Synopsis of the Pacific Herring Spawn-on-Kelp Fishery in British Columbia

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V9T 6N7

2018

Canadian Manuscript Report of Fisheries and Aquatic Sciences 3148

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Canadian Manuscript Report of
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SYNOPSIS OF THE PACIFIC HERRING SPAWN-ON-KELP FISHERY IN BRITISH COLUMBIA

by

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Cat. No. Fs 97-4/3148E ISSN 1488-5387

ISBN 978-0-660-24555-3

Correct citation for this publication:

Schweigert, J.F., Cleary, J.S., and Midgley, P. 2018. Synopsis of the Pacific Herring Spawn-on-Kelp Fishery in British Columbia. Can. Manuscr. Rep. Fish. Aquat. Sci. 3148: vi + 33 p.

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The commercial herring spawn-on-kelp fishery (SOK) began in British Columbia in 1975 with 13 participants increasing over the next 25 years to the present 46 licences. The fishery operates in all areas of the coast except the Strait of Georgia where kelp is difficult to obtain. With one exception each licence is permitted to harvest 16,000 pounds of SOK product and is allocated 100 tons of herring if operating an impoundment or 35 tons if they are using open ponding techniques. Operators primarily use closed ponding or impoundments to hold herring for a few to several days until they mature and spawn eggs on the giant kelp (*Macrocystis integrifolia*) suspended in the ponds. In a number of areas operators have been more successful using open pond techniques where kelp suspended from lines is either anchored in areas expected to attract spawning herring or frames are towed into areas of active spawning. Difficulty in estimating the tonnage of fish impounded, any resultant mortality in the ponds, and the long-term impact of disease on the population are ongoing issues in the precautionary management of this fishery as is the impact of the annual removal of large numbers of eggs on population productivity and viability.

RÉSUMÉ

Schweigert, J.F., Cleary, J.S., and Midgley, P. 2018. Sommaire de la pêche aux œufs sur varech du hareng du Pacifique en Colombie-Britannique. Can. Manuscr. Rep. Fish. Aquat. Sci. 3148: 33 p.

La pêche commerciale d'œufs sur varech du hareng a commencé en Colombie-Britannique en 1975 avec 13 participants, nombre qui a augmenté au cours des 25 années suivantes pour atteindre le nombre actuel de 46 permis. La pêche est répartie dans toutes les zones de la côte, à l'exception du détroit de Georgie où le varech est difficile à obtenir. À une exception près, chaque permis autorise à pêcher 16 000 livres d'œufs sur varech et 100 tonnes de hareng pour un bassin de retenue de 35 tonnes et usage de techniques de mise en étang ouvert. Les exploitants utilisent principalement la mise en étang fermée pour retenir les harengs quelques jours, jusqu'à ce qu'ils atteignent la maturité et pondent des œufs sur l'algue géante (*Macrocystis integrifolia*) suspendue dans les étangs. Dans certains endroits, les exploitants ont eu de meilleurs résultats à l'aide des techniques de mise en étang ouvert où le varech, suspendu à des lignes, est soit ancré dans des endroits susceptibles d'attirer le hareng reproducteur, soit disposé sur des cadres et remorqué dans des zones de frai actif. La difficulté d'estimer le tonnage des poissons dans les étangs, la mortalité survenue dans les étangs, et les répercussions à long terme de maladies sur la population sont des enjeux constants dans la gestion prudente de cette pêche, tout comme les répercussions de la récolte annuelle d'œufs sur la viabilité et la productivité de la population.

INTRODUCTION

The harvesting of Pacific herring (*Clupea pallasi*) eggs on evergreen boughs or seaweed has been undertaken by First Nations people for many generations and is an important cultural element of many of the coastal tribes in British Columbia. In Japan, herring eggs spawned or deposited on kelp, primarily *Macrocystis integrifolia* , has also been a traditional delicacy consumed primarily in conjunction with New Years celebrations. The collapse of Japanese herring populations during the 1960s resulted in an interest in developing a commercial herring egg on kelp or so-called spawn-on-kelp (SOK) fishery in British Columbia in the early 1970s. The focus of this report is a description of the history and development of the commercial SOK fishery and its practices and to document the distribution, quotas, effort, and harvests throughout this period to present and to recommend an approach for inclusion of the harvest in the stock assessment process.

HISTORY OF THE FISHERY

The commercial herring fisheries in British Columbia began in 1877 and were initially directed at a limited domestic food market that subsequently expanded to a dry-salted product exported to Asia. In the late 1930s, the fishery expanded rapidly becoming focussed on reduction of the herring for oil and meal until the stocks collapsed in the late 1960s (Hourston and Haegele 1980). As a result of the coincident collapse of Japanese herring fisheries by the 1970s, Canada initiated experimental fisheries for both roe herring and herring spawn-on-kelp for the Japanese market (ARA & AMR 1993). The roe herring (H licence) fishery targeted herring in near spawning condition during March and April, processors removed the roe, brined and salted the product that was then shipped for sale to Japan. While the primary focus of the fishery was on the roe skeins, there was a smaller but important component directed at the harvest of the spawn-on-kelp (J licence) fishery.

In 1955, the Fisheries Act was amended to prohibit the harvest of herring eggs, except by First Nations for personal food use in the Food, Social and Ceremonial fishery but not commercial sale (Harris 2000). The first permit for experimental production of herring SOK within a herring enclosure (pond) was issued in April 1971 in Skidegate Inlet, Haida Gwaii. Due to problems with the operation the permit was cancelled after a small amount of product was obtained (Dickson 1976a). No permits were issued in 1972 as the Fisheries Service, Environment Canada (now Fisheries & Oceans or DFO) conducted two experimental studies in Haida Gwaii "to assess the feasibility of the impoundment technique and the effects upon both herring and kelp" (Dickson 1976a). The first study utilized a modified herring bait pond in Skidegate Inlet with strips of kelp suspended from the floating frame of the enclosed pond (Dickson et al. 1972, Harris 2000). A seine net was used to catch pre-spawning herring and they were towed and transferred to the enclosure where the fish would spawn on the kelp suspended by lines in the enclosure. The 'closed-pond' method became the preferred technique to produce the SOK product. The other study conducted in Cumshewa Inlet, Haida Gwaii consisted of harvest of spawn covered kelp from a natural algal bed just offshore. The so-called 'beach harvest' method was simpler and less capital intensive, however DFO scientists concluded that it damaged kelp beds and produced an inferior product. No permit was issued in 1973 and in 1974 a single permit

was issued to the Skidegate Indian Band and the operation was monitored by fisheries staff who deemed it a success although only a small amount of product was produced. Under Section 21A of the Pacific Fishery Regulations it became possible to obtain a permit to commercially propagate, harvest and sell herring SOK in 1975 and the Fisheries Service decided to expand the SOK fishery on a trial basis issuing 13 permits from a pool of 22 applicants (Dickson 1976a, Harris 2000). Selection considerations were: 1) experience handling and ponding live herring; 2) place of residence; and 3) whether the applicant was aboriginal (First Nations applicants were given preference). An additional 8 licences were added in 1976 and a further 3 in 1977 for a total of 24. In 1978, five more licences went to Native bands – Port Simpson (now Lax Kw'Alaams), Masset (now Old Masset Village Council), Kitasoo, Kitkatla (now Gitxaala), and Bella Bella (now Heiltsuk) for a total of 29 (AMA & ARA 1993). Government policy prevented licence holders from participating in both H and J licence fisheries. Several operators chose participation in the SOK or J licence fishery rather than roe herring but in 1979, one operator relinquished his licence in favour of participation in the roe fishery reducing the SOK fishery to 28 participants. The history of the allocation and distribution of SOK licences among management areas is presented in Table 1. SOK licenses are area-based and are not generally permitted to operate in other areas, however exceptions have been made under extraordinary circumstances. They are not transferrable to other parties.

The fishery was expanded again in 1991, primarily as a result of the large increase in applications due to the five-fold increase in the value of the product since the mid-1970s. In late 1989, the Minister of Fisheries announced 10 new licences were to be issued to First Nations bands going to Ehattesaht, Ahousaht, Gwa'sala'-'nakwaxda'xw, Hartley Bay (now Gitga'at), Kwakiutl, Kyuquot (now Ka:'yu:'k't'h'/Chek'tles7et'h'), Metlakatla, Oweekeno (now Wuikinuxv) and Nuxalk (jointly), Skidegate, and Toquaht. A condition of the licence was that the Band needed to relinquish permanently one roe herring seine licence or six roe herring gillnet licences to prevent additional impact on the resource. DFO estimated that these licences 'used' about the equivalent amounts of herring, i.e. 75 short tons (ARA & AMA 1993). The new licence holders requested that they render inactive the leased herring licences for 1991 rather than acquiring and relinquishing them due to the short time frame and cost. One year leasing was less than 20% of the purchase cost and the practice continued in 1992 and 1993. In 1993, the Heiltsuk First Nation obtained another J licence through negotiation under the Aboriginal Fisheries Strategy (AFS) bringing the total in the fishery to 39 (Harris 2000). In 1995, the AFS program offered these licence eligibility holders $75,000 to assist with licence retirement and the number to be retired was reduced to five gillnet or one seine licence through a reduction in the herring quota allocated to the food and bait fishery. In 1996, the AFS program permanently reallocated one gillnet licence from the allocation transfer program to each Band and reduced the retirement requirement to four gillnet or one seine licence and they were to be permanently retired by 1999. In 1996, the Gladstone decision handed down by the Supreme Court of Canada recognised the right of the Heiltsuk Tribal Council (HTC) to harvest spawn-on-kelp for commercial purposes (Harris 2000). As a result of subsequent negotiations in 1997 and 1998, the HTC received an additional 7 licences (6 open, 1 closed) bringing their total to 9 licences and the coastwide total to 46. In 2001, the HTC negotiated the conversion of their 3 closed pond licences to open ponding and a tripling of the quota from 16,000 pounds to 48,000 pounds bringing their annual allowable harvest to 240,000 lbs of SOK product. Since then, the management of the Heiltsuk SOK fishery is negotiated in conjunction with the overall management plan for the fishery. No additional expansion of the SOK fishery has occurred to the present.

The Pacific herring spawn-on-kelp (SOK) fishery generally occurs between March and June in various locations along the coast of British Columbia, typically in 4 of the 5 major Pacific herring stock assessment areas: Queen Charlotte Islands (now Haida Gwaii); Prince Rupert District or North Coast; Central Coast; and the west coast of Vancouver Island (Figures 1, 2, 3 and 5). SOK operations also occur in some years in Statistical Areas 2W and 27 which are considered minor stocks with routine assessments. The SOK fishery has also occurred intermittently in Statistical Areas 10 (southern Central Coast) and 12 (Johnstone Strait). Although attempted with limited success in the past, the fishery does not currently occur in the Strait of Georgia, primary due to the lack of suitable kelp.

SOK QUOTA AND MONITORING

The quota for production of SOK product was initially set at 6 short tons (5.44 metric tonnes) for 1975 and 1976. It was increased to 10 short tons (9.07 metric tonnes) in 1977 but then reduced to 8 short tons (7.26 metric tonnes) in 1978 to accommodate the additional licences without further impacting the resource (ARA & AMR 1993). In 1986 the quota was also reduced to 6 short tons (5.44 metric tonnes) because of low stock abundance and closure of the entire south coast (Strait of Georgia and west coast Vancouver Island) roe fishery. Subsequently, the quota was increased back to 8 short tons where it has remained through to 2016. From 1991 to 1993 some of the new Band licence holders were unable to inactivate the full complement of 6 gillnet licences and consequently DFO prorated their quota accordingly (e.g. 3 of 6 licences equated to a 4 ton quota).

Prior to 1996, the harvest was monitored by inspections of DFO Fishery Officers at the processing plant. The standard weight of the product was "drained weight" in which the totes used to transfer the spawn-on-kelp would be drained for up to 12 hours prior to weighing at the processing plant (Chalmers and Miller 1985). During processing the product takes up salt and liquid with the result that processed weight is greater than landed weight. As a result, 5% of the weight was deducted as a salt allowance. Numerous problems arose with this measuring system due to the time involved in weighing the totes, transferring the product, and weighing the totes again. This system proved to be cost inefficient to both the fishermen and producers. In 1988 the quota was converted to landed rather than processed weight to reduce the necessary monitoring efforts and to stem the disappearance of product from the processing plant but it effectively increased the product each licensee could harvest by 10 to 15 percent (ARA & AMR 1993).

In 1996, the SOK licencees formed the Spawn-on-kelp Operators Association (SOKOA) and contracted J.O. Thomas and Associates to conduct at-sea and dockside weight validation of all landings coastwide from 1996 to 2000. From 2001 to 2005 J.O. Thomas and Associates conducted at-sea and dockside validation of all landings except for Heiltsuk licences under contract to SOKOA. Validation of the Heiltsuk landings was done by DFO Fishery Officers with support from Resource Managers. Since 2006, J.O. Thomas and Associates conduct a hail program and dockside validation of all landings under agreements with individual licence holders except for the Heiltsuk licences. Validation of the Heiltsuk landings continues to be done by DFO Fishery Officers and Resource Managers.

SOK quota and licences are restricted to the licenced management area, however product can be transferred between operators within the same area. Operators may also consolidate their fishing operations but must notify the monitoring agency prior to beginning fishing (DFO 2016). There is also a "zero quota, zero fee" provision for operators who cannot or do not wish to operate in a given year. Annually, by September 15 each licence holder must submit a 'Catch and Sales Report' specifying the landed weight and processed weight, and the value and price by product grade (ARA & AMR 1993, DFO 2004).

A carryover provision for SOK harvest was introduced in 1996 to limit the harvest of excess product some of which entered the illegal market. It allowed operators to carry over or transfer 1000 pounds of overage or underage of their quota from one year to the next. However, if they exceeded the quota by more than 1000 pounds, product exceeding the overage limit would be forfeited and the entire overage was deducted from the following year's quota. In 1999, the underage provision was changed to 2000 pounds while the overage provision remained at 1000 pounds. Licence holders whose product weight is under the quota by 2000 pounds or less will have the equivalent weight of the underage added to their individual quota the following licence year while those whose product weight is under the quota by more than 2000 pounds will only have 2000 pounds added to their quota and forego the rest (DFO 2016). Any licence holder whose product weight is over their quota by as much as 1000 pounds, may retain the overage while any product landed in excess of that amount may be seized and charges may result. The equivalent weight of any overage will be subtracted from the next licence year's quota.

ALLOCATION OF HERRING FOR SOK

The SOK fishery annually harvests a substantial quantity of herring eggs on kelp and in so doing removes the reproductive products and potential of a portion of the adult herring population. The management of the herring fishery therefore requires that the herring utilized to produce the SOK product must be accounted for and an allocation included in the preparation of the annual fisheries management plan. Since 1987 the allocation of herring to each closed pond licence is 100 short tons (90.72 metric tonnes) and to each open pond licence 35 short tons (31.75 metric tonnes). The allocations of herring to the SOK fishery as part of the combined fisheries quota established for each management area are presented in Table 2.

The allocation of 35 short tons of herring to an open pond licence is based on the estimated total egg removals in 16,000 pounds of SOK product. From a biological perspective the amount of herring required to produce the SOK is variable inter-annually being affected by the age structure and hence female size of the herring population and the degree of ripeness or roe maturity at the time the fish spawn their eggs as well as the number of layers of eggs on the product and the mean size of the eggs. The tons of herring required to produce 8 tons of product can be determined from the calculation (Thomas and Associates 2011):

$$Q = \left[\left(h - (h * k)\right) * \ l\ \right]/m$$

where

Q = quantity of herring required to fulfill a single 8 ton license

h = harvest or quantity of SOK product (16,000 pounds)
k = proportional weight of kelp in the harvest
l = pre-fertilized to fertilized egg weight ratio
m = average proportion roe weight (roe yield) in the population.

The proportion of eggs in 16,000 pounds of product (eggs plus kelp) is about 88 percent (Dickson et al. 1972, Shields et al. 1985) and equates to approximately 14,080 pounds of eggs. An unfertilized herring egg absorbs water after release by the female and weighs about 65 percent of that of a fertilized egg (Shields et al. 1985). Therefore 14,080 pounds of fertilized eggs equates to about 9,152 pounds of unfertilized eggs or approximately 3.075 billion eggs removed from the spawning population. A metric tonne of herring (assuming equal numbers of males and females) produces on average $1x10^8$ eggs so about 30.75 tonnes (33.9 tons) of herring would be required for production of 8 tons of spawn-on-kelp. In practice, Shields et al. (1985) report that 31.6 tons (28.6 tonnes) of herring (14.8% roe yield) were required to produce 8 tons of processed product or 38.6 tons (35.0 tonnes) if eggs from the trimmed portion of the product were included. With a more typical 12% roe yield Shields et al. (1985) estimated that 35.2 tons of herring would be required to fulfill one 16,000 pound licence. The current 35 tons of herring allocated to each open pond licence is consistent with the available information on resource utilization.

The allocation of 100 tons of herring to each closed pond licence is based on the combination of egg removals from the reproductive potential of the population (35 tonnes) and the average mortality (65 tonnes) estimated in producing the 16,000 pounds of SOK product. However, determining the mortality associated with a typical SOK operation has been difficult. In order to investigate the existence of dead herring underneath or in the bottom of a closed pond, SCUBA divers attempt to make measurements of the quantity of herring carcasses. Often there will be concerns from the operators regarding fish disturbance which results in a delay of the measurements until after the product has been harvested and herring are released and the web has been dropped to the seafloor or the pond has been moved. As a result, the dead and decaying herring at the bottom of the pond become difficult to measure and estimating the volume of an irregularly shaped mass of carcasses is inexact. Shields and Kingston (1982) estimated that a cubic meter of dead herring equates to about 0.6 tons (0.54 tonnes) of fish but this also is uncertain depending on the degree of decomposition. Initial estimates of herring mortality in impoundments were determined by Shields et al. (1985) and are presented in Table 3. Following the expansion of the SOK fishery in 1991 there were concerns by managers that inexperienced operators were causing excess mortality in some of the new SOK operations (e.g. 1992 RMS QCI) and as a result DFO conducted diver observations on many impoundments between 1993 and 1997. The results of these investigations are presented in Table 3 and indicate that there is significant variation in mortality estimates between areas and years. The tonnages estimated here should be considered relative only because of the difficulty in measuring the mounds of carcasses accurately, the degree of decomposition, and uncertainty in the conversion factor.

Mortality rates appear to depend on the behaviour of the herring stocks and the industry operating practices (AMA and ARA 1993). The mortality in the ponds is typically a function of 1) stress and descaling of fish during towing and transport to the pond; 2) length of time the fish are held in the pond; 3) loading density or crowding of fish in the pond, and 4) disease. Shields et al. (1985) estimated an average mortality rate of 31% for 12 operators utilizing 18 ponds in Haida Gwaii and

the North Coast regions in 1982. Estimates of mortality are also inexact because it is not possible to quantify the tonnage of herring that are placed in each pond since it is a visual estimate or expert opinion provided by the operator who has loaded the fish into the pond. In addition, operators often require more than one pond to produce their quota and so may load more than 100 tons into one or more ponds, e.g. Shields et al. (1985) report that the 12 operators loaded approximately 1762 tons of herring into 18 ponds utilizing an average of 1.5 ponds and 147 tons of herring per licence to obtain their quotas. Similarly, AMA & ARA (1993) report that the operators used between 80 and 300 tons to produce their SOK quota with an average of 157 tons per licence. More recent data collected through the monitoring program are presented in Table 4 and indicate a trend towards a reduction in both the number of ponds utilized and the tonnage of herring impounded consistent with the present allocation. For comparison, Alaska assumes a herring utilization of 20 tons in each herring pound which are one-fifth the volume of the impoundments used in British Columbia so the allocations are equivalent although they assume a higher mortality rate with only 25% survival of fish in the pounds (Carlile et al. 1996, K. Hebert, Alaska Department of Fish and Game, pers. comm.). Given the uncertainty around the actual quantities of herring utilized annually in each SOK operation and the inter-annual variability in mortality associated with impoundment the current allocation of 100 tons per closed pond licence is appropriate until further studies are undertaken to clarify the herring usage in the fishery.

IMPOUNDMENT AND DISEASE

The early research on the factors determining the success and viability of the herring impoundment or SOK fishery in British Columbia indicated that density or crowding of fish in the ponds was the main contributor to mortality (Brett and Solmie 1982, Kreiberg et al. 1982, 1984a,b). They concluded that density should be maintained at less than 8 kg/m^3 and mortality rates were higher in towed seines than in barge transport. Subsequent research conducted in response to the dramatic decline and lack of recovery of the Prince William Sound herring population in Alaska following the Exxon Valdez Oil Spill of 1989 began to focus on disease as the proximal factor in the mortality of herring. Viral hemorrhagic septicemia virus (VHSV) and *Icthyophonus hoferi* were identified as the principal diseases in Pacific herring associated with impoundments that may lead to mortality (Marty et al 1998, 2010, Elston and Meyers 2009, Pearson et al. 2012). Hershberger et al. (1999) were the first to demonstrate that the youngest age classes of herring held in SOK impoundments were the most susceptible to VHSV infection, acquiring the virus within a few days of being placed in a pond and experiencing significant mortality. Subsequently, they demonstrated the rapid shedding of virus by infected individuals resulting in high levels of virus within the impoundment (Hershberger et al. 2010a), the long-term persistence of VHSV infection in a population whereby individuals that survive an infection continue to harbour the virus for months following exposure and apparently continue to shed virus (Hershberger et al. 2010b). It was subsequently also demonstrated that cooler temperatures such as would be experienced during spawning increased susceptibility to VHSV infection and resultant mortality (Herberger et al. 2013). Finally, Meyers and Winton (1995) and Hershberger et al. (1999, 2015) found that VHSV is endemic to Pacific herring and the stress of impoundment in SOK fisheries is sufficient to precipitate an outbreak of the disease resulting in subsequent mortality. However, at this time the extent and severity of disease outbreaks cannot be predicted nor is it possible to infer the impact of potentially diseased herring that are released from SOK ponds on the wild populations that are rejoined by infected individuals.

HERRING USE AND SOK LANDINGS

The annual allocation of herring to the SOK fishery in each area based on the distribution of licences and available quota is presented in Table 2. The allocations are documented in the Integrated Fishery Management Plans since 1994 and prior to that in the Record of Management Strategy reports back to the mid-1980s. For earlier years, we have inferred allocations from the number of licences operating in each area as there is no documentation of these allocations for prior fisheries. To obtain a clearer understanding of the amount of herring used by the fishery in each area we also estimated the number of closed ponds used in each area every year (Tables 5 to 9). We tabulated the number of ponds reported in the Record of Management Strategy and more recently the Operations Reports by J.O. Thomas and Associates. However, we found that the number of ponds was not an accurate proxy for the quantity of herring used in the fishery because many operators set up several closed ponds often in different locations and it was not possible to assess how much herring was placed in each pond. Many operators used multiple smaller sets to fill their ponds, others used a single large set but in all cases the quantity of herring placed in the pond was a visual estimate by the vessel captain conducting the fishing. In addition, many operators used a combination of open and closed ponding to achieve their quota. Typically, in a closed pond operation, herring are seined nearby, towed to the pond, transferred into the pond, and after one or more days, kelp (usually *Macrocystis integrifolia*) suspended from lines is introduced into the pond for one to several days or until herring spawn eggs on it or the kelp degrades. In some instances, the herring in a pond attract other herring and spawning may commence outside of the pond causing the operator to open part of the pond to allow spawning herring to enter the enclosure. In other instances, the herring may be released from the pond and the kelp towed into an area of active spawning if nearby. In an open pond operation, kelp is suspended from a floating frame tethered along the shoreline in or near the preferred spawning locations: sheltered bays and estuaries, where herring are expected to spawn. Once spawning begins, the frames are often towed into the midst of the spawning activity.

The preferred substrate for the SOK fishery is *Macrocystis integrifolia* kelp likely because the herring eggs adhere more strongly than to *Laminaria saccharina* which has been used to a limited extent. Recently, some First Nations have expressed interest in using *Egregia menziesii* or boa kelp that is a traditional substrate along with hemlock (*Tsuga heterophylla)* boughs. The Province of British Columbia requires a licence to harvest aquatic plants and collection must be done by hand. A recent preliminary study found that the proportion of kelp by weight on *Egregia menziesii* is about twice that on *Macrocystis sp.* (Thomas and Associates 2011) suggesting that the egg removals on a similar quantity of boa kelp would be much less than on *Macrocystis sp.* At this time, no estimates have been made of the number of eggs in spawn on bough harvest that occurs through the Native food fishery.

The total landings of herring spawn-on-kelp product over the course of the commercial fishery since 1975 were tabulated from a number of sources and are presented and referenced in Table 10.

HERRING SOK REMOVALS IN STOCK ASSESSMENT

Stock assessment models assume that all removals from the population are known and accounted for in reconstructing abundance and forecasting future productivity. The herring SOK fishery is an anomaly since no fish are removed from the population although there is some difficult to quantify ancillary mortality. In addition, the removal of eggs has an impact on future productivity but accounting for this loss in stock assessment modelling is complicated.

Historically, herring removals associated with the SOK fishery have been either ignored or more recently included in different formulations. Schweigert et al. (1998) report that allocations of 100 tons (91 tonnes) of catch were included in the stock assessment beginning in 1990 for the 39 SOK licences but prior to that there was no consideration of SOK removals in the assessment. Schweigert (2004) notes that 100 tons of herring was allocated to the closed pond licences and 35 tons to the open pond licences as seine fishery catch in these assessments. Beginning with the 2006 assessment, no catch was allocated to the SOK fishery (Schweigert and Haist 2007). Instead, "the validated landed weight of SOK product was used to estimate the egg removal from the spawning grounds and these data were converted to tonnes of fish equivalents based on data provided in Shields et al. (1985). These estimates of tonnes of foregone spawning biomass were then added to the estimated spawning biomass for each area over the course of the SOK fishery from 1975 to present." In other words, the SOK egg removals were assumed to represent fish equivalents that would have spawned and so were treated as spawning biomass as though they were observed in the annual spawn assessment survey. This approach continued until the 2011 assessment in which the Integrated Statistical Catch Age Model (ISCAM) was first implemented (Martell et al. 2011). Unfortunately, the ISCAM model did not include any formulations for considering the SOK removals either as catch or as spawning biomass and so these data have been excluded from subsequent stock assessments.

It is apparent that SOK fishery removals of herring eggs should be included in future stock assessments to provide unbiased estimates of population status and productivity. Although there is substantial variation in herring recruitment from year to year due to environmental variability, annually removing a portion of the total population egg production must negatively impact long-term population productivity. However, the best approach for assessing the impact of these removals on conservation and population viability is unclear. Shelton et al. (2014) conducted a series of simulations of the Haida Gwaii herring population to investigate the trade-off between traditional removal fisheries and a SOK-like fishery on existing fishery management reference points. The approach they utilized was to approximate the catch or harvest of herring eggs by an egg fishery and to deduct them from the estimated total pre-fishery population egg production given known maturity at age and fecundity by weight thereby incorporating the removals into the stock recruitment function so that egg removals would impact estimated future recruitment to the population assuming a Beverton-Holt stock-recruitment formulation. Such an approach would be appropriate for a strictly wild fishery in which no herring are impounded because the Shelton et al. (2014) model does not account for any mortality of adult herring in the impoundment and holding process. However, given the difficulty and expense of conducting an annual assessment of the herring mortality in each herring impoundment in all the SOK operations in British Columbia it may be impossible to determine the true adult herring removals or mortality associated with this fishery. Instead, we recommend that 65 tons of the 100 tons allocated to each

closed pond licence and assumed as mortality be treated as seine fishery removals. In addition, we suggest that the total validated egg removals by the SOK fishery should be added to the estimate of the spawn index in the assessment model thereby accounting for the foregone egg production. Taken together the inclusion of catch and egg removal will directly affect the calculation of fishing and natural mortality rates in the assessment model and indirectly the determination of spawning biomass and recruitment analogous to the Shelton et al. (2014) approach. Incorporating both removals in this fashion will account for any longer term impacts of this fishery on the productivity of British Columbia herring populations.

ACKNOWLEDGMENTS

We are grateful to Francis Dickson for documenting the initial development of the commercial SOK fishery. The Record of Management Strategy (RMS) narratives of the herring fisheries provides the only record of the SOK operations prior to the initiation of the on-grounds monitoring program and the efforts of the Fishery Resource Managers throughout the coast to produce these reports annually is gratefully acknowledged. The efforts of the many Fishery Officers who annually validated SOK landings throughout the coast are also acknowledged. Charles Fort, Dennis Chalmers, and Stefan Beckmann dove on many SOK ponds and observed, measured and documented many of the mortality events. We thank John Davidson of the DFO Data Unit for providing landing slip data (1985-1995). We are grateful to Doug Tallman of J.O. Thomas and Associates for providing access to their landings and monitoring data and to the many monitors who collected the product landing data and provided narratives on the operation of the fishery since 1996. Finally, we thank R. Kanno, S. Groves, P. Katinic, C. Martens, K. Wong, B. Rusch, B. Spence, and M. Thompson of DFO for providing access to RMS reports and other historical records and comments on an earlier draft of this report.
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Table 1. Number and distribution of herring spawn-on-kelp licences by Statistical Area from 1975 to 2016. In some years, areas were closed or a reduced number of licences operated. See Table 2 for the available quota by year and area.

	No. of Permits	Haida Gwaii[a]		Prince Rupert District		Central Coast				John-stone Strait	St. of Georgia	W. Coast Vancouver Is.			Source
Year		2W	2E	3/4	5	6/7	7	8	10	12	13-18	23/24	25	27	
1975	13		2	1	2			2		1	3	2			Dickson 1976a
1976[b]	21	1	6	5	1	1				1	4	2			Dickson 1976b
1977[c]	24		11	4	2	1					6				Dickson 1976c
1978	29		11	4	5	1	1				7				Dickson 1978
1979	28		11	4	6		1			1	5				Macgillivary 1984
1980	28		11	6	4		1		1	1	4				Macgillivary 1984
1981	28	1	10	4	4	1	1		1	1	4	1			Macgillivary 1984
1982	28		11	4	5	1	1		1		5				Macgillivary 1984
1983	28		3(8)[d]	4	3(2)	1	(1)		1	1	3			1	Macgillivary 1984
1984	28		6(5)	8		4					3			2	Chalmers and Haase 1985
1985	28		6(5)	8		3			2		1			(3)	Chalmers 1986; 1985Plan
1986[e]	28[f]		6(5)	5	3	2	(1)		2		1			(3)	Chalmers 1988; 1986Plan
1987[g]	28		6(5)	8		2	(1)		2					(4)	Chalmers 1989a
1988	28		6(5)	5	3	2	1		2					1(3)[h]	Chalmers 1989b
1989	28		10(1)	5	3	2	1		2					1(3)[h]	Chalmers 1990
1990	28		11	5	3	2	1		2					4	Chalmers 1991a
1991	37		12	5	4	4	1		3	2		2[i]	1	2(2)	Chalmers1991b
1992	38		12	5	4	3	1	(1)	3	1		2	2	1(3)	Chalmers 1993;1992Plan
1993	39		12	6	3	2	3-2	1	1(2)	1		2	2	1(3)	1993 RMS
1994	39		12	7	3	1	3-2	1	1(2)	1		1(1)	2	(4)	1994 Mgmt Plan
1995	39		0	7	6	4	3		1(2)	1		4	6	(5)	1995 Mgmt Plan
1996	39		0	9	3	5	4	1	1(2)	2		4	4	(4)	1996 Mgmt Plan
1997	43		3[j]	8	3	4	3(4)	2	1(2)	2		4	4	(3)	1997 Mgmt Plan
1998	46		8	8	3	3	3(7)	2	1(2)	2		2	2	(3)	1998 Mgmt Plan
1999	46		9	8	3	2	3(7)	2	1(2)	1		2	3	(3)	1999 Mgmt Plan
2000	46		10	8	3	3	(9)	2	1(2)	1		2	2	(3)	2000 Mgmt Plan
2001	46		10	8	3	3	(9)	2	1(2)	1		2	2	(3)	2001 Mgmt Plan
2002	46		10	7	3	4	(9)	2	1(2)	1		2	4	(1)	2002 Mgmt Plan

	No. of Permits	Haida Gwaii[a]		Prince Rupert District		Central Coast				John-stone Strait	St. of Georgia	W. Coast Vancouver Is.			Source
Year		2W	2E	3/4	5	6/7	7	8	10	12	13-18	23/24	25	27	
2003	46		10	7	3	4	(9)	2	1(2)	1		2	3	(2)	2003 Mgmt Plan
2004	46		10	7	3	4	(9)	2	1(2)	1		2	2	(3)	2004 Mgmt Plan
2005	46	4[k]	6[k]	7	3	4	(9)	2	1(2)	1		2	2	(3)	2005 Mgmt Plan
2006	46[m]		10[l]	7-5	3-0	3	(9)	3-2	(2)1-0	1-0		4[n]		(3)	2006 Mgmt Plan
2007	46[m]	4[k]	6[k]	7	3-1	3	(9)	3-2	1(2)	1		4[n]		(3)	2007 Mgmt Plan
2008	46	2.7[k]	7.3[k]	7	3	3[n]	(9)[n]	3[n]	1(2)	1		4[n]		(3)	2008 Mgmt Plan
2009	46[m]	2[k]	8[k]	7	3	3[n]	(9)[n]	3[n]	1(2)	1		4[n]		(3)	2009 Mgmt Plan
2010	46[m]	4.5[k]	5.5[k]	7-6	3-1	3[n]	(9)[n]	3[n]	1(2)[n]	1		4[n]		(3)-2	2010 Mgmt Plan
2011	46[m]	0	10-0[k]	7-5	3	3[n]	(9)[n]	3[n]	1(2)[n]	1		4[n]		(3)-2	2011 Mgmt Plan
2012	46[m]	2[k]	8[k]	7	3-1	3[n]	(9)[n]	3[n]	1(2)[n]	1		4-0		(3)-2	2012 Mgmt Plan
2013	46[m]	2[k]	8[k]	7-3	3-2	3[n]	(9)[n]	3[n]	1(2)[n]	1		4[n]		(3)-2	2013 Mgmt Plan
2014	46[m]	2	8-0	7-4	3	3	(9)	3	1(2)[n]	1		4-0		(3)-1	2014 Mgmt Plan
2015	46[m]		10-0	7-5	3-2	3	(9)	3	1(2)[n]	1-0		4-0		(3)-0	2015 Mgmt Plan
2016	46		10[n]	7-0	3-2	3	(9)	3-2	1-0(2)-1	1		4[n]		(3)-0	2016 Mgmt Plan

[a] Reported as Queen Charlotte Islands prior to 2011.
[b] Quota was 6 tons per licence
[c] Quota was 10 tons per licence
[d] Number in parentheses indicates number of open pond operations.
[e] Quota reduced to 12,000 pounds due to low stock levels.
[f] Allocations reported as 75 tons to closed ponds and 30 tons to open pond operations.
[g] Allocations reported as 100 tons to closed ponds and 35 tons to open pond operations as at present.
[h] Assume 3 open pond operations as 4 licences were allocated 200 tons (i.e. 100 + 3*35 = 205).
[i] One of the new WCVI licences didn't operate in 1991.
[j] Due to low stock levels only 3 licences operated in Haida Gwaii, the other 9 relocated to other areas.
[k] Due to low stock levels in Area 2E no fishery occurred, but some licences were permitted in Area 2W.
[l] Due to low stock levels no fishery occurred in Area 2E, but 1 licence was permitted in Area 2W but none operated.
[m] Due to market conditions, some license holders chose a zero quota option and didn't operate. The number before the hyphen indicates the number of licences permitted in an area, the number after the hyphen is the number that actually harvested product in the area.
[n] Due to low stock levels in the area no fishery occurred.

Table 2. Quota allocations (tons) to the spawn-on-kelp fishery by stock assessment region and Statistical Area from 1975 to 2016.

	Haida Gwaii		Prince Rupert		Central Coast				Strait of Georgia		WC Vancouver Island			
Year	2W[a]	2E	3/4	5	6	7	7/8	10[a]	12[a]	13-18	23/24	25	27[a,b]	Total
1975[c]		150	75	150		150			75	225	150			975
1976[c]	75	450	375	75	75				75	300	150			1575
1977[c]		825	300	150	75					450				1800
1978[c]		825	300	375	75	75				525				2175
1979[c]		825	300	450		75			75	375				2100
1980[c]		825	450	300		75		75	75	300				2100
1981[c]	75	750	300	300	75	75		75		375				2025
1982[c]		825	300	300	75	75		75		375				2025
1983[c]		465	300	285	75	30		75	75	225	75			1605
1984[c]		600	600		300					225		60		1785
1985[c]		600	600		225			150		75		90		1740
1986[c]		600	375	225	150	75		150		75		90		1740
1987		775	800		235			200				140		2150
1988		775	800		300			200				200		2275
1989		1035	800		300			200				200		2535
1990		1100	800		300			200					400	2600
1991		1200	900		500			300	200		200	100	400	3800
1992		1200	900		500			300	100		200	100	500	3800
1993		1200	900		500			300	100		300		500	3700
1994		1200	900		600			300	100		300		500	3900
1995		0	1400		900			300	100		500		375	3575
1996		0	900	300	500	400	100	300	100		400	400	240	3640
1997		200	800	300	500	300	100	300	200		400	400	105	3605
1998		1200	700	300	200	200	100	170	200		200	200	105	3575
1999		900	800	300	200	510	300	170	100		200	200	205	3885
2000		1000	800	300	300	510	200	170	100		200	200	105	3785
2001		450[d]	800	300	300	510	200	170	100		240[d]		105	3175
2002		1000	700	300	400	525	200	170	100	200[e]	600		35	4130
2003		500	700	300	400	525	200	170	100		435		70	3400
2004		1000	700	300	400	525	200	170	100		400		105	3900
2005	400	0	700	300	400	525	200	170	100		400		105	3300
2006	35	0	700	300	300	525	300	170	100		0	0	105	2535
2007	400	0	700	300	300	525	300	170	100		0	0	105	2900
2008	269	0	700	300	0	0	0	170	100		0	0	105	1644

	Haida Gwaii		Prince Rupert		Central Coast				Strait of Georgia		WC Vancouver Island			
Year	2W[a]	2E	3/4	5	6	7	7/8	10[a]	12[a]	13-18	23/24	25	27[a,b]	Total
2009	200	0	700	300	0	0	0	170	100		0	0	105	1575
2010	455	0	700	300	0	0	0	0	100				105	1660
2011	300	0	700	300	0	0	0	0	100				105	1505
2012	600	0	700	300	0	0	0	0	100		300		105	2105
2013	600	0	700	300	0	0	0	0	100		0		105	1805
2014	496[f]	1000	700	300	300	525	300	0	100		400		105	3730
2015	375[f]	1000	700	300	300	525	300	0	100		400		105	3730
2016	100	0	700	300	300	100	200	35	100				105	1905

[a] Allocations outside of the major stock assessment regions.
[b] Area 27 was considered to be part of the WCVI North stock assessment region from 1987 to 1993 after which it was considered a minor stock.
[c] Allocations assumed based on number of licences and closed pond operations, prior to 1987 closed ponds were allocated 75 tons and open ponds 30 tons.
[d] Low stock forecasts in QCI and WCVI resulted in open pond allocations of 35 tons per licence and use of closed attractor ponds.
[e] An additional set aside of 200 tons in the SOG and WCVI was made to compensate for the possible movement of licences out of Area 27.
[f] Available allocation in Area 2W was considered part of the 1000 ton allocation to Area 2E if any licences chose to operate in 2W.

Table 3. Estimates of herring mortality (tons) associated with individual spawn-on-kelp ponds determined from diver measurements for 1982 to 1997.

Year	Stat. Area	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7	Pond 8	Pond 9	Pond 10	Mean	Source
1982	2	32	56	27	10	14	29	52	25	16	14	27.5	Shields[a]
1982	4	63	3	113	3	0.1	82	0.1	0.1			33.0	Shields[a]
1993	23	0.1										N/A	Fort[b]
	25	0.1										N/A	Fort[b]
	6	144	47									95.5	Fort[b]
	7	0.1	11	48								19.7	Fort[b]
1995	4	60	0.1	0.1	0.1	12	0.1	2.5	12	0.1	0.1	8.7	Schweigert[c]
	5	4	10	6	0.1	19						7.8	Schweigert[c]
	12	4	12									8	Chalmers[d]
	23	23	12	4								13	Chalmers[d]
	25	67	43									55	Chalmers[d]
	27	0.1	0.1									0.1	Chalmers[d]
1996	12	61	11									36	Beckmann[e]
	23	1	1									1	Beckmann[e]
	24	21	100	10	8							35	Beckmann[e]
	25	3	2	14	6							6	Beckmann[e]
	27	17										N/A	Beckmann[e]
1997	12	36	3	0.1								13	Beckmann[f]
	23	>10*	101									N/A	Beckmann[f]
	24	21	2	10	5	0.1						7.6	Beckmann[f]
	25	0.1	0.1	0.1	2	0.1	45	5	0.1			6.6	Beckmann[f]

*Visual estimate due to reduced visibility.

[a] Shields, T. L., G. S. Jamieson, and P. E. Sprout. 1985. Spawn-an-kelp fisheries in the Queen Charlotte Islands and northern British Columbia coast - 1982 and 1983. Can. Tech. Rep. Fish. Aquat. Sci. 1372: 53 p.

[b] Fort, C. 1993. Herring mortality observed under roe on kelp ponds 1993. Unpublished report, 2p.

[c] Schweigert, J. 1996. 'Excessive' herring mortality in SOK operations. Memorandum to R. Lauenstein, dated February 15, 1996.

[d] Chalmers, D. 1995. Spawn on kelp mortality WCVI and Beaver Harbour. Memorandum to C. Todd, dated April 6, 1995.

[e] Beckmann, S. 1996. Spawn on kelp dive survey assessment report for 1996. Memorandum to Distribution, dated October 2, 1996.

[f] Beckmann, S. 1997. 1997 Spawn on kelp dive survey report. Memorandum to Distribution, dated July 8, 1997.

Table 4. Estimate of the amount of herring utilized in the Prince Rupert District spawn-on-kelp fishery from 2011 to 2015. Data from J.O. Thomas Operational Reports.

Year	Number of Licenses	Number of Ponds	Tonnage Impounded	Tons per license
2011	7	20	1104	138
2012	8	15	811	101
2013	5	15	796	133
2014	7	12	775	111
2015	7	13	700	88

Table 5. Estimates of the number of closed ponds used in the spawn-on-kelp fishery in Haida Gwaii from 1987 to 2016 based on Record of Management Strategy (RMS) reports and J.O. Thomas monitoring data.

		Haida Gwaii Herring Sections						
Year	Area 2W	006	021	023	024	025	HG Total	022[a]
1987[b]			3				3	
1988			4		1		5	
1989			7				7	
1990			13		7		20	
1991			6		1	3	10	
1992			18	1			19	8
1993			9			3	12	
1994		1	3		1	6	11	1
1995							Closed[c]	
1996							Closed[c]	
1997			2		1		3	
1998		6			4	7	17	
1999			7		3	10	20	
2000			1	1	5	16	23	
2001							UNK[d]	
2002			12				12	
2003							UNK	
2004			4		4	10	18	
2005[e]	4							
2006	Closed[c]							
2007	5							
2008	2							
2009	5							
2010	5							
2011	3[f]							
2012	8							
2013	6							
2014	7							
2015	NF[g]							
2016	NF[g]							

[a] Section 22 is not included in the assessment region.
[b] SOK fishery occurred in the area annually since 1975 but no documentation of the number or location of closed ponds utilized in the commercial harvest exists for earlier years.
[c] Area closed to herring harvesting due to conservation concerns.
[d] SOK operations occurred but the number and location of closed ponds is not documented.
[e] Beginning in 2005 Haida Gwaii was closed to all fisheries for conservation but licences were given the opportunity to operate in Area 2W where a small quota was available in some years.
[f] Three licences operated in the area, assume each set up one closed pond.
[g] Quota was available to permit harvest but no licences chose to operate in 2015 or 2016.

Table 6. Estimates of the number of closed ponds used in the spawn-on-kelp fishery in Prince Rupert District from 1989 to 2016 based on Record of Management Strategy (RMS) reports and J.O. Thomas monitoring data.

	Prince Rupert District Herring Section				
Year	33	42	43	52	Total
1989[a]		4	9	UNK[b]	13
1990					UNK[b]
1991					UNK[b]
1992	2	6	11	UNK[b]	19
1993		UNK[b]	UNK[b]	3	3
1994	1	9	3	3	16
1995	2	8	5	3	18
1996		24	7	9	40
1997		17	2	9	28
1998		12	20	3	35
1999	4	16	6	6	32
2000	2	23	2	7	34
2001		12	8	UNK[b]	UNK[b]
2002		13	4	9	26
2003					UNK[b]
2004	5	6	11	7	29
2005					UNK[b]
2006			17	1	18
2007			16		16
2008	5	17		12	34
2009		18	1	13	32
2010		17	5	1	23
2011		6	6	8	20
2012		12	1	2	15
2013		5	4	6	15
2014		6		6	12
2015		9	2	2	13
2016		1		5	6

[a] SOK fishery occurred in the area annually since 1975 but no documentation of the number or location of closed ponds utilized in the harvest exists for earlier years.

[b] SOK operations occurred but the number and location of closed ponds is not documented.

Table 7. Estimates of the number of closed ponds used in the spawn-on-kelp fishery in the Central Coast from 1986 to 2016 based on Record of Management Strategy (RMS) reports and J.O. Thomas monitoring data.

	Central Coast Herring Sections								
Year	67	72	74	75	76	77	85	86	Total
1986[a]	3					1			4
1987	1		3			2			6
1988	3		1			3			7
1989	3		3			3			9
1990	3		3			3			9
1991	6		2			3			11
1992	2		2	1		1	1		7[b]
1993	1		6			1	1		9[b]
1994	2		3			2	1		8[b]
1995	3		2			2			7[b]
1996	6	1	1			6	1		15[b]
1997	11	2	5			2	6		28
1998	5	4	8	2	1	4	6		30
1999		3	5	1	1	6	7		23
2000	2	6	5			3	5		21
2001									UNK[c]
2002		3				8	3		14
2003	3	3				2	2		10
2004	3					6	3		12
2005	3	2				1	4		10
2006	4	3				3	3		13
2007	5	1				3			9
2008									0
2009									0
2010									0
2011									0
2012									0
2013									0
2014	7							2	9
2015	6								6
2016	6							4	10

[a] SOK fishery occurred in the area annually since 1975 but no documentation of the number or location of closed ponds utilized in the harvest exists for earlier years.

[b] Inferred from RMS report and should be taken as a minimum estimate.

[c] SOK operations occurred but the number and location of closed ponds is not documented.

Table 8. Estimates of the number of closed ponds used in the spawn-on-kelp fishery in the west coast of Vancouver Island from 1991 to 2016 based on Record of Management Strategy (RMS) reports and J.O. Thomas monitoring data.

	W.C. Vancouver Island Herring Sections							Area 26[a]		
Year	232	243	244	245	252	253	Total	261	262	263
1991[b]	1		1			1	3			
1992	1		1			2	4			
1993	1		1			2	4	1	1	
1994	1	1	1			2	5	1	1	1
1995	6					4	10	1		
1996	4	2			1	2	9			
1997	2	2				8	12			
1998				5		5	10			
1999				3		6	9			
2000				3		6	9			
2001		2				5	7			
2002	2	3				5	10			
2003		2				4	6			
2004	3	1				5	9			
2005		3				1	4			
2006							Closed[c]			
2007							Closed[c]			
2008							Closed[c]			
2009							Closed[c]			
2010							Closed[c]			
2011							Closed[c]			
2012							0[d]			
2013							Closed[c]			
2014							0[d]			
2015							0[d]			
2016							Closed[c]			

[a] Not included in the west coast Vancouver Island assessment region.
[b] Only previous commercial SOK fishery here occurred in 1975 and 1976, see Tables 1 and 2.
[c] Area closed to herring harvesting due to conservation concerns.
[d] Quota was available in the area but no licences chose to operate.

Table 9. Estimates of the number of closed ponds used in the spawn-on-kelp fishery in Statistical Areas 10, 12, and 27 from 1985 to 2016 based on Record of Management Strategy (RMS) reports and J.O. Thomas monitoring data.

		Area 12 Herring Sections			Area 27 Herring Sections		
Year	Area 10	122	124	126	272	273	Total
1985[a]						2[b]	2[b]
1986	1				1[b], 0[c]	2[b]	3[b]
1987	2						UNK
1988	2[b]						UNK
1989	2[b]						UNK
1990	2				2[b], 0[c]	2[b]	4[b]
1991	4				1[b], 0[c]	1[b]	2[b]
1992	3[b]				0[c]	2[b]	2[b]
1993	3				0[c]	1, 0[c]	1
1994	1[b]				0[c]	1, 0[c]	1
1995	1	3			0[c]	1, 0[c]	1
1996	1[b]	3		1	0[c]	1, 0[c]	1
1997	2	3				1, 0[c]	1
1998	4	2	1	2		0[c]	
1999	1	3				0[c]	
2000	4	2				0[c]	
2001	1[b]	2[b]				0[c]	
2002	0[c]	2				0[c]	
2003	1	2[b]				0[c]	
2004	0[c]	2				0[c]	
2005	0[c]	2[b]				0[c]	
2006	0[c]	NF[d]				0[c]	
2007	0[c]	2				0[c]	
2008	1	1				0[c]	
2009	0[c]	2				0[c]	
2010	Closed[e]	2				0[c]	
2011	Closed[e]	3				0[c]	
2012	Closed[e]	2				0[c]	
2013	Closed[e]	3				0[c]	
2014	Closed[e]	2				1, 0[c]	1
2015	Closed[e]	NF[d]				NF[d]	
2016	0[c]	3				NF[d]	

[a] The SOK fishery occurred in these areas intermittently since 1975 but the number and location of any closed ponds used is not documented.

[b] Number of closed ponds inferred from the RMS reports of the number of licences operating in the area and narrative that 'closed ponds were set up'.

[c] Only open ponding used in the area during this year.

[d] Quota was available in the area but no licences chose to operate.

[e] Area closed to herring harvesting due to conservation concerns

Table 10. Total reported landings (lbs.) in the herring spawn-on-kelp fishery in British Columbia by geographical region and coastwide from 1975 to 2016.

Year	Haida Gwaii[a]	Prince Rupert District	Central Coast	Strait of Georgia	West Coast Vancouver Is.	Total B.C. Coast
1975[c]	N/A[b]	25233	0	N/A	N/A	32503
1976[d]	44180	56775	0	20291	N/A	123846
1977[e]	83000	108000	0	54000	0	245000
1978[f]	139704	158916	0	36609	0	335229
1979[g]	167258	183213	N/A	58289	0	421410
1980[g]	173461	111966	N/A	61096	0	370453
1981[g]	186686	117787	42035	53281	N/A	411921
1982[g]	172354	129674	43502	45203	0	390733
1983[g]	175947	139445	48217	55174	N/A	423183
1984[h]	158607	119782	63343	32230	N/A	379562
1985[h]	167395	125452	60066	N/A	32020	415424
1986[h]	140325	92912	59558	N/A	37091	331008
1987[h]	184930	114828	76986	0	50412	427156
1988[h]	193933	130363	87534	0	68673	480503
1989[h]	187864	130249	89405	0	62080	469598
1990[h]	198916	133622	87788	0	73125	493451
1991[h]	214857	145954	145410	N/A	115533	637836
1992[h]	155196	148454	164388	N/A	135035	616841
1993[h]	203124	157514	125946	N/A	103278	604040
1994[h]	178516	179944	102316	N/A	110925	578137
1995[h]	0	162411	178079	N/A	222164	581660
1996[i]	0	154550	204961	N/A	167825	559235
1997	52431	176946	233867	N/A	182580	678368
1998	116356	171017	284362	N/A	113147	706213
1999	136770	186034	278239	N/A	126477	744258
2000	163087	165262	267918	N/A	105411	716350
2001	160682	155262	364688	N/A	103930	802504
2002	116719	177360	371399	N/A	120412	797616

Year	Haida Gwaii[a]	Prince Rupert District	Central Coast	Strait of Georgia	West Coast Vancouver Is.	Total B.C. Coast
2003	168959	149273	383246	N/A	85572	804876
2004	152957	135134	384338	N/A	102797	792084
2005	64423	156183	265521	N/A	58809	560865
2006	0	82202	453494	0	43082	578778
2007	59019	111762	158776	N/A	52691	398578
2008	42054	166572	N/A	0	41291	265696
2009	N/A	158118	0	N/A	42325	246209
2010	46556	108835	0	N/A	N/A	187855
2011	0	123626	0	N/A	N/A	174959
2012	N/A	87494	0	N/A	N/A	160447
2013	N/A	72895	0	N/A	N/A	133050
2014	N/A	113269	240811	N/A	N/A	400517
2015	0	84066	169470	0	0	253536
2016	0	N/A	367296	N/A	0	411897

[a] Reported as Queen Charlotte Islands prior to 2011.
[b] N/A indicates that landings cannot be reported due to privacy issues.
[c] Total landings reported by Dickson (1976a).
[d] Total landings reported by Dickson (1976b).
[e] Total landings as reported in the British Columbia catch statistics for 1977 for Statistical Areas. Total landings for the year are taken from Leitz (1979) and exceed the report in the B.C. catch statistics.
[f] Total landings reported by Dickson (1978).
[g] Total landings reported by Macgillivray (1984).
[h] Total weight of processed product provided by J. Davidson, Fisheries Management Data Unit, DFO, personal communication.
[i] Total landings for 1996 to 2016 provided by D. Tallman, J.O. Thomas and Associates, Heiltsuk landings for 1997 to 2016 provided by K. Wong, DFO, personal communication.

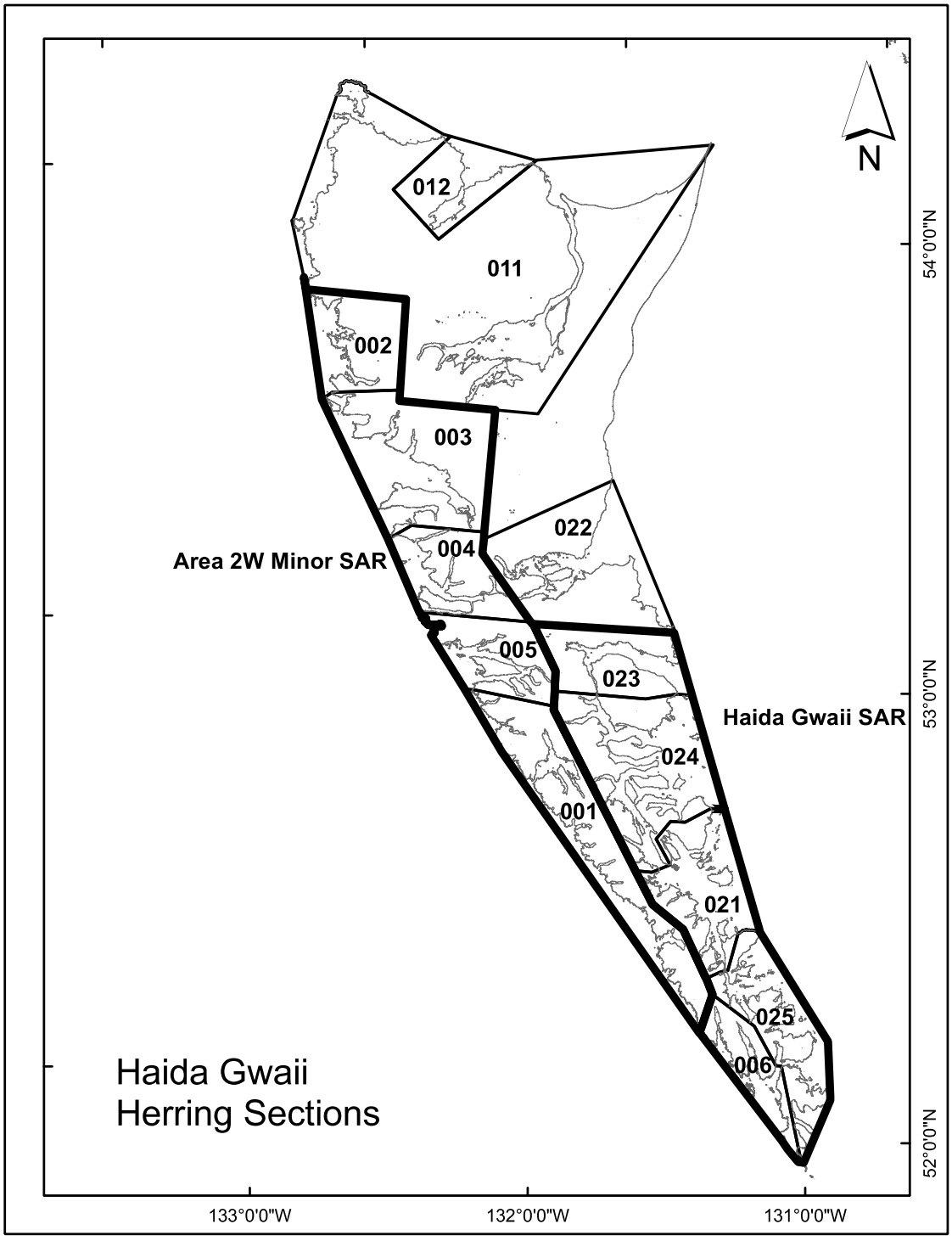

Figure 1. Herring sections in the Haida Gwaii stock assessment region (006, 021, 023, 024, 025).

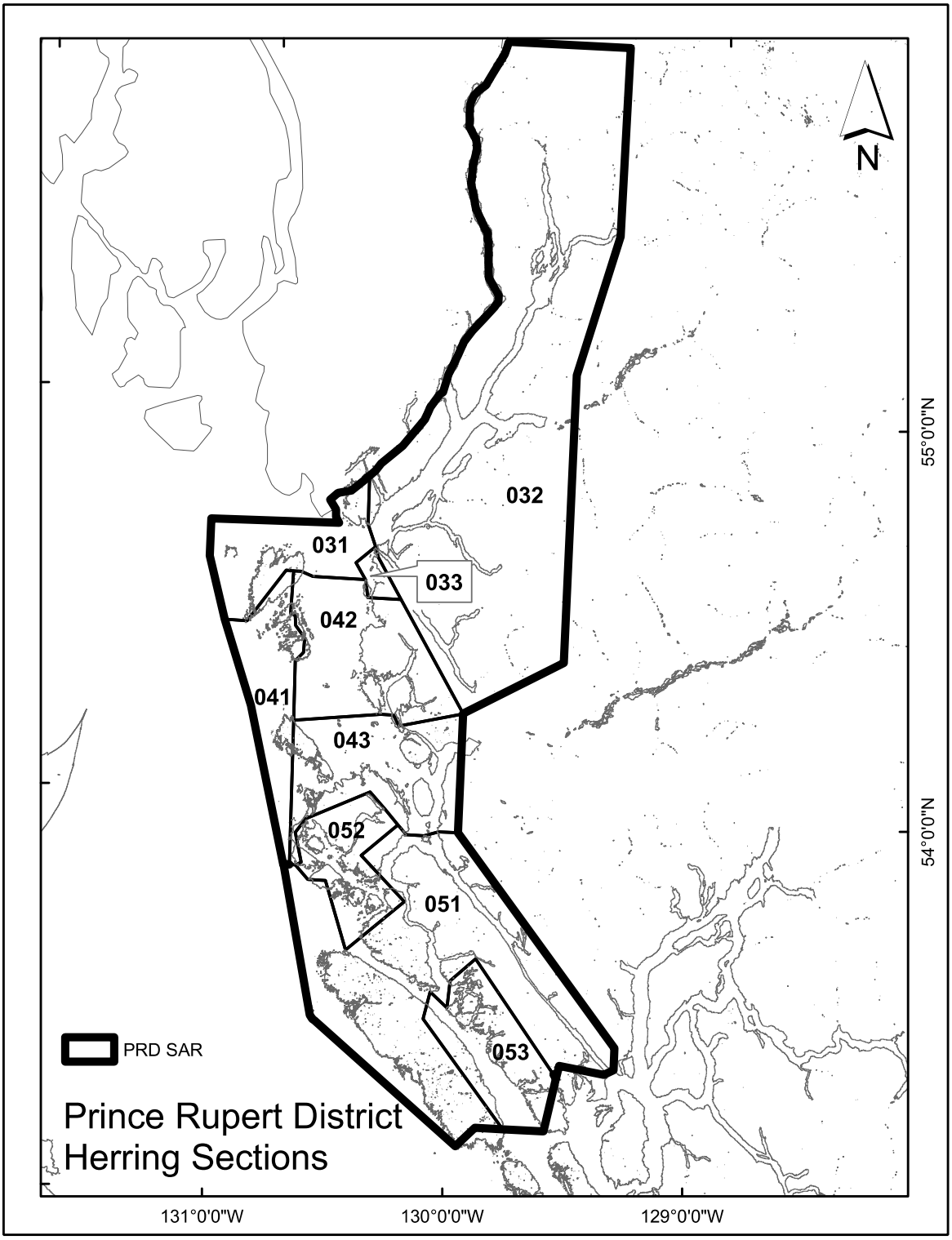

Figure 2. Herring sections in the Prince Rupert District stock assessment region (031, 032, 033, 041, 042, 043, 051, 052, 053).

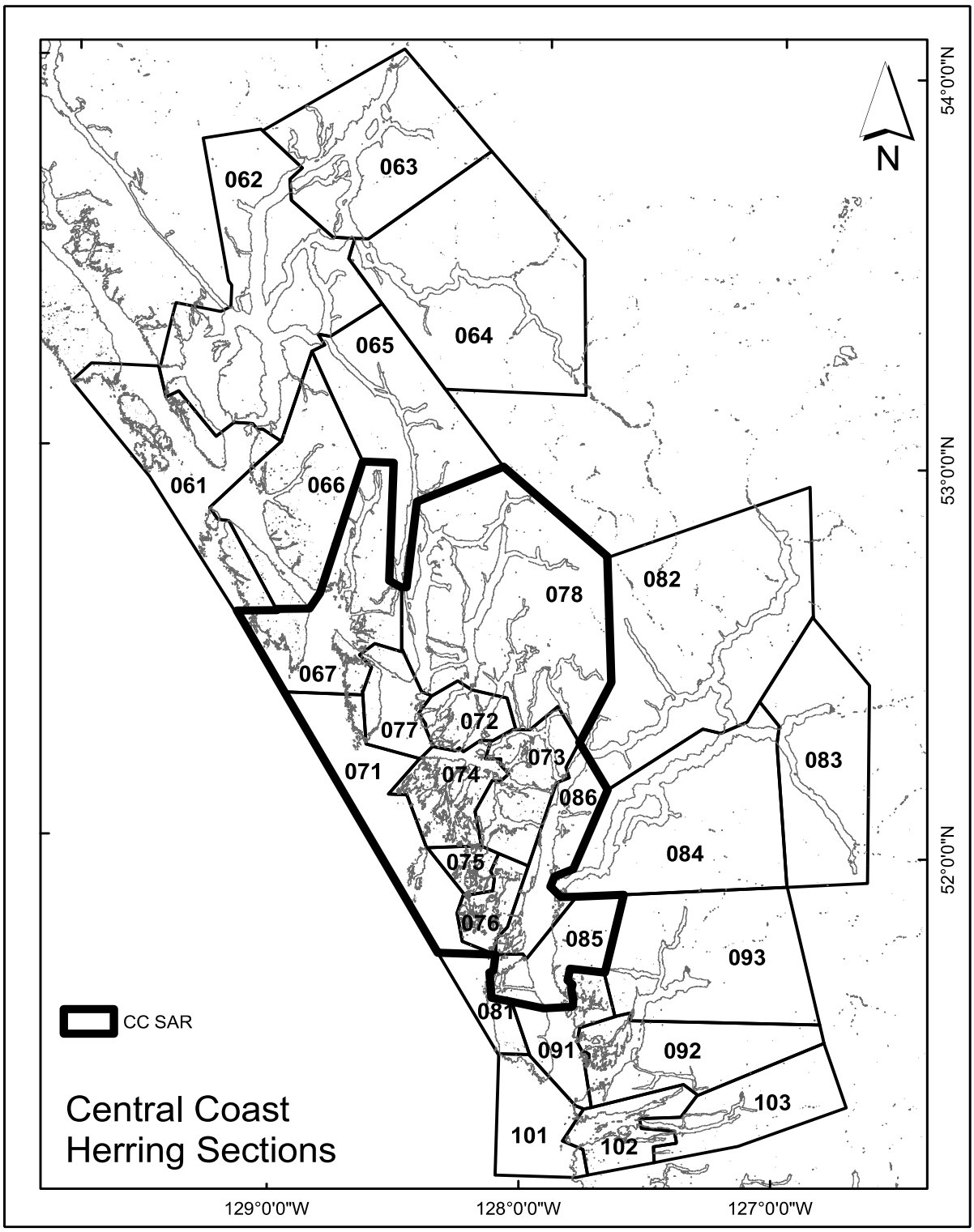

Figure 3. Herring sections in the Central Coast stock assessment region (067, 071, 072, 073, 074, 075, 076, 077, 078, 085, 086).

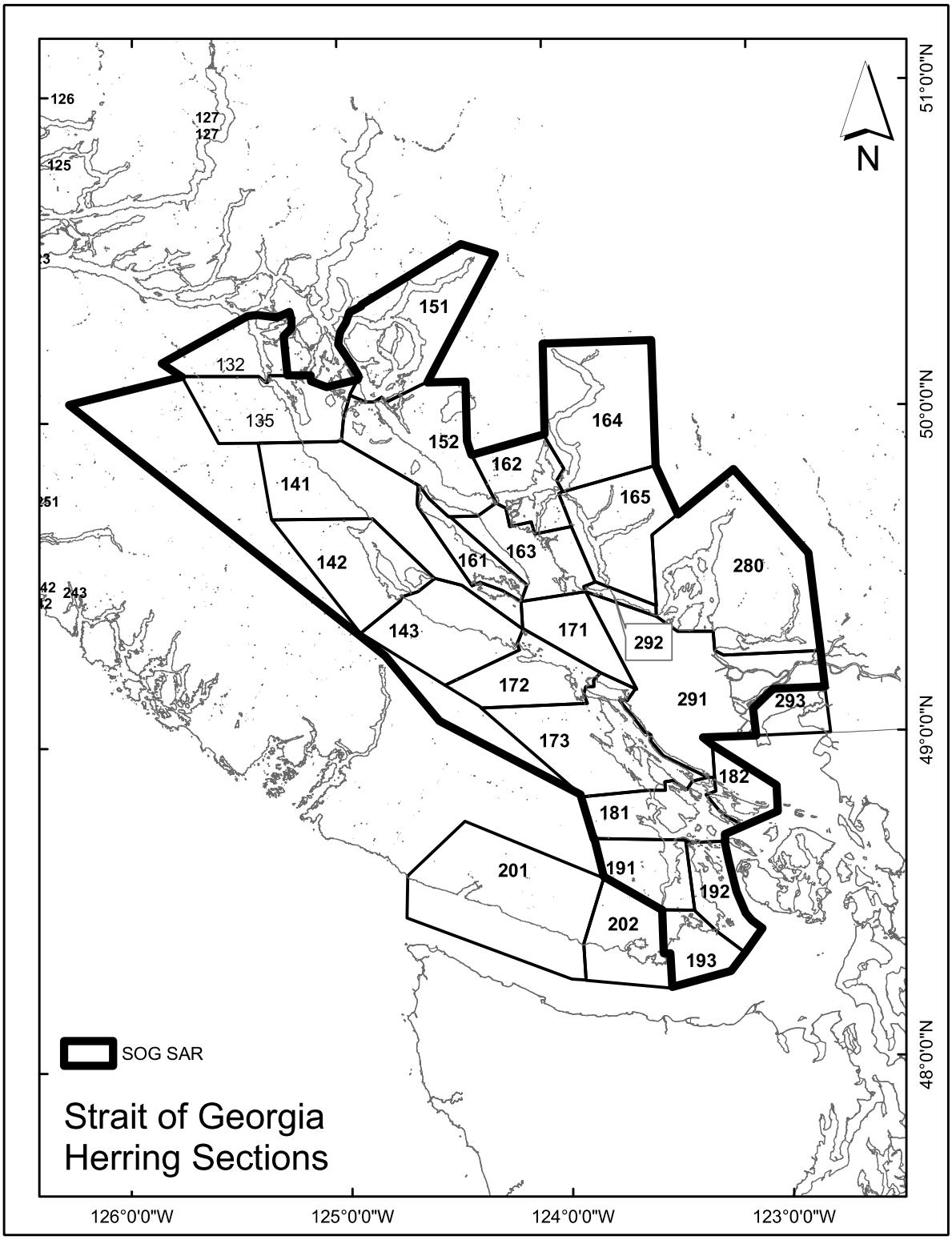

Figure 4. Herring sections in the Strait of Georgia stock assessment region (132, 135, 141, 142, 143, 151, 152, 161, 162, 163, 164, 165, 171, 172, 173, 181, 182, 191, 192, 193, 280, 291, 292).

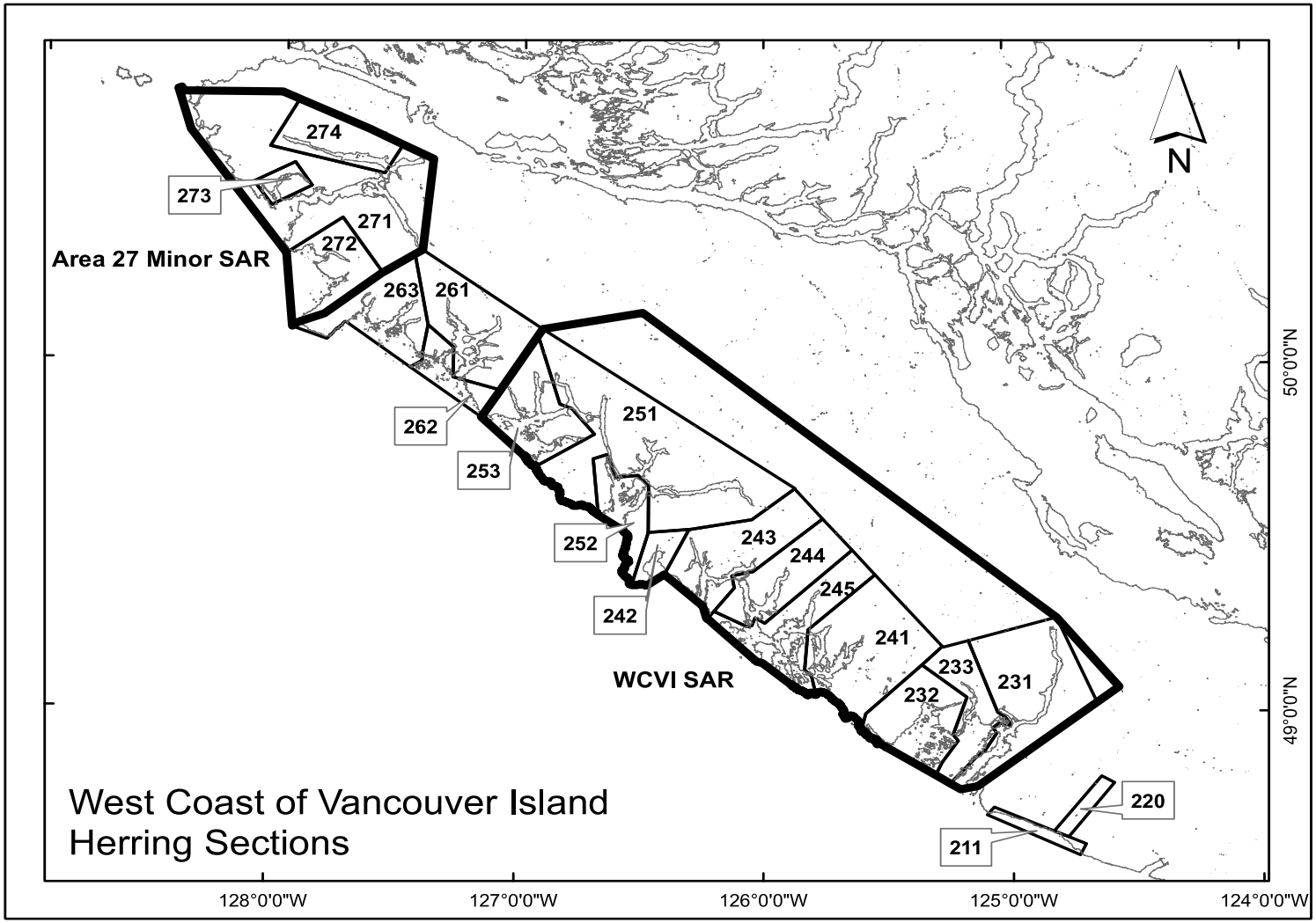

Figure 5. Herring sections in the west coast of Vancouver Island stock assessment region (231, 232, 233, 241, 242, 243, 244, 245, 251, 252, 253).

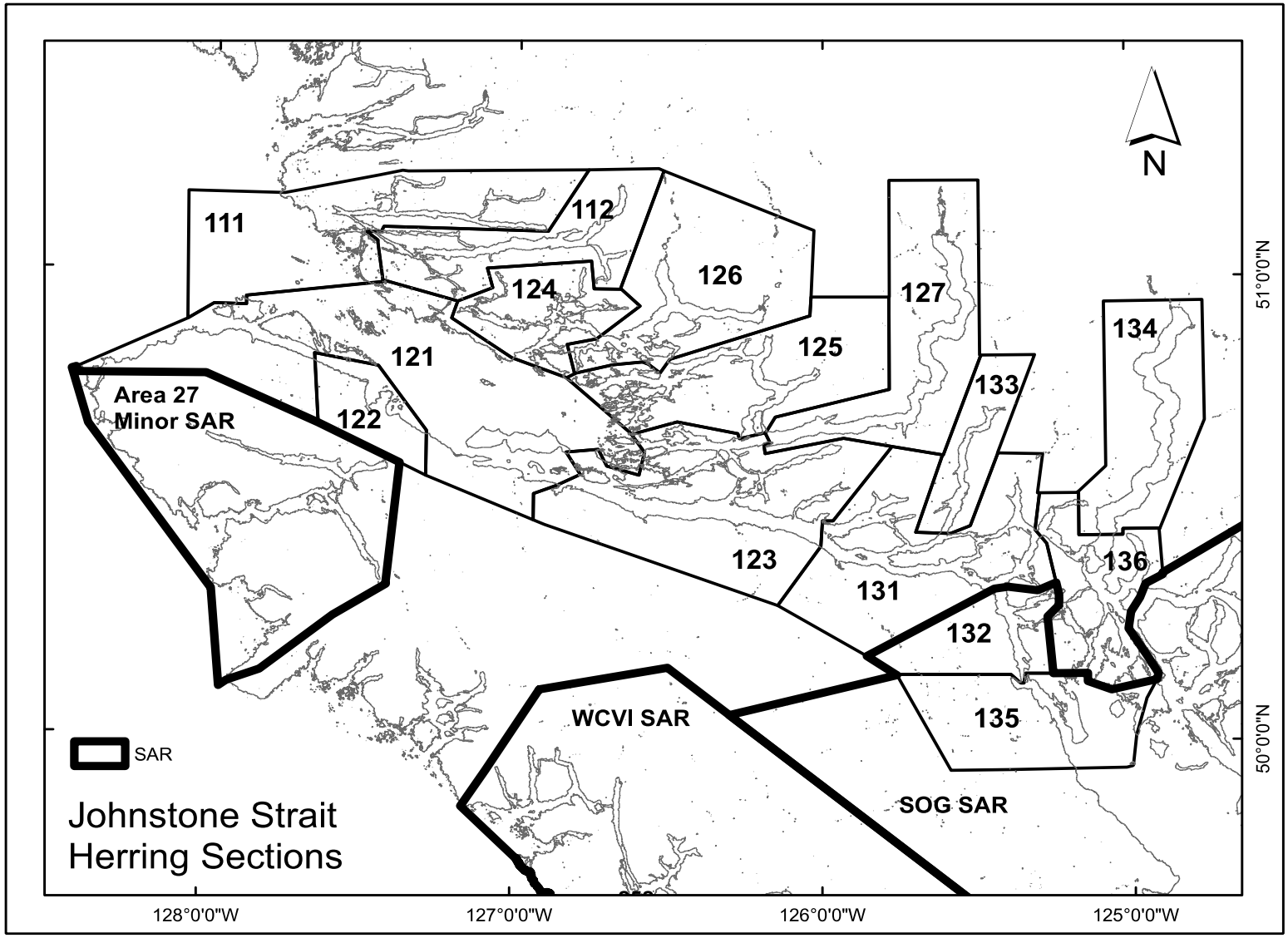

Figure 6. Herring sections in the Johnstone Strait (111, 112, 121, 122, 124, 125, 126, 127, 131, 133, 134, 136).