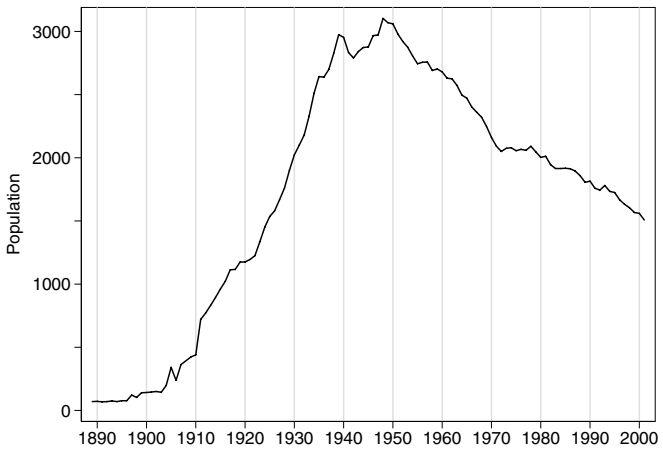

FIG. 8. Winter (non-seasonal) population of Siglufjörður, 1889–2000. Data source: Statistics Iceland, 1997, 2002.

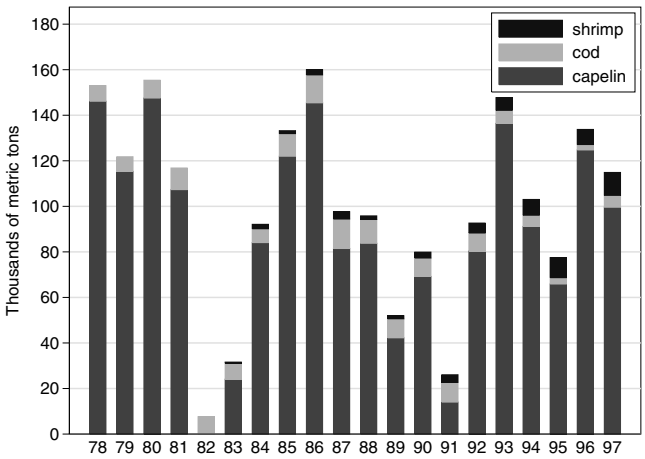

FIG. 9. Tons of capelin, cod and shrimp processed in Siglufjörður 1978–97. Data source: Fiskifélag Íslands, 1998.

catches from Hvalfjörður (Fig. 4). After 1949 there were no more windfalls from Hvalfjörður, and Siglufjörður's own landings dropped off markedly in a series of poor years. The town's population began a long period of decline. Siglufjörður's golden reputation gave way to one of unemployment and insolvency. The secretary of a government ministry reportedly said that the people of Siglufjörður ought to be flogged until they paid their debts (Sigurðsson, 1990).

Catches improved briefly in the early 1960s, but the summer of 1964 was the last herring season on northern Icelandic grounds. When the herring in 1965 and subsequent years met the cold and unproductive polar water within the East Icelandic current, they did not cross it. Figure 1 (right map) depicts the situation in 1965–66, with herring off east Iceland but no longer to the north, and a more remote feeding area (partially visible on the map) past Jan Mayen Island, far to the northeast. In 1967–68 only this far-northeast feeding area remained (Vilhjálmsson, 1997). Siglufjörður residents recall hoping that the herring would come back and hearing optimistic reports from scientists that herring were approaching again, year by year, from the east. But the fishable stock was in fact growing smaller and more distant.

Until 1968, Siglufjörður's factories still imported large quantities of herring for reduction. A transport vessel, *Haförninn* (Sea Eagle), was purchased in 1966 to bring herring back from the distant grounds. There was no longer any fresh local supply for salting, however (Fig. 4). Herring jobs in Siglufjörður faded, although trawlers and a freezing plant for cod, built in the 1950s for economic relief, provided some alternative employment. Residents recall no great social problems or poverty, but the uncertainty was difficult to live with. Many young people left town. There was talk about not wanting to be "the last person to leave."

As Siglufjörður declined in the 1960s, eastern herring towns such as Seyðisfjörður reached unprecedented economic peaks. The eastern herring fishery's buildup and 1968 crash were both much quicker than Siglufjörður's slow-paced experience. Despite the sudden end to the fishery, however, human impacts were generally softer in the east. These towns had historically more diversified fisheries and thus were less dependent on herring. Moreover, the eastern boom in the 1960s came at a time when fishing and processing were more mechanized and required fewer workers than did Siglufjörður in the golden years. The Eastfjords consequently did not repeat either the best or the worst elements of the Herring Capital's story.

The herring collapse was a national shock, with impacts not confined to the herring towns. Unemployment increased around Iceland; net out-migration jumped in 1969–70 to its highest levels since 1887 (Statistics Iceland, 1997). Herring and cod had been the economy's main pillars; the loss of one highlighted the nation's vulnerability to environmental forces.

SUSTAINABLE DEVELOPMENT

For several years after the 1968 collapse, Siglufjörður seemed immobilized, still waiting for the herring to come back. By 1973, steps toward a new and hopefully more sustainable economy were visible. Responding to the dismal situation, the state had provided capital for new trawlers and a factory. Cod, redfish, and haddock were now important catches. The cannery brought in herring from other countries, but capelin had become the major industrial species. Around 1976, a dredge was brought in to deepen the harbor. Destruction of the now-dilapidated herring docks and buildings began—an expensive process, necessary to remove sad reminders of what had been lost, and make room for new activities. Some businesses converted to new tasks, such as the state-owned barrel-making factory that switched in 1972 to making prefabricated houses for use elsewhere in Iceland. The nation's expansion of territorial waters out to 50 miles in 1972,

FIG. 10. Siglufjörður harbor in March 2003, seen from the same vantage point as in Figure 3. The herring docks and international fleet are gone; remaining factories process mainly capelin or shrimp. At center is a shrimp trawler. Photo by Lawrence Hamilton.

leading to the "cod wars" against Britain (1972–73), and its subsequent extension out to 200 miles along with other coastal nations in 1976, increased processing and employment opportunities onshore (Sigurðsson, 1990).

Over 1975–85, new houses were built at both ends of town, giving Siglufjörður its present shape. Through the herring years, housing had been "packed," with multiple families living in each house. Instead of creating vacant houses, population decline allowed the remaining residents to spread out more comfortably.

Today fishing remains the town's main livelihood, although not on its former labor-intensive scale. Figure 9 graphs the amounts processed from three main species over 1978–97. Capelin (*Mallotus villosus*) forms the bulk of the landings. This high-volume, low-value pelagic species goes mainly to the factories for fish meal and oil. Catches fluctuate wildly from year to year, yielding an unpredictable income. Shrimp (*Pandalus borealis*) catches have been steadier, and their higher prices make this species economically more important than the volume might suggest. The rising importance of fisheries for invertebrates such as shrimp has been a familiar theme around the North Atlantic, as fish species such as herring and cod are depleted (e.g., Hamilton and Butler, 2001; Hamilton et al., 2003, 2004b). Cod make a minor contribution to Siglufjörður's economy, unlike their major contributions in other parts of the country.

Siglufjörður's northern location, its great advantage in the herring era, has proven to be a drawback in other respects. It sits isolated at the end of a peninsula, at the end of the road; there was no road at all until 1946, and no winter road until 1969. Even today, in bad weather the drive can be difficult. The nearest villages are small, offering few prospects for trade. The vicinity contains little good farmland. In contrast, the town of Akureyri, two hours away by car, has prospered to become the urban center of north Iceland. Akureyri's advantages—a central location along the main highway, comparatively rich farmlands, and its historically diversified, trade-based (and now increasingly tourism and education/science-based) economy—seem a mirror image of Siglufjörður's disadvantages. Today the hope most often expressed for the economic future in Siglufjörður involves the possibility of state support for a mountain tunnel that would connect the town more directly to Akureyri. Such a tunnel could bring in new trade and activities, but might also reduce the need for some local stores and services.

Many Siglufjörður residents, like those of other northern communities, view tourism as a leading possibility for future development. Visually the town gives no impression

of hardship; it is a colorful and attractive community in a dramatic fjord setting (Fig. 10). Besides striking scenery, the main tourism draw could be its history as the former Herring Capital. The Herring Era Museum (awarded the European Museum Foundation's Micheletti Prize in 2004) has been established in Roaldsbrakki, a waterfront structure built in 1907 to house the herring girls who worked at what was once among the largest salting stations in Iceland. There is certainly a fine story to tell. Without easier links to the main road or the airport and cruise-ship harbor of Akureyri, however, the potential tourist traffic is limited—leading back again to hopes for a tunnel.

CONCLUSIONS

The climatic events of the 1960s affected north Iceland society through interactions among physical, biological, and social systems. Biologically, the physical changes curtailed phytoplankton production, which then reduced the copepods upon which herring feed. These biological changes alone would certainly have reduced herring populations and changed their migration. The estimated biomass of the Norwegian spring-spawning herring stock declined almost 80% between 1950 and 1965, however, reflecting an unsustainable fishery before the impacts of climate change. In the late 1960s these two unfavorable forces, overfishing and polar water, overlapped to cause a total fishery collapse. Moving ashore, the effects of this collapse proved disastrous for the specialized Herring Capital of Siglufjörður, but not so for the nearby, more diversified commercial center of Akureyri. Other herring towns such as Seyðisfjörður experienced the herring collapse differently, depending on their own geography, history, investments, and alternative resources. Thus the physical changes alone did not cause the herring collapse, and the collapse alone did not determine the outcomes for coastal communities.

Some general themes emerge repeatedly from integrated case studies of fishery-dependent regions. We see that living resources fluctuate through interactions between their own dynamics, environmental variations, and the pressures of human exploitation. Resource-dependent communities exhibit characteristic demographic changes, driven by interactions between resource changes and other socioeconomic forces. Resource change creates winners and losers, particularly among places. Individuals and families, with the adaptive choice of migration and new livelihoods, can fare better—as many from and in Siglufjörður did. Which places or people benefit, and which are harmed, by resource change depends not simply on environmental advantages (natural capital), but also on other variables of interest to social scientists, including institutional response, real capital (investments), human capital (education and skills), and social capital (networks and patterns of cooperation). It seems reasonable to suggest that similar generalizations could apply to communities not dependent on a fishing resource, including many other cities and settlements in the North.

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